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MRGO ECOSYSTEM RESTORATION PLAN FEASIBILITY STUDY

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MISSISSIPPI RIVER GULF OUTLET (MRGO)

ECOSYSTEM RESTORATION PLAN
FINAL FEASIBILITY STUDY

FINAL
ENGINEERING APPENDIX

U.S. Army Corps of Engineers
Mississippi Valley Division
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MISSISSIPPI RIVER GULF OUTLET (MRGO) ECOSYSTEM RESTORATION PLAN DRAFT FEASIBILITY STUDY DRAFT ENGINEERING APPENDIX

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MRGO ECOSYSTEM RESTORATION PLAN FEASIBILITY STUDY
ENGINEERING APPENDIX

1.0 PURPOSE

This Engineering Appendix outlines the engineering and design work done to support the preparation of the MRGO Ecosystem Restoration Plan Feasibility Study. It includes geotechnical investigations, structural design, levee and channel design, shoreline protection design, marsh creation design and cost estimates.

1.1 INTRODUCTION

The study is authorized by the Water Resources Development Act of 2007 Section 7013 to develop a plan:

- to physically modify the MRGO and restore the areas affected by the navigation channel;
- to restore natural features of the ecosystem that will reduce or prevent damage from storm surge;
- to prevent the intrusion of saltwater into the waterway;
- that integrates the recommendations of the Louisiana Coastal Area Report and the Louisiana Coastal Protection and Restoration Technical Report
- that considers the use of native vegetation; and diversions of fresh water to restore the Lake Borgne ecosystem.

The study area includes portions of the Deltaic Plain within coastal southeast Louisiana and southwest Mississippi. The area encompasses approximately 3.86 million acres. In Louisiana, the study area includes the Upper, Middle and Lower Lake Pontchartrain Sub-basins (figure 1).

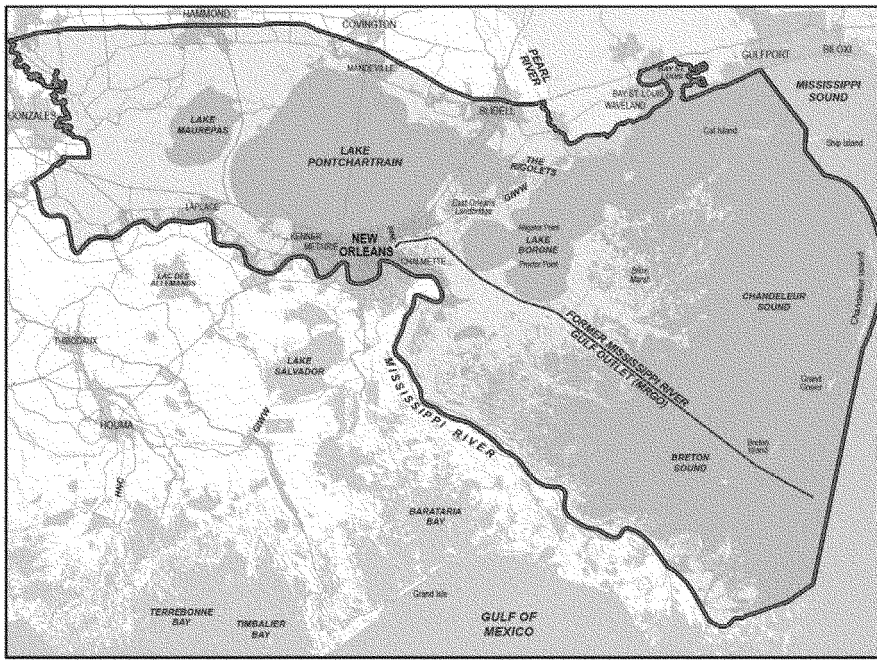

Figure 1- Study Area

1.2 ALTERNATIVES

Management measures were developed to address study area problems. A management measure is a feature (a structural element that requires construction or assembly on-site) or an activity (a nonstructural action) that can be combined with other management measures to form alternative plans. A detailed description of these measures is contained in the main report. After an initial screening, cost estimates were developed for the remaining features for use during higher level screening. Measures were combined in different to create alternatives and then alternatives were evaluated against each other. The screening/evaluation process is described in detail in the main report. Table 1 shows a list of the measures for which costs were developed. Estimated cost for each of these measures can be found in table 38. Figure 2 shows the location of these measures. The diversion at Violet was included in all alternatives evaluated.

Table 1 Alternative Measures		
Measure Label (Original)	Measure Label (New)[1]	Measure Type
005-sp	ES1	Shoreline Protection
006-sp	ES2	Shoreline Protection
007-sp	ES3	Shoreline Protection
007	EM5	Marsh Creation
009	EM1	Marsh Creation
090	EV1	Breakwater for SAV
010a	EM3	Marsh Creation
010b	EM4	Marsh Creation
011	EM2	Marsh Creation
028	LM4	Marsh Creation
014	LM1	Marsh Creation
015a	LM2	Marsh Creation
008sp	LS1	Shoreline Protection
015c	LM3	Marsh Creation
024		Marsh Creation
024	MRGO7	Channel Narrowing Marsh Creation
021	MRGO2	O&M Shoreline Protection
022	MRGO1	O&M Shoreline Protection
025	MRGO3	O&M Shoreline Protection
027	MRGO5	Channel Narrowing Shoreline Protection
026	MRGO8	Channel Narrowing Shoreline Protection
087	MRGO6	Shoreline Protection
104	MRGO4	O&M Shoreline Protection
		Violet Diversion
026e	CC4	Cypress Swamp Restoration
026c	CM2	Marsh Creation
026d	CM5	Marsh Creation
026b	CM1	Marsh Creation
026a	CC3	Cypress Swamp Restoration
025b	CC2	Cypress Swamp and Marsh Restoration
025a	CC1	Cypress Swamp Restoration

Table 1 Alternative Measures		
Measure Label (Original)	Measure Label (New)[1]	Measure Type
027a	CC5	Cypress Swamp Restoration
027b	CC6/CM4	Cypress and Marsh Restoration
030sp		Shoreline Protection
010sp		Shoreline Protection
011sp		Shoreline Protection
013sp	BS1	Shoreline Protection
014sp		Shoreline Protection
081	BM1	Marsh Creation
042		Marsh Creation
020		Marsh Creation
98asp		Shoreline Protection
98bsp		Shoreline Protection
111sp		Shoreline Protection
017sp		Shoreline Protection
107sp		Shoreline Protection
087	BM2	Marsh Nourishment
081sp	BS3	Shoreline Protection
029asp	BS2	Shoreline Protection
029bsp	JS1	Shoreline Protection
110		Shoreline Protection
133a	BR1	Ridge Restoration
133b		Ridge Restoration
028	JS1	Shoreline Protection
242	TM4	Marsh Creation
241	TM6	Marsh Creation
244	TM5	Marsh Creation
243	TM3	Marsh Creation
245	TM2	Marsh Creation
002a	TM1	Marsh Creation
002b	TM7	Marsh Creation
002c	TM8	Marsh Creation

Table 1 Alternative Measures		
Measure Label (Original)	Measure Label (New)[1]	Measure Type
190	HM1	Marsh Creation
004		Marsh Creation
013		Marsh Creation
022		Marsh Creation
023		Marsh Creation
78		Marsh Creation
191		Marsh Creation
240		Marsh Creation

[1] **New Measure Labels are Only For Measures In The Final Array Of Alternatives**

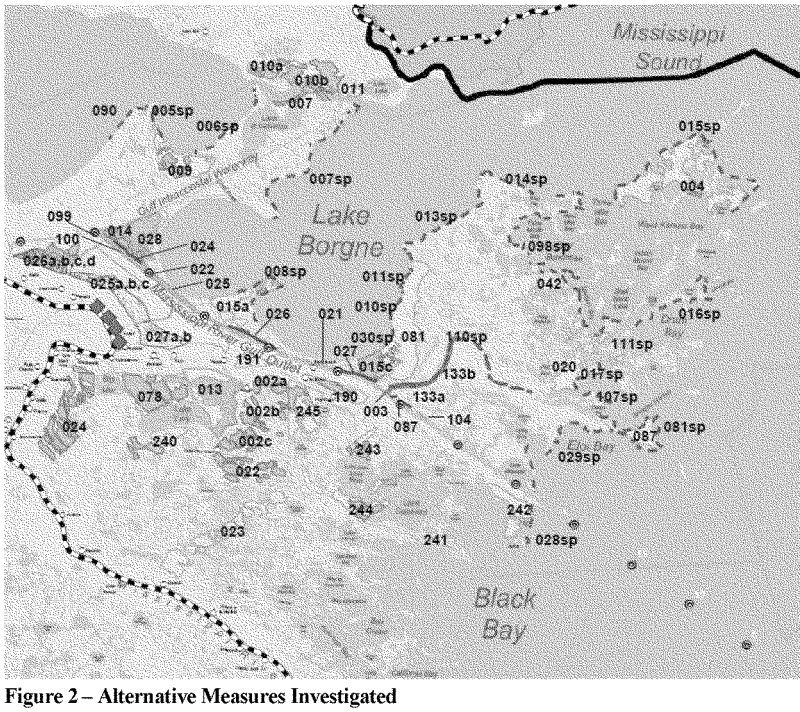

Figure 2 – Alternative Measures Investigated

1.3 TSP

Features included in the Tentatively Selected Plan (TSP) are listed in Table 2 below and shown in Figure 3.

Table 2 Tentatively Selected Plan

Area	Feature
Biloxi Marsh	BM1
	BS1
	BS2 (now oyster reef)
	BR1
Central Wetlands	CC1
	CC2
	CC3
	CC4
	CC5
	CC6
	CM1
	CM2
	CM3
	CM4
	CM5
MRGO	MRGO1
	MRGO2
	MRGO3
	MRGO4
	MRGO5
	MRGO6
	MRGO7
	MRGO8
East Orleans	EM1
	EM2
	EM3
	EM4

Table 2 Tentatively Selected Plan	
Area	**Feature**
	ES1
	ES2
	ES3
S. Lake Borgne	LM1
	LM2
	LM3
	LM4
	LS1
Terre aux Boeufs	TM1
	TM2
	TM7
	TM8
Hopedale	HM1
Diversion	D1

1st letter – area:

B – Biloxi Marsh
C – Central Wetlands
M – MRGO Channel
E – East Orleans
L – South Lake Borgne
T – Terre aux Boeufs
H - Hopedale
J – Jetty
I – Island (if needed)

2nd letter – measure type:

C – Cypress swamp restoration/nourishment
M – Marsh creation/nourishment
S – Shoreline protection
V – SAV restoration
R – Ridge restoration
B – Barrier island restoration (if needed)

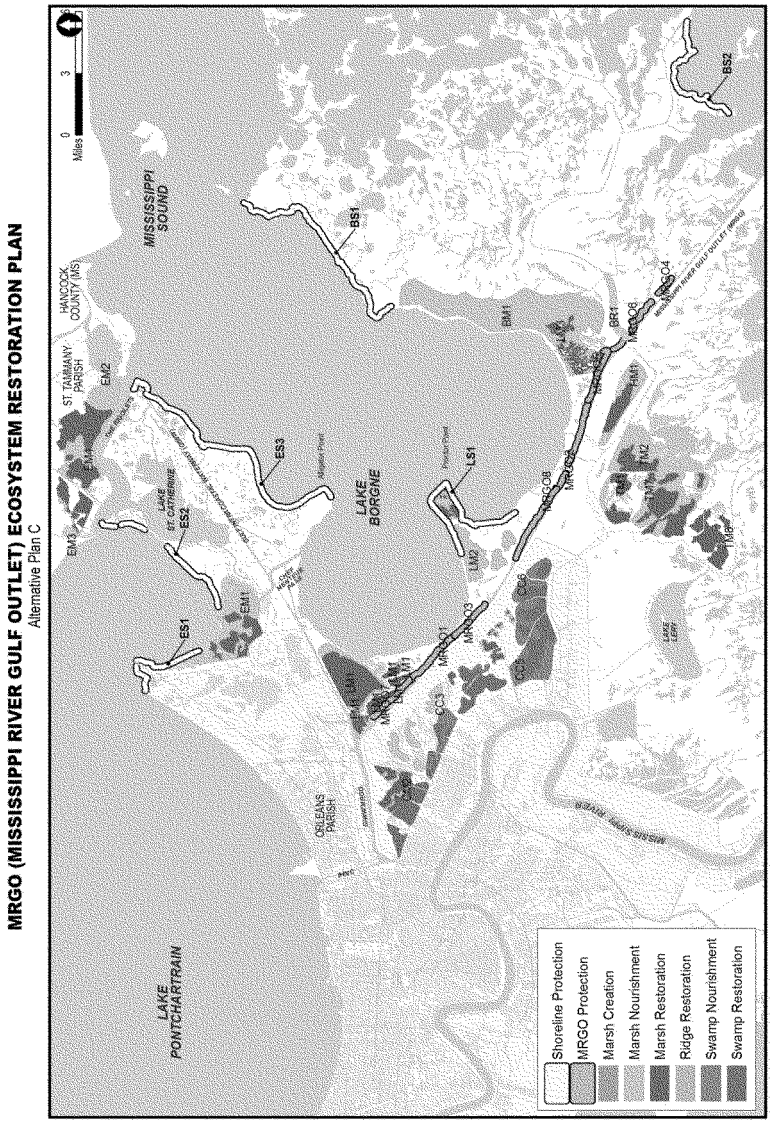
MRGO (MISSISSIPPI RIVER GULF OUTLET) ECOSYSTEM RESTORATION PLAN
Alternative Plan C
Miles
0
3
MISSISSIPPI SOUND
HANCOCK COUNTY (MS)
ST. TAMMANY PARISH
LAKE ST. CATHERINE
LAKE BORGNE
ORLEANS PARISH
LAKE PONTCHARTRAIN
LAKE LERY
MISSISSIPPI RIVER
BS1
BS2
ES1
ES2
ES3
LS1
EM1
EM2
EM3
BM1
BR1
HM1
LM1
LM2
CC3
CC6
MRGO1
MRGO3
MRGO4
MRGO6
MRGO8
Shoreline Protection
MRGO Protection
Marsh Creation
Marsh Nourishment
Marsh Restoration
Ridge Restoration
Swamp Nourishment
Swamp Restoration

Figure 3 - TSP

1.4 VIOLET DIVERSION

The freshwater diversion is a system driver to create conditions conducive to the full restoration of historic salinity levels in the vicinity of the MRGO. The Violet Freshwater Diversion would mimic natural river flooding processes and enhance the sustainability of the system through the input of freshwater, nutrients and sediment. The diversion would also help to restore historic salinity conditions and nourish existing and restored wetlands in the study area. However, additional study is needed to improve decisions about where, when, and how to divert Mississippi River flows in a systems context. Therefore, the final recommendations for the MRGO Ecosystem Restoration Plan include additional analysis, design and implementation of the Violet Freshwater Diversion as authorized by WRDA 2007 Section 3083 which states "The Secretary shall design and implement a project for a diversion of freshwater at or near Violet, Louisiana...". The additional analysis for the diversion will be accomplished and documented under the separate study authorized under WRDA 2007 Section 3083.

The modeling and design work done for the Violet Diversion as a part of this study is included in this appendix to document the work completed to this point. Additional modeling and design done to confirm diversion size and location and provide feasibility level of design will be done as recommended and will be documented in a separate report done under a separate study authorization as stated above.

2.0 HYRDOLOGY AND HYDRAULICS

2.1 INTRODUCTION

The study area includes portions of the Deltaic Plain within coastal southeast Louisiana and southwest Mississippi. The area encompasses approximately 3.86 million acres. In Louisiana, the study area includes the Upper, Middle and Lower Lake Pontchartrain Sub-basins.

2.2 CLIMATOLOGY

2.2.1 Climate

The climate is warm and humid subtropical due to its latitude and proximity to the Gulf of Mexico. The area has mild winters, hot summers, heavy precipitation, and generally high humidity. Prevailing winds are southeasterly during the spring, southwesterly in the summer, and northeasterly in the fall and winter. In the coastal area, winds have a strong impact on coastal water levels. Winds from a southerly direction may push water into the bays and lakes, frequently raising water levels in the upper part of the estuarine zone. On the other hand, winds from a northerly direction may depress water levels.

The general circulation of air over the area follows the sweep of the western extension of the Bermuda High during the spring and summer months. High pressure systems over the North American continent modify the patterns for the remaining months. These high pressure systems and their associated extra tropical cyclones are responsible for the wide pressure ranges of winter. The Bermuda High has greater constancy than the continental high pressure systems and in late spring and summer maintains a rather steady flow of warm, moist air that, to a large degree, controls the climate over the area. Periods of good weather tend to be longer during late spring and summer than during late fall, winter, and early spring. The monthly mean pressures range from a maximum of 30.1 inches of mercury in December and January to a minimum of 29.97 in September.

Many polar air masses and associated frontal conditions penetrate to the Gulf of Mexico each winter. During the cooler season, about 15 to 20 of these systems bring strong northerly winds, cold temperatures, and adverse weather. These polar air masses ordinarily scour from November to March and last about a day and a half. Severe polar air masses usually occur from December to February and occasionally later, and may last for 3 to 4 days.

Monthly mean relative humidity is high throughout the year with negligible seasonal variation because of the influence of the gulf waters. Maximum values of the monthly means occur in spring, the time of greatest consistency of southeasterly winds. Minimum humidity generally occurs during the fall.

2.2.2 Hurricanes and Tropical Storms

Hurricanes or tropical storms originating in the North Atlantic and Caribbean Sea occasionally come into the study area during the hurricane season, June through October. These weather systems can

cause considerable property and environmental damage and loss of human life. Historical data from 1899 to 2007 indicate that 30 hurricanes and 41 tropical storms have made landfall along the Louisiana coastline (National Weather Service, http://www.srh.noaa.gov/lch/research/tropical5.php and National Hurricane Center, http://www.nhc.noaa.gov). Winds and waves generated by these storms have caused substantial damage to the marshes and have contributed to erosion and land loss. Table 3 presents a chronology of major hurricanes that have struck the study area.

Table 3 Hurricane Data

Storm	Date	Lowest Pressure	Sustained Winds
HILDA	10/3/1964	950 mb	115 mph
BETSY	9/19/1965	948 mb	125 mph
CAMILLE	8/17/1969	909 mb	190 mph
ANDREW	8/26/1992	956 mb	115 mph
KATRINA	8/29/2005	920 mb	125 mph

2.3 HYDROLOGY AND HYDRODYNAMICS – GENERAL INFORMAITON

2.3.1 Study Area

Most of the study area consists of the Lake Pontchartrain basin. The basin can further be divided into the Upper, Middle, and Lower sub-basins. In Mississippi, the study area includes the Western Mississippi Sound, its bordering wetlands, and Cat Island. These areas include portions of the Pearl River and the Coastal Streams hydrologic basins. The Lake Borgne ecosystem is also influenced by the Pearl River to the north and received hydrologic interchange from areas located as far south as the River Aux Chenes ridge. To the east, the Western Mississippi Sound is an extension of Lake Borgne. The Western Mississippi Sound, Chandeleur Sound, and Breton Sound form the eastern boundary of hydrologic influence into the Lake Borgne ecosystem.

2.3.2 Lake Pontchartrain Basin

The Lake Pontchartrain Basin consists of Lake Maurepas, Lake Pontchartrain, Lake Borgne, the Biloxi Marshes, Chandeleur Sound, plus associated marshlands and waterways. Lakes Maurepas, Pontchartrain, and Borgne cover 55 percent of the basin. Lakes Maurepas and Pontchartrain are hydrologically connected by Pass Manchac, separated only by land bridges of cypress swamp and fresh/intermediate marsh. Lake Borgne is hydrologically connected to Lake Pontchartrain through Chef Menteur and Rigolets. They are separated by a brackish marsh land bridge.

The basin contains approximately 483,400 acres of wetlands, consisting of nearly 38,500 acres of fresh marsh, 28,600 acres of intermediate marsh, 116,800 acres of brackish marsh, 83,900 acres of saline marsh, and 215,600 acres of cypress swamp. Since 1932, more than 66,000 acres of marsh have converted to water in the Pontchartrain Basin--over 22 percent of the marsh that existed in 1932.

The basin has several freshwater tributaries, which are the single most important factor affecting salinities in Lake Pontchartrain. The Blind, Amite, and Tickfaw Rivers flow into Lake Maurepas. The Tangipahoa and Tchefuncte Rivers, the Lascombe and Bonfouca Bayous enter from the north shore of Lake Pontchartrain. Bayou St. John, the Inner Harbor Navigation Canal (making a connection between the Mississippi River and the Basin), the Bonnet Carre Spillway, and several canals which discharge storm water runoff discharge into Lake Pontchartrain from the south shore. Over the long-term, flood releases from the Bonnet Carre Floodway are a poor predictor of salinity variation in Lake Pontchartrain. Large flood releases from Bonnet Carre in excess of the total volume may enter the Lake during a single flood event (Swenson 1981), which depresses salinities to 0% in the eastern region in a matter of days. However, once the spillway is closed, salinities in the western portion of Lake Pontchartrain take as long as two months to return to steady state values (Sikora, 1985). The annual freshwater flow into Lake Pontchartrain averages about 3,800 cfs. The largest tributary to the basin, Pearl River with its mean annual flow of about 10,000 cfs, discharges into Lake Borgne near the mouth of the Rigolets. Several smaller rivers, the largest of which are the Amite, Tickfaw, Tangipahoa, and Tchefuncte Rivers, flow into Lake Pontchartrain and Lake Maurepas. Lake Borgne is connected to the Mississippi River Gulf Outlet by several bayous; the principal ones being Bayous Bienvenue, Dupre, Ysclosky, LaLoutre, and St. Malo. There was once major freshwater (as well as sediment and nutrient) input into the basin as a result of seasonal flooding of the Mississippi River, however this has succumbed to saltwater intrusion as a result of the construction of levees, which confined the river to a channel.

Tides in the basin are principally diurnal, with mean ranges of 0.3 ft (Lake Maurepas) to 0.5 ft (Lake Pontchartrain) to 1.4 ft (Chandeleur Sound). Mean water levels are affected by winds, freshwater runoff, and seasonal trends in the Gulf of Mexico. Sustained winds can raise or lower peak astronomical tide levels by several feet for short periods. The mean water levels are lower in winter and midsummer while higher in spring and fall. Currents and circulation are controlled by tides, winds, freshwater discharges, and gulf currents (Tate, Carrillo, Berger, and Thibodeaux 2002).

2.3.3 Hydrodynamics and the MRGO, GIWW, and IHNC

Saltwater intrusion occurs when freshwater flows decrease in volume, allowing saltwater from the tidal body, which is heavier than freshwater, to move inland or "upstream". Saltwater can then infiltrate fresh groundwater and surface water supplies and damage freshwater ecosystems. Saltwater intrusion can result from natural causes as well as human induced activities. The rate of saltwater intrusion depends on the amount of freshwater flows traveling downstream and the water depth in the wetlands, channels, and/or canals. Generally, high-inflow/low-salinity periods occur from late winter to late spring and low inflow/high-salinity periods from late spring to fall. Saltwater intrusion is the principle factor in the conversion of freshwater habitats to saline habitats. Extreme salinity

changes can stress fresh and intermediate marshes to the point where vegetation dies and the wetlands convert into open water (Flynn et al. 1995).

A discussion of salinity within the Lake Pontchartrain Basin due to saltwater intrusion is discussed in relation to the construction and operation of the MRGO. Salinity within the basin can be chronologically divided into before and after construction. The channel directly and indirectly impacted the natural geomorphology of the St. Bernard deltaic complex. Construction and operation also affected the geomorphology and hydrodynamic regime of the Lake Pontchartrain Basin. A study across areas of the current channel was conducted from 1959 – 1961 to evaluate the major hydrodynamic parameters, including circulation and salinity, prior to opening the MRGO to marine traffic in 1963 (Rounsefell, 1964). These data indicated that the Bayou La Loutre ridge provided a boundary that limited the flow of saline water from the Breton Sound area into Lake Borgne. An analysis of typical tidal flow across the region also indicates that since construction of the MRGO, circulation patterns have been altered along its length in areas between Breton Sound and Lake Borgne (Wicker et al., 1982). Breaching the Bayou La Loutre ridge, which served as a hydrodynamic boundary, has altered circulation patterns in areas along the lower southeastern length of the channel and across areas between Breton Sound and Lake Borgne. Compounding the issue is the fact that relative sea level rise of up to 0.96 feet per century (3 mm per year) has given saltier waters greater access to basin wetlands. Additional areas that may have been impacted by the construction and operations of the MRGO include the Pass Manchac near Ponchatoula; Lake Pontchartrain including the North Shore and Little Woods; Chef Menteur Pass near Lake Borgne; Bayou LaLoutre near Alluvial City; Breton Sound and Gossier Barrier Island Chain. Monthly summaries of salinity for pre- and post- MRGO indicate that salinity has increased on the average by the following amounts (although in recent years, salinities have stabilized).

- 0.4 ppt at Pass Manchac near Pontchatoula.
- 1.1 ppt at Lake Pontchartrain, North Shore.
- 1.9 ppt at Lake Pontchartrain, Little Woods.
- 2.3 ppt at Chef Menteur Pass near Lake Borgne
- 4.5 ppt at Bayou LaLoutre, Alluvial City.

To facilitate navigation, three man-made waterways were constructed which may have modified the hydrologic regime of Lake Pontchartrain (Sikora, 1985). These are the MRGO, Inner Harbor Navigation Canal and Gulf Intracoastal Waterway (GIWW). Lake Pontchartrain has undergone numerous physical and chemical changes resulting from expansion and urbanization of the surrounding area including the city of New Orleans. The construction of the MRGO navigation channel contributed to the existing conditions of Lake Pontchartrain: High salinity water can enter Lake Pontchartrain via MRGO through two routes, Chef Menteur Pass and the IHNC. The IHNC is the more direct route via the GIWW. The cross-sectional areas at Lake Pontchartrain and percent of the total tidal flow in and out of the lagoon are shown in Table 4.

As shown in the table, the high salinity water generally enters the Lake via the Mississippi Sound and Lake Borgne through the Rigolets and Chef Menteur passes. However, flow from the Pearl River can block this route (Sikora, 1985).

Table 4 - Salinity Routes to Lake Pontchartrain; Cross Sectional Area and Percent of Tidal Flow in and out (Swenson and Chuang 1983).

Name of Pass	Cross-Sectional Area, m^2	Percent of Total Flow
Rigolets	6800	60
Chef Menteur	3200	30
IHNC	80	10

Increased salinity levels have negatively impacted the Louisiana oyster (*Crassostrea virginica*) fishery and its industry by shrinking the area within the seeding grounds that serve as ideal oyster habitat (Chatry et al., 1983). Chatry et al. (1983) developed an optimum salinity regime for oysters (see Table 5) by studying salinity, spatfall, and seed oyster production data from a 10-year time period. Meeting this established salinity regime at least 40 percent of the time has become a goal of the MRGO Ecosystem Restoration Plan.

Table 5 Salinity Targets For The Biloxi Marshes

Salinity Targets for the Biloxi Marshes, ppt							
Month	Chatry Average Target	Mean Ambient Salinity	Needed Reduction	Chatry Optimum Limits		Chatry Range Limits	
				Low	High	Lowest	Highest
Jan	16.5	19.5	3.0	15.5	17.5	15.0	19.0
Feb	14.5	16.5	2.0	13.5	15.0	11.0	17.0
Mar	11.5	15.0	3.5	10.5	12.5	7.5	15.0
Apr	8.0	14.0	6.0	7.0	9.5	2.0	13.0
May	7.0	15.0	8.0	6.0	8.0	4.5	11.5
Jun	12.5	17.0	4.5	12.0	13.5	9.0	6.0
Jul	13.0	20.5	7.5	12.5	13.0	10.5	15.0
Aug	16.0	22.0	6.0	15.0	16.5	13.0	17.5
Sep	17.0	23.0	6.0	16.0	18.0	15.0	24.0
Oct	17.0	24.0	7.0	16.0	18.0	13.0	18.5
Nov	16.0	24.0	8.0	15.0	17.0	11.5	18.5
Dec	16.0	23.0	7.0	15.5	16.5	13.0	17.0

Note: Salinity targets were estimated to the nearest 0.5 ppt using the graphical display in Chatry et at. (1983). Ambient salinities were rounded to the nearest 0.5 ppt using Pankow et al. (1989) Equation 10a and 50

2.3.4 Canals

A vast network of canals (mostly dredged between 1950 and 1980), pipelines, and production facilities has been created to service the oil industry. Canals that stretch from the Gulf of Mexico inland to freshwater areas allow saltwater to penetrate much farther inland, particularly during droughts and storms, which has had severe effects on freshwater wetlands. These canals have caused secondary indirect impacts by altering the natural hydrology of marshes and by accelerating erosion rates along the channel and canal banks. Dredged material banks, which are much higher than the natural marsh surface and the many smaller canals dredged for oil and gas exploration, alter the flow of water across wetlands. Hydrodynamic alteration changes important hydrogeomorphic, biogeochemical, and ecological processes, including chemical transformations, sediment transport, vegetation health, and migration of organisms. Because of the presence of dredged material banks, partially impounded areas have fewer but prolonged periods of flooding and reduced water exchange when compared to unimpounded marshes (Swenson and Turner 1987). This results in increased waterlogging and frequently in plant death. More importantly, dredged material banks also block the movement of sediment resuspended in storms, which play a major role in sustaining land elevations (Reed et al. 1997). These effects combine to eliminate soil-building processes necessary to counteract subsidence. Additionally, channels and canals provide avenues for higher salinity water to move into previously freshwater dominated marshes, which ultimately leads to degradation and land loss. Extreme salinity changes can stress fresh and intermediate marshes to the point where vegetation dies and the wetlands convert into open water (Flynn et al. 1995). Also, by altering salinity gradients and patterns of water and sediment flow through marshes, canal dredging not only directly changed land to open water, but also indirectly changed the processes essential to a healthy coastal ecosystem. Habitat switching is another impact caused by altering salinity gradients.

One advantage to the dredging of canals was that elevated dredged material embankments may provide important wildlife refuge during storm events and valuable habitat for neotropical migratory birds, and the value of this habitat should be considered as restoration of these areas occurs (LCA 2004).

2.4 RELATIVE SEA LEVEL RISE DUE TO EUSTATIC SEA LEVEL RISE AND SUBSIDENCE

Sea level rise in southern Louisiana is a combination of eustatic rise (due to global factors), general land settlement and other local factors which have an impact on sea level and is significantly higher than either the global or regional average sea level rise changes.

Historic rates of relative sea level rise vary across Louisiana and can also vary depending on the methods used to estimate those rates. The two most commonly cited methods of estimating historic relative sea level rise rates in Louisiana are radiometric dating of organic deposits (mostly peat) and

analysis of long-term tide gage data. Relative sea level rise rates are determined from tide gage data that are based on more recent (20th century) data than radiometric dating. The relative sea level rise rate determined from gage data is generally greater than the rates determined from radiometric dating.

Data from two local gages together with work from an earlier Louisiana Coastal Protection and Restoration (LACPR) technical report were reviewed as part of this study. The historic trend in sea level rise from the Shell Beach gage was adopted for this study. The historic trend was established as 10.2mm/year using a dataset of 42 years from 1961 to 2002.

The future rates of sea level rise were established in accordance with EC 1165-2-212 and produced three estimates into the future as detailed in Appendix B. The three estimates (low, intermediate, and high) are based on the following:

1. Low - continuation of the historic rate
2. Intermediate - accelerating rate of eustatic rise based on the National Research Council (NRC) Sea Level Curve I
3. High - accelerating rate of eustatic rise based on the NRC Sea Level Curve III

A global (eustatic) rate of 1.7mm/year was used, in accordance with the guidance, for the purpose of extracting the changes of regional origin from the total sea level rise.

When considering a study period from 2011 to 2065, the increases in sea level over this period were calculated as:

1. Low rate (based on a historic trend of 10.24 mm/yr) = 1.8ft (0.55m)
2. Intermediate rate (based on a NRC Curve I and 8.54mm/yr for land subsidence) = 2.2ft (0.69 19 m)
3. High rate (based on a NRC Curve III and 8.54 mm/yr for land subsidence) = 3.7ft (1.12 m)

A plot of the sea level rise over the period is shown in Figure 4.

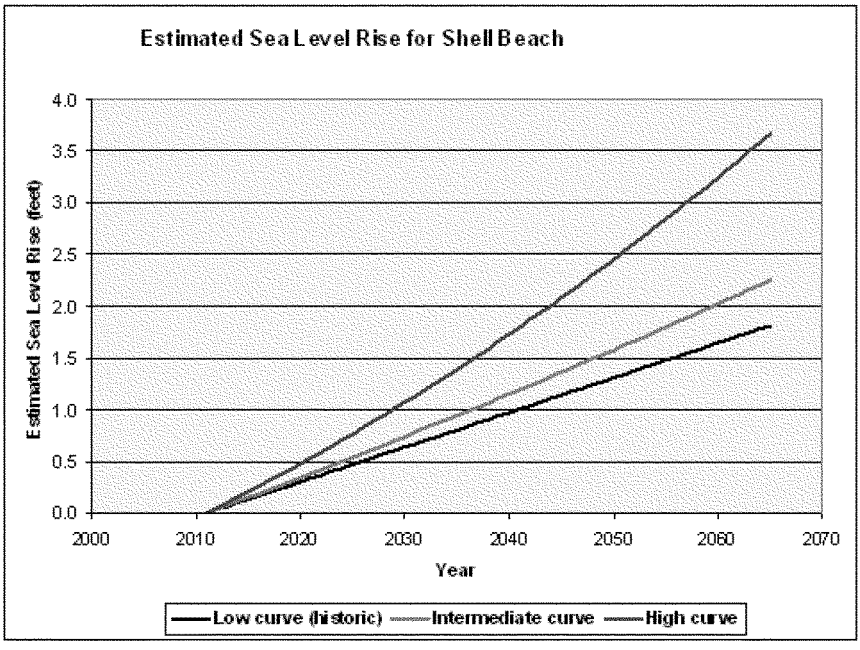

Figure 4 Sea Level Rise Curves

2.5 HYDRODYNAMIC MODELING

2.5.1 General

Computer model studies were conducted to determine if salinity targets set in the Biloxi Marsh set for the study can be met by diverting freshwater from the Mississippi River through a hydraulic structure and conveyance system near the Violet, Louisiana. The resultant flow regime would then be the basis of design for a new, or modification to an existing, hydraulic structure that would deliver fresh water to benefit the Biloxi Marsh. A secondary objective is the use of the proposed hydraulic modifications to introduce freshwater to the CWA in order to enhance cypress swamp and freshwater marsh restoration.

The required salinity targets for the Biloxi Marshes are shown in the Chatry report (reproduced in Figure 5) as monthly optimum salinity values, together with a standard error about the optimum value (+/- one standard deviation about the monthly mean). In addition, this graph depicts the range of values (denoted as range limits) analyzed to obtain the target value and standard error values (denoted as optimum limits). The graph was based on eight years of data which preceded years of good oyster production. The optimum salinity around the mean is a very narrow range, much smaller

than the daily variability in salinity due to tidal and other coastal forcing parameters such as river flow, winds, and atmospheric pressure. All of these parameters drive salinity values up or down by significant amounts, and depending on the specific conditions at a given time can have remarkable impacts on the salinity mean.

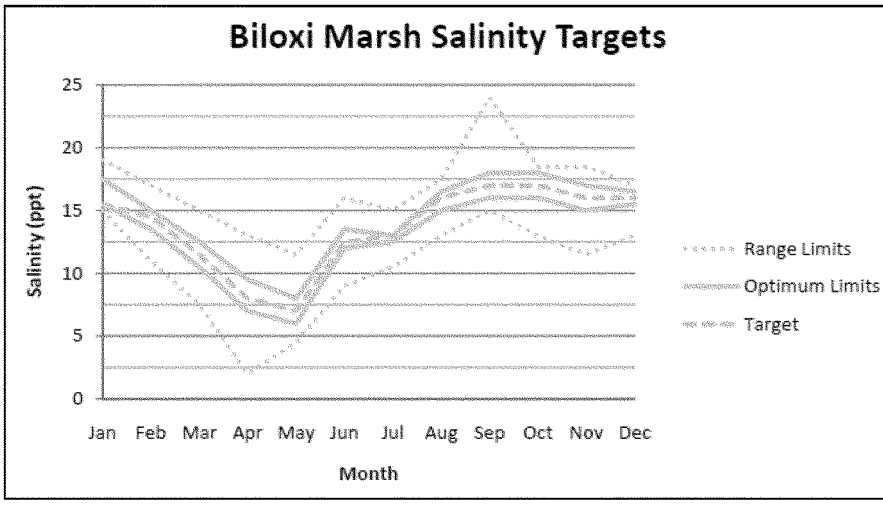

Figure 5 Biloxi Marsh Salinity Targets

A final design of the freshwater diversion will balance the efficiency of delivery of freshwater to the Biloxi Marsh region, and the ecological restoration goals to the CWA. Considerations in the design are the available head in the Mississippi River and the potential negative impacts to the CWA that could result from inundations due to increased water levels.

2.5.2 Methodology

To meet the objectives, a modeling initiative was developed to establish details of a diversion near Violet, La. This was undertaken as follows:

1. Collecting and collating data on flows, salinity, nutrients and future projects and evaluating their impact on the study area.
2. Modifying and re-calibrating the existing Pontchartrain Basin UNO Mass Balance model.
3. Undertaking a series of model runs to establish the feasibility of a diversion in the vicinity of the Violet Canal to meet Biloxi Marsh salinity targets and to determine flows and generalized flow regime details.

4. Developing a 2D detailed model of the CWA area using Mike21 to characterize the impacts of different alternative diversion locations on the area in terms of salinity, stage and flow.
5. Using UNO's FVCOM to consider the sensitivity of the UNO Mass Balance model results to wind shear and, if necessary, refine the error bands on selected alternatives from the model to reflect these results.
6. Running the UNO Mass Balance model with the final preferred alternative based on flow characterized in the detailed modeling to evaluate the effect on salinity in the Biloxi Marsh.

2.5.3 UNO Mass Balance Model

2.5.3.1 General Description

The UNO Mass Balance model is a mathematical tool that performs first-order approximations of mass transfer due to physical inputs like water level, flow, and salinity. The modeling approach is valid if the results are interpreted in the appropriate manner and at the appropriate temporal and spatial scale. The model is ideally used early in feasibility studies in order to look at large numbers of alternatives over long time frames. The model was selected for this planning study because it has been demonstrated to accurately characterize salinity variability on monthly time scales in the Lake Pontchartrain/Lake Borgne regions (McCorquodale, et. al., 2008). The model has a coarse resolution with grid cells sized on the order of 10 x 10 km., and makes volume and salinity calculations for each box. There is no vertical gradient defined and the model is only capable of predicting large-scale (>> 10km) gradients in the salinity pattern because of its resolution. The model provides a reasonable representation of the spatial distribution of salinity over large areas at these low (monthly) frequencies of interest. The facility of this model is that it is readily available for use, has the ability to make a significant number of operational runs over long time scales, and is easy to modify to include new changes to the system such as the MRGO barrier.

The following stipulations are acknowledged when using Mass Balance model:

- Study area is composed of well mixed cells and cannot represent stratified flows
- Flow in the channels depends on difference in water levels between cells and friction
- Tides are diurnal (one maximum per day) with a lunar cycle
- Short-term wind effects are not included; seasonal Gulf water level is included
- Coriolis force (earth's rotation) is neglected
- Based on the model calibration error of 17%, a standard error in the prediction of the salinity in any cell can be +/-17%.

2.5.3.2 Application to Study

For this study, the results of the model were used to define discharge rates at the diversion necessary to meet the salinity targets in the Biloxi Marsh/Lake Borgne regions. Accordingly, the model domain was modified to better represent the Biloxi Marsh and the Chandeleur Islands in order

to characterize the effects of a Violet Freshwater Diversion on salinity in the Biloxi Marsh/Lake Borgne area.

2.5.3.3 Data Collection-Collation

2.5.3.3.1 Freshwater Inflow

An extensive effort of data collection was needed to drive the hydrodynamic models used in the study. Freshwater inflows into Lakes Maurepas and Pontchartrain, Mississippi Sound, Mobile Bay and the passes of the Mississippi River were obtained to be used as boundary conditions for the models. Flow data for diversion structures such as Caernarvon, Blind River and Hope Canal, and flood control structures such as the Bonnet Carré Spillway were also used. Where gaged data was not available, the flow was established by considering the flow from a neighboring gaged area and assigning a flow based on the proportion of the two drainage areas, assuming similar rainfalls in the ungaged and gaged areas.

For the Lake Pontchartrain basin area, daily flow values from the USGS for the Amite, Tchefuncte, Tickfaw, Tangipahoa and Pearl Rivers were used.

For the Pearl River (which presents the largest percentage of freshwater flow into the Biloxi Marsh region), daily flows from 1990 through 2008 were used. The entire Pearl River record from 1938 through 2008 was analyzed to obtain monthly averages and statistics for the monthly averages.

The ungaged areas around Lake Maurepas and Lake Pontchartrain were grouped into the following areas: ungaged South Lake Maurepas, ungaged Southwest Lake Pontchartrain, ungaged South Central Lake Pontchartrain (Jefferson Parish), ungaged Southeast Lake Pontchartrain (Orleans Parish), ungaged Northeast Lake Pontchartrain (Bayous Lacombe and Bonfouca), and ungaged South Lake Borgne.

Daily flow values from the USGS were used for the Wolf, Biloxi and Pascagoula Rivers (areas around the Mississippi Coast). Flow for the Jourdan River was apportioned according to its drainage area. Daily freshwater flows into Mobile Bay were obtained from the USGS.

Daily flows for the Mississippi River were obtained from the USACE and were distributed into the various passes according to the average percentage of flow determined from more than two dozen surveys of discharges in the passes from 1970 through 2004.

Flow data for the Bonnet Carré Spillway was obtained for periods when the structure was being operated for flood control in 1997 and 2008. For other high Mississippi River conditions when the structure was not being operated for flood control, leakage through the needles of the structure was considered significant enough to be included as freshwater input. Leakage was calculated using a slot flow equation and was checked against USGS flow measurements and a leakage curve supplied by the USACE.

2.5.3.3.2 Salinity

There was no extensive continuous record of salinity data for the Lake Pontchartrain-Lake Borgne Basins. Conversely, many independent sets of data, obtained for various reasons, was available. This data was collected and sorted in a database by latitude, longitude, and date.

For the Mass Balance Model (which is based on a large-scale grid), to generate data sets appropriate for comparison with model results, the data was aggregated together based on their locations relative to the model grids. The aggregated cells were then averaged together over each month to generate monthly "mean" values in each year data was collected. If enough data was collected over each one month period then the average of all these data points over each aggregated grouping provides the best estimate of the average salinity for that month and year. A high number of data points will effectively filter out high frequency variability in the salinity data caused by winds and tides.

Salinity in the Biloxi Marsh can be represented by the aggregation of zones J and L (Figure 6) which represent the grouping of several monitoring stations that are in the vicinity of the Biloxi Marsh. Figure 7 shows the monthly average salinity for aggregated zones J and L against the Chatry limits. The historic salinity falls within or below Chatry's optimum upper limits during January, February, March, August, September, November and December. The average salinity falls just above Chatry's limits in June, July and October. In April and May, historic salinity levels are significantly higher than the target. An analysis of the relationship between the freshwater discharges from the Pearl River system and salinity values in Biloxi Marsh can be developed (Figures 8 and 9). If there is a direct relationship, higher river flows would correlate with lower salinity values. To test this hypothesis, salinity data from the Biloxi Marsh area was aggregated together as described above from zones J and L. The monthly salinity values were plotted directly against the monthly river flows. The results illustrate that prior to the mid 1980s there seems to be a poor relationship between the river and salinity as demonstrated by lack of the expected inverse correlation (Figure 10). This poor relationship is robably due to lack of enough salinity data being available prior to 1989 which will create a bias in the data sets. For the data set from 1989 to the present which is consistent with the data set used in the modeling effort, the anticipated inverse relationship is present (Figure 11).

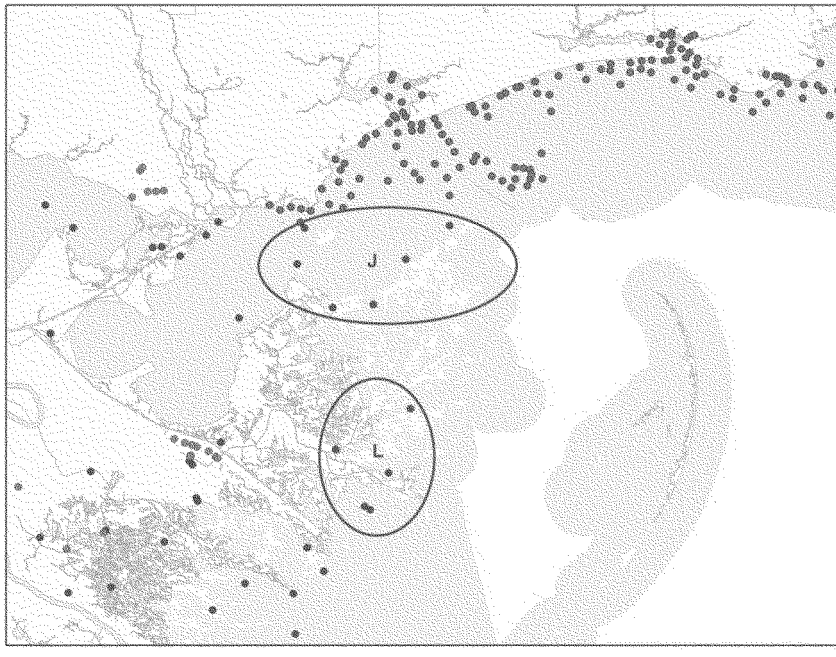

Figure 6. Location of J and L data points

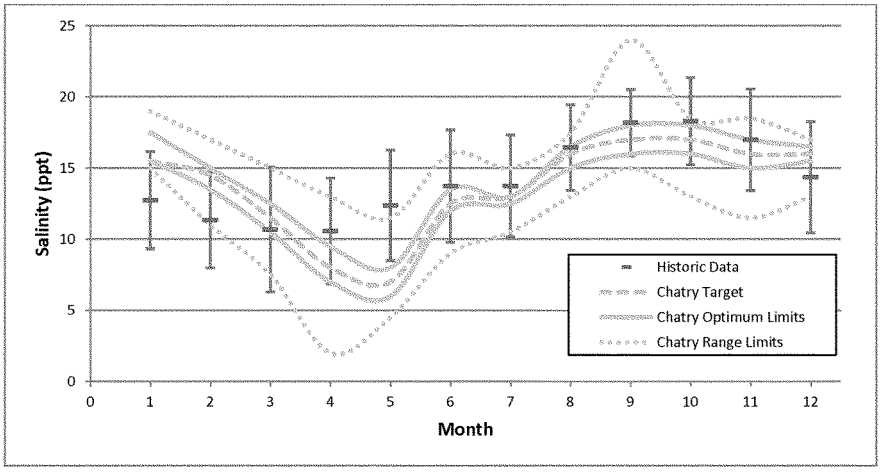

Figure 7. Comparison of historic data with the Chatry limits

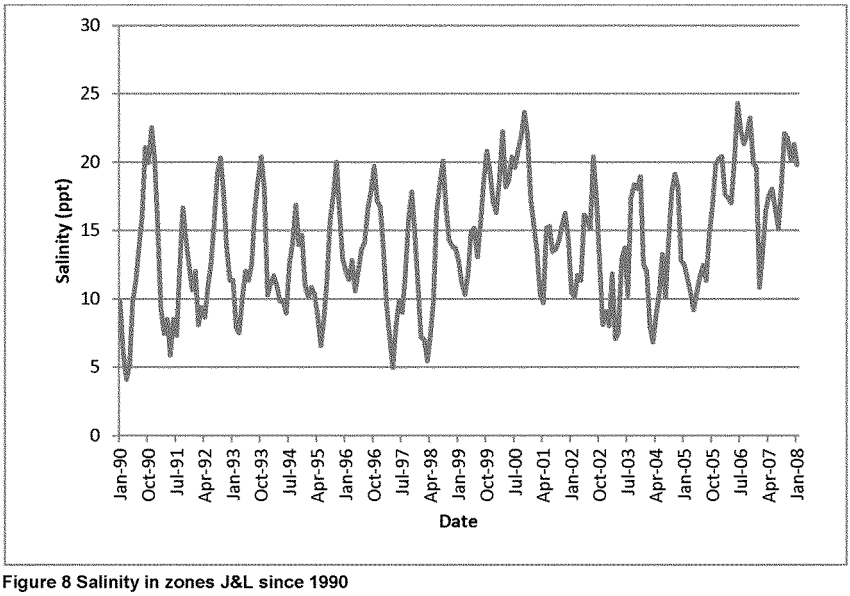

Figure 8 Salinity in zones J&L since 1990

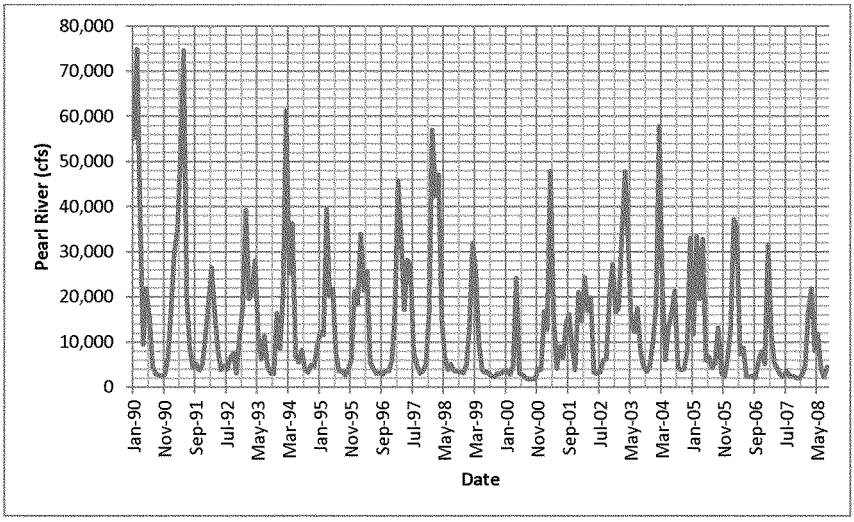

Figure 9 Historical Pearl River flow rates

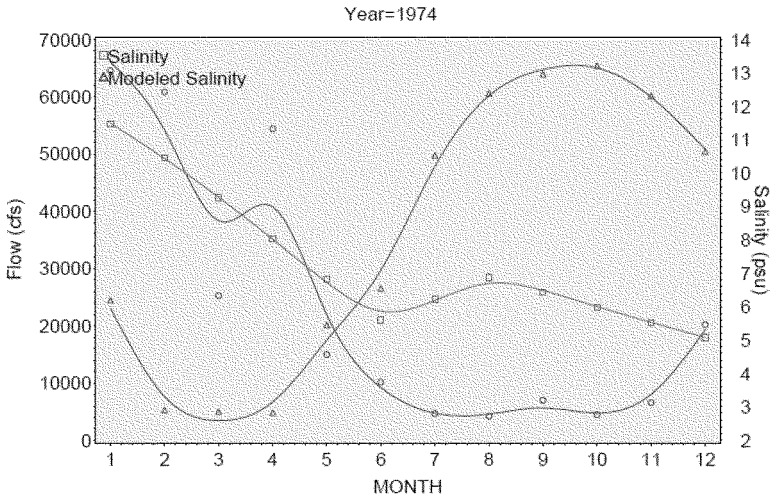

Figure 10. Example of poorly correlated data (1974)

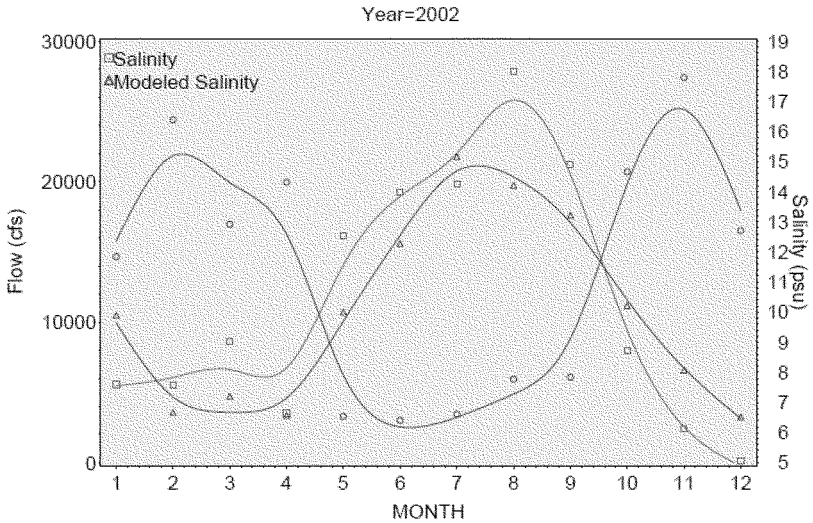

Figure 11. Example of well correlated data (2002)

A multiple linear regression model was developed to describe the relationship between salinity in the Biloxi Marsh and 3 independent variables related to flow in the Pearl River. The equation of the fitted 22 model is:

Monthly Mean Salinity = 53.0764 - 1.69051*logflow - 1.33071*loglf1 - 1.66414*loglf2

Where: logflow = log transformed mean flow for predicted month
loglf1= log transformed mean flow for month prior to predicted month
loglf2= log transformed mean flow for month two months prior to predicted month

The P-value from the analysis of variance (ANOVA) analysis is less than 0.05, indicating a

statistically significant relationship between the variables at the 95.0% confidence level. The R32 Squared statistic indicates that the model, as fitted, explains 69.09% of the variability in the salinity. The adjusted R-squared statistic, which is more suitable for comparing models with different numbers of independent variables, is 68.61%. The standard error of the estimate shows the standard deviation of the residuals to be 2.50. The mean absolute error of 1.98 is the average value of the residuals. The Durbin-Watson statistic tests the residuals to determine if there is any significant correlation based on the order in which they occur in the data file. Since the P-value is less than 0.05, there is an indication of possible serial correlation at the 95.0% confidence level.

In determining whether the model can be simplified, the highest P-value on the independent variables is 0.0001, belonging to loglf1. Since the P-value is less than 0.05, that term is statistically significant at the 95.0% confidence level. Consequently, all variables should remain in the equation of the fitted model.

The analysis demonstrates that gage data in the Pearl River can, within the errors demonstrated, predict salinity in the Biloxi Marsh. With this relationship operational models may be developed to help managers predict those times when diversions of Mississippi River water may be needed. The analysis only touches on the functional scheme framework that would be required for a diversion. The result provides an initial piece of the overall data requirements and methodology necessary to create this management framework.

2.5.3.4 General Description

The UNO Mass Balance model is a mathematical tool that performs first-order approximations of mass transfer due to physical inputs like water level, flow, and salinity. The modeling approach is valid if the results are interpreted in the appropriate manner and at the appropriate temporal and spatial scale. The model is ideally used early in feasibility studies in order to look at large numbers of alternatives over long time frames. The model was selected for this planning study because it has been demonstrated to accurately characterize salinity variability on monthly time scales in the Lake Pontchartrain/Lake Borgne regions (McCorquodale, et. al., 2008). The model has a coarse resolution with grid cells sized on the order of 10 x 10 km., and makes volume and salinity calculations for each box. There is no vertical gradient defined and the model is only capable of predicting large-scale (>> 10km) gradients in the salinity pattern because of its resolution. The model provides a reasonable representation of the spatial distribution of salinity over large areas at these low (monthly) frequencies of interest. The facility of this model is that it is readily available for use, has the ability to make a significant number of operational runs over long time scales, and is easy to modify to include new changes to the system such as the MRGO barrier.

The following stipulations are acknowledged when using Mass Balance model:

- Study area is composed of well mixed cells and cannot represent stratified flows
- Flow in the channels depends on difference in water levels between cells and friction
- Tides are diurnal (one maximum per day) with a lunar cycle
- Short-term wind effects are not included; seasonal Gulf water level is included
- Coriolis force (earth's rotation) is neglected
- Based on the model calibration error of 17%, a standard error in the prediction of the salinity in any cell can be +/-17%.

2.5.3.5 Application to Study

For this study, the results of the model were used to define discharge rates at the diversion necessary to meet the salinity targets in the Biloxi Marsh/Lake Borgne regions. Accordingly, the model domain was modified to better represent the Biloxi Marsh and the Chandeleur Islands in order

to characterize the effects of a Violet Freshwater Diversion on salinity in the Biloxi Marsh/Lake Borgne area.

2.5.3.6 Performing the Model Simulation

2.5.3.6.1 Input Parameters

The main (implying their dominance in determining the salinity distribution in the cells) inputs are:

- The freshwater budget (rainfall, evaporation, tributary flow and diversions)
- The open boundary conditions (tides and salinities)
- The cell and link bathymetry
- The link friction factors (Manning's n and eddy loss coefficients)
- The diffusivities for the links

2.5.3.6.2 Geometry

The model consists of boxes (cells) and links. Figures indicating the cells and cell-link configuration, the dimensios of each cell and link, and other geometry data are included in Appendix D of Annex 1.

2.5.3.6.3 Boundary Conditions

The open boundary was located in the Gulf of Mexico in order to minimize its influence on the area of interest. Diurnal tides were imposed with a spring range of 0.66 m. The salinities at the Gulf boundary vary from 34 to 36 ppt with surface values on average less than deeper values. The model used 34 ppt which is more representative of mean surface salinities.

The freshwater input data (depicted in Table 6) was comprised of daily flow data for rivers discharging into Lakes Maurepas and Pontchartrain, Mississippi Sound, Mobile Bay and the passes of the Mississippi River . A regression analysis with the USGS Bogalusa gage was completed to determine flow for the Pearl River. Flow data for diversion structures such as Caernarvon and flood control structures such as Bonnet Carré were also used as inputs into the model. Salinity of the freshwater inputs was set at 0.2 ppt.

Table 6 Freshwater Input Data

Location	Average Flow (cfs)	Minimum Flow (cfs)	Maximum Flow (cfs)
Amite River	2,005	132	79,600
Tangipahoa River	1,072	73	36,400
Tchefuncte River	137	25	4,667
Tickfaw River	493	55	20,760
Pearl River	10,277	1,140	97,400
South Lake Maurepas	1,042	69	35,980
Southwest Lake Pontchartrain	261	17	8,995
South Central Lake Pontchartrain (Jefferson Parish)	265	24	8,995
Southeast Lake Pontchartrain (Orleans Parish)	353	28	12,593
Northeast Lake Pontchartrain (Bayou LaCombe)	384	24	13,493
Northeast Lake Pontchartrain (Bayou Bonfouca)	385	26	13,493
Lake Borgne (Violet Wetlands)	82	6	841
Wolf River	542	12	19,448
Jourdan River	667	15	23,936
Biloxi River	156	4	5610
Pascagoula River	8,474	898	103,000
Mobile Bay	17,533	128	157,788
Southwest Mississippi River (Southwest Pass, Grand Pass and West Bay Diversion)	179,728	45,115	433,500
Central Passes Mississippi River (Pass a Loutre and South Pass)	250,302	62,831	603,723
East Passes Mississippi River (includes Main Pass to Bayou Lamoque and Bohemia Spillway)	107,124	26,890	258,380
Caernarvon Diversion	1,300	0	9,267
Bonnet Carre Diversion			240,000
Blind River and Hope Canal Diversion			4,500

2.5.3.6.4 Bathymetry

Model bathymetry was obtained from NOAA navigation charts, a previously compiled bathymetry mesh for ADCIRC model runs Barrett (1970).

2.5.3.6.5 Meteorological Inputs

Daily precipitation, evapotranspiration, air temperature, water temperature and daily wind speed were used as inputs for the entire simulation.

2.5.3.6.6 Salinity Calibration

Since the base Lake Pontchartrain model was originally developed, calibrated, and validated for Lake Pontchartrain/Lake Borgne area (McCorquodale, et. al., 2008), the model domain had to be extended to examine the Biloxi Marsh area. The extended model was calibrated using flow and salinity data for the period 1990 through 2008. It should be noted that the base and existing conditions are different, as existing conditions have changed with the closure of the MRGO at the Bayou La Loutre Ridge. Since the collected salinity data is from the period prior to the construction of the MRGO closure structure, the calibration effort was conducted using the conditions existing prior to the construction of the closure structure. Calibration values are included in Appendix 15 D of Annex 1. Tidal fluxes were compared with data from the UNO/USGS Synoptic Survey. For salinities, data from the LDWF and MS Division of Wildlife, Fisheries and Parks were supplemented with salinities from NOAA, USACE, USGS, LADEQ, LADNR, UNO and LSU.

The Caernarvon diversion freshwater flow into the area was set at an average flow of 1,300 cfs, a maximum flow of 9,267 cfs, and a minimum flow of 0 cfs. The Bonnet Carré Spillway Diversion was included also, its maximum flow set at 240,000 cfs, (which occurred during the 1997 operation of the structure).

Figure 12 shows the tidal fluxes through the passes into Lake Pontchartrain and Lake Maurepas. Table 4 compares the spring ebb tidal fluxes in the model with measured values. The values for Pass Manchac into Lake Maurepas are within one percent. The values for the IHNC through Seabrook are within five percent. The model under-computes the peak spring tide flow in the Chef Menteur Pass by 23 percent and over-computes the Rigolets by eight percent (8%). However, the combined ebb flux into Lake Pontchartrain through the IHNC, Chef Pass and the Rigolets in the model is within 2.3 percent of the observed value. The spring tidal range in Lake Pontchartrain is predicted within 4% of the observed range. Figure 13 is a plot of modeled data compared to collected data at Grand Pass, in the Biloxi Marsh area. This data represents the output from Box 14, which is in the western Mississippi Sound just north of the Biloxi Marsh area, over the time period shown. Box 14 is a "deeper" water region where a significant transfer of flow occurs along the Mississippi coast where water mixes with saltier gulf waters. The data sets show good agreement though the model does not agree with the extreme high and low salinity points probably due to the depth-averaged feature of the model and its weakness in calculating the higher frequency variability. The 14-day moving average provides a trendline of the measured data, which correlates well to the results.

Figure 14 is a plot of the modeled data compared to the measured data at Rigolets over the time period shown. The data is the output from cell 3, which is the area in east Lake Pontchartrain. Similar to the Grand Pass data, the model does not capture the high and low salinity values but is able to follow the trend of the data well. Figure 15 graphs the maximum and minimum salinity values for the areas shown in Figure 16 versus the mean salinity value of the nearest cell in the model. Linear curves are given for the maximum, minimum, and calculated mean of the salinity points. In general,

there is high confidence in the ability of the model to provide accurate estimates of average salinity values and thus to predict average salinity values due to any proposed diversions.

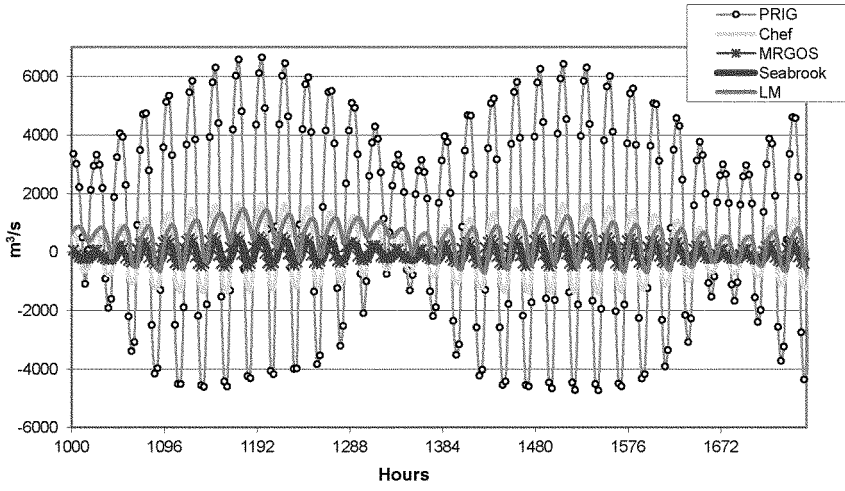

Figure 12. Tidal fluxes through the passes for calibration. PRIG is Rigolets, LM is the pass into Lake Maurepas.

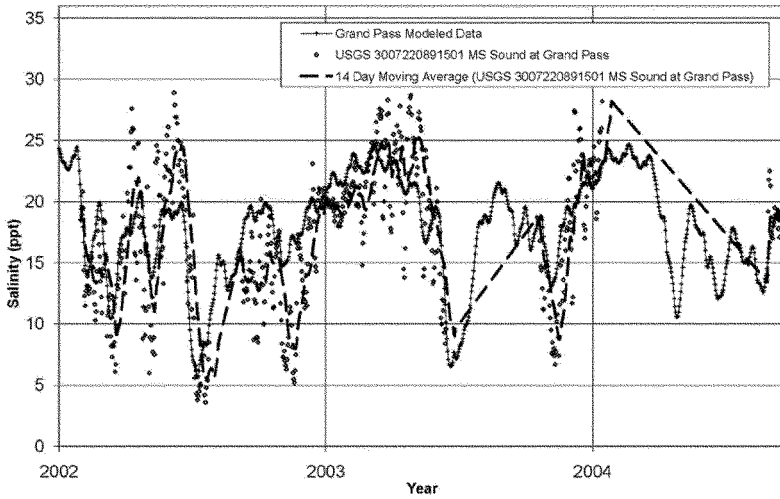

Figure 13 Model data vs. measured data for Grand Pass

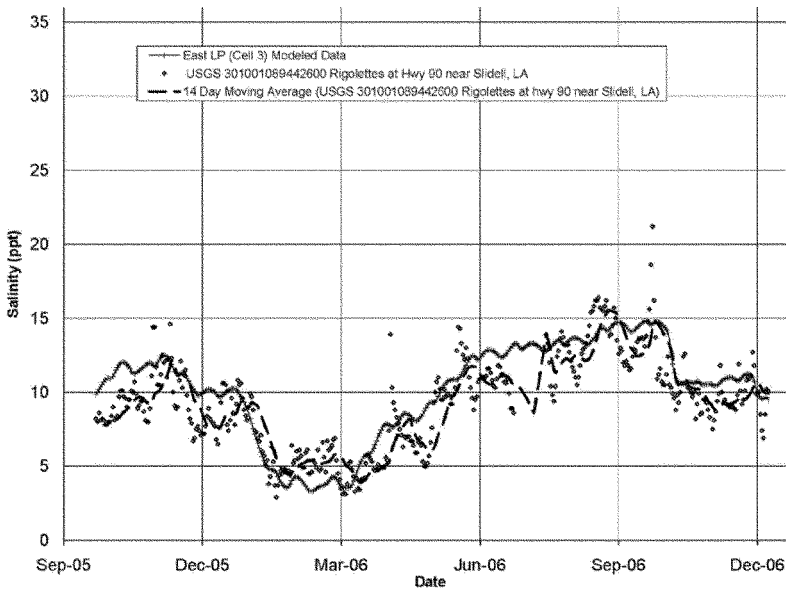

Figure 14 Modeled data vs. measured data at the Rigolets

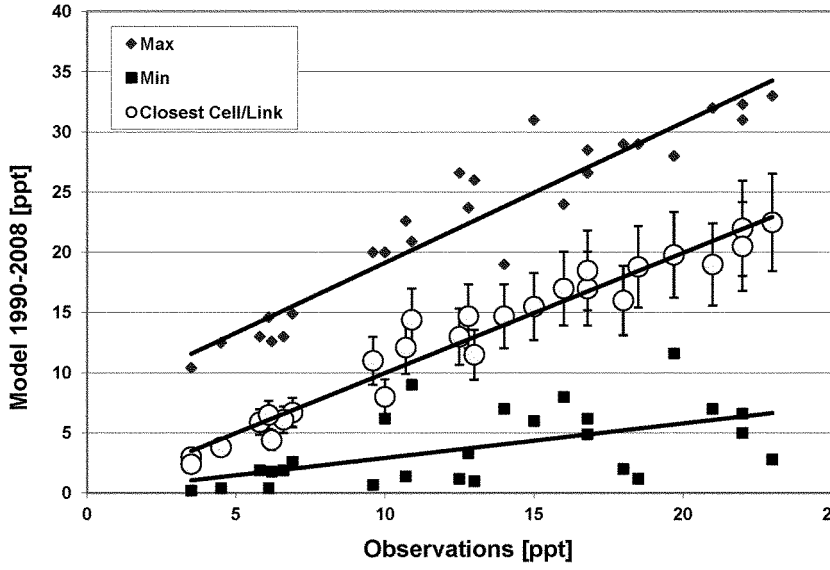

Figure 15 Plot of modeled data versus observed data

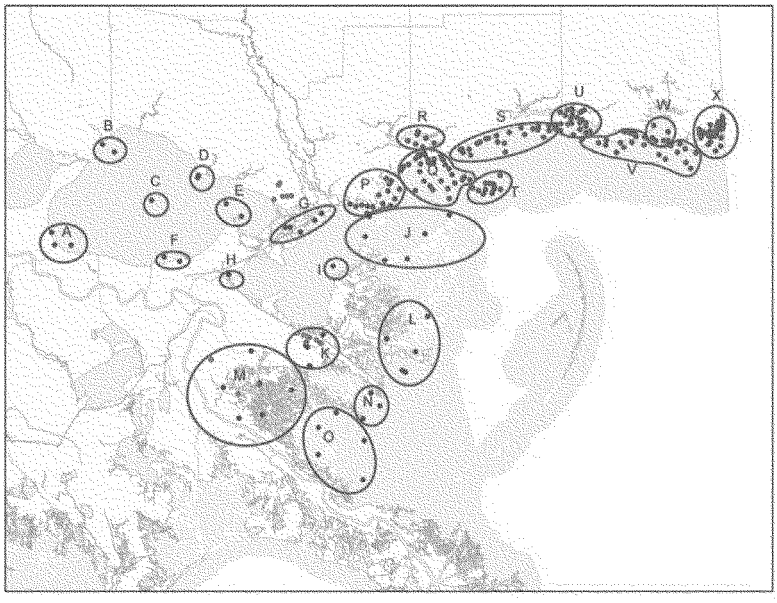

Figure 16 Locations of salinity data

2.5.3.6.7 Salinity Validation

Validation of a model consists of verifying that the model produces expected results for a simulation in which the observed data set is different from the one used in the calibration. No formal validation of the results was been completed. Lack of enough salinity data taken after the closure of the MRGO did not allow for validation of model results. The construction of the MRGO closure has significantly changed (lowered) the salinity patterns in Lake Borgne that existed since the 1950s dredging of the MRGO. Therefore, validation of this condition is not possible until a reliable long-term data set is generated. The existing UNO Mass Balance model previously validated for Lake Pontchartrain was calibrated to analyze the effects in the Biloxi Marsh. Comparison of model output with existing data provides confidence in the model results.

2.5.3.6.8 Model Simulation – Salinity Targets

2.5.3.6.8.1 Salinity Targets - Location and Calculation

The measure of meeting the salinity targets is defined as meeting the targets along a specific line (contour) defined in the Chatry et at. (1983). The Salinity Target Line, is defined in the "Flood Control of the Mississippi River and Tributaries Mississippi and Louisiana Estuarine Areas, Design

Memorandum No 1, Bonnet Carré Freshwater Diversion Structure, Appendix C, Salinity Study Results" and is the designated "point" in Biloxi Marsh where salinity from the model can be aggregated to compare against the Chatry limits. This line passes through computational boxes 14, 13, 78, 74, and 28 in the salinity model. Box 14 has been excluded from the analysis as the majority of this box is deeper water and not marshland and is subject to higher salt gradients and skews the depth averaged value to the saltier side. Box 28 within the model represents the MRGO seaward of the Bayou la Loutre and is not thought to represent the salinity within the Biloxi Marsh. Although the line does not pass through Box 73 this has been included in the weighting as this is a significant part of the marshland. From the salinity values of the remaining four boxes, salinity along the Salinity Target Line was determined by dividing the line into twelve points and using an inverse distance weighted process to establish the average salinity along the line. Each salinity value is weighted inversely to the square of the distance of the centroid of each box from the line. All points weighting gives a single set of weights that can be used to represent the average value along the whole line. A distance weighting factor of 1 was been used.

2.5.3.6.8.2 Methodology for Establishing Compliance with Salinity Target Values

Neither the target nor results from the UNO Mass Balance model represent a single number but a range or averaging of values over spatial and temporal scales. For the target values, the ranges have occurred due to the variability of the data analyzed to produce the results. The salinity values vary from year to year and the target ranges were statistical ranges about the mean value of selected years correlated to high oyster production. The optimum limits (which are the target of this exercise) are based on one standard deviation about this mean, whereas the range is the maximum and minimum values recorded in those months which were seen to contribute to optimize oyster production.

For the modeling results, there is a range in the values as a result of uncertainties within the model and also as a result of the averaging process to establish salinity values to compare against the target value. The model uncertainties were established as being around ±17% of the modeled salinity (e.g. a modeled value of 10ppt would have a model uncertainty of ±1.7ppt). In addition, a standard deviation associated with the averaging process defined in section 4.4 was established. These two values were combined as a vector sum to give a standard error for the modeled results.

Having established these standard deviations for both the target and modeled result it is then possible to plot the frequency distributions (based on a t-distribution) of the modeled salinity and the target value (an example of which is shown in Figure 17). This figure shows that for some percentage of the time the modeled distribution overlaps the target distribution. Significantly, most values are demonstrated to be lower in salinity than the upper optimum limit identified by Chatry. The results of the distributions were plotted as cumulative, as shown in Figure 18. From Figure 18 it can be seen that the percentage of time that the modeled results intersect with the Chatry limits is the models prediction against the target for that month. For this example the model generated salinity values in May along the target line below the Chatry Optimum upper value 30% of the time and above the Chatry optimum upper value 7% of the time, therefore the overlap within the optimum range is 23%.

For compliance with the 40% criteria, freshening of the system is examined. Therefore, all values lower than the upper Chatry limit are considered. In this example, the UNO Mass Balance model has

generated salinity values lower than the upper target for 30% of the Mays (over 19 years). Therefore, this scenario does not meet the 40% target.

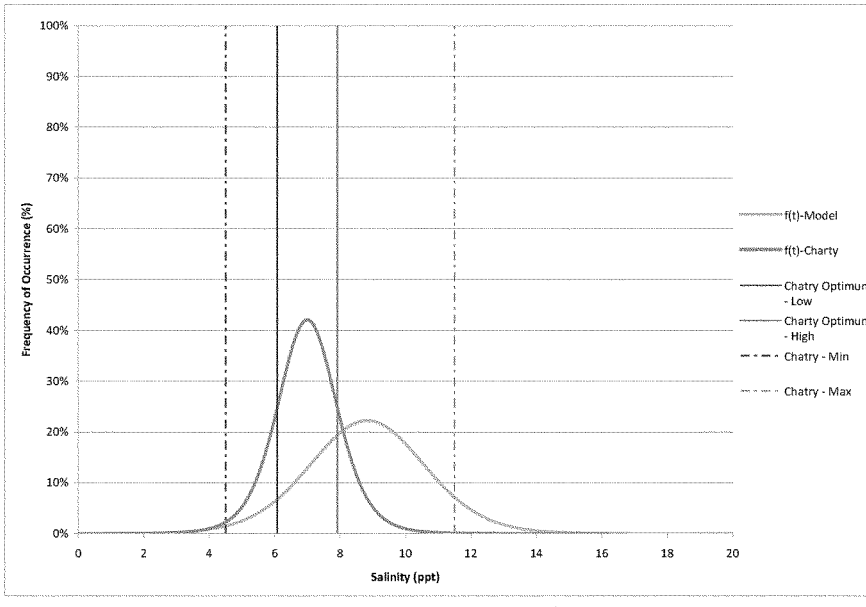

Figure 17 Salinity targets and modeled results plotted as t-distributed about the mean values

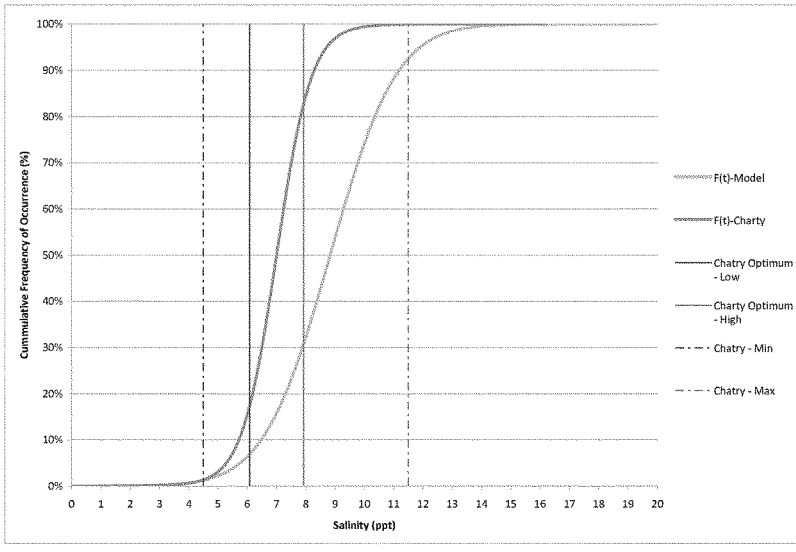

Figure 18 Salinity targets and modeled results taken as cumulative frequencies about the mean values

2.5.3.7 Model Results

2.5.3.7.1 Pre-MRGO Closure (Historic)

The Mass Balance model was run for a number of scenarios during the development of the diversion alternatives. The historic scenario was the calibration run. The recently constructed MRGO closure and other structures recently built are expected to have a substantial impact on salinity in Lake Borgne and surrounding areas but no data have been collected since construction to date to evaluate this impact. To demonstrate the reliability of the model, the alternatives and their detail are discussed further in the following sections.

The historic scenario simulation indicated, in agreement with the actual data, that the Chatry salinity target was met only 4% of the time in the critical month of May and only 24% in April. The salinity values fell below Chatry's optimum limits for the months of January, February, March, August, September, November and December; while falling just above Chatry's limits in June, July and October. Table 7 depicts the Historic Condition Model Runs. Figures 19 and 20 graphically compare the J and L data with the historic condition model run. The model agrees well with the physical data, especially in the months of April and May. These model runs point to the impact the MRGO had in the salinity regime of Lake Borgne, resulting in higher salinities in critical months (April, May) in the Biloxi Marsh.

Table 7 Pre-MRGO Closure (Historic)

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	13.3	3.72	2.55	94%
February	10.6	3.92	2.10	98%
March	9.9	3.80	1.99	90%
April	10.8	2.94	2.05	24%
May	12.5	4.12	2.44	4%
June	13.5	3.78	2.58	47%
July	14.2	3.67	2.69	37%
August	15.8	2.94	2.93	59%
September	16.7	3.14	3.08	67%
October	17.8	2.68	3.26	48%
November	17.7	2.85	3.25	41%
December	16.2	3.33	3.01	50%

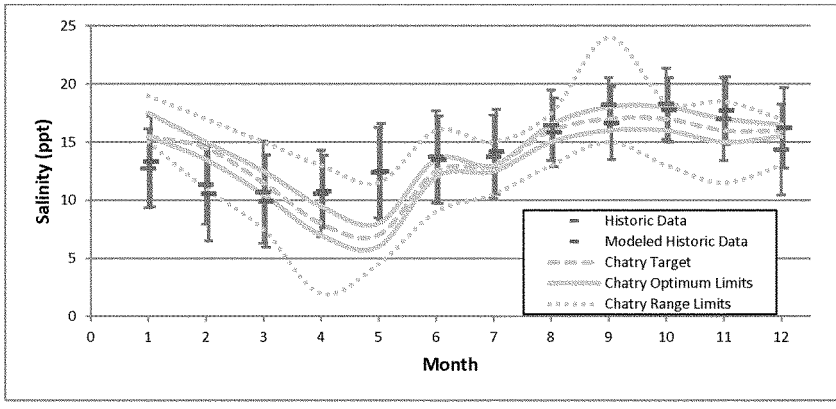

Figure 19 Monthly averages of modeled historical data compared with historic data from zones J&L

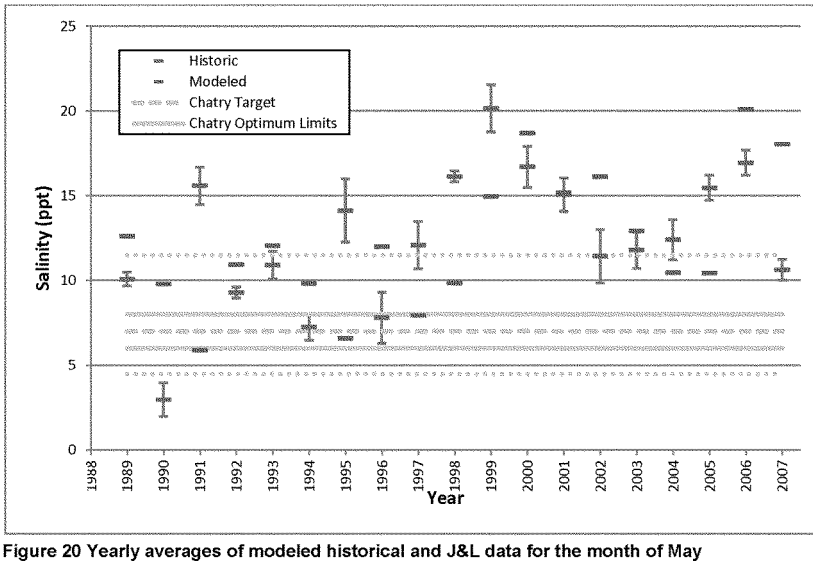

Figure 20 Yearly averages of modeled historical and J&L data for the month of May

2.5.3.7.2 Post-MRGO Closure (Baseline)

Baseline conditions for the model simulations included the MRGO closure structure at the La Loutre Ridge, the Seabrook Gate, and the IHNC Barrier (with openings for Bayou Bienvenue and the GIWW) all in place. For the Baseline model runs, the salinity targets were met for all months except May where the target is met only 6% of the time. The results for the baseline run are seen in Table 8.

This modeling scenario indicates that the existing closures and other changes to system that induce lower salinity levels would not be enough solely to reduce salinities to the recommended target in May in the Biloxi Marsh. Consequently, additional freshwater would need to be input into the system via diversions. Also to consider is the fact that April barely meets the criteria with salinity calculated below the upper limit 41% of the time. The salinities were above the upper limit over 50% of the time for the 19 year simulation.

Table 8 Post MRGO Closure (Baseline)

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	12.3	3.69	2.37	98%
February	9.4	3.85	1.91	99%
March	8.8	3.74	1.81	98%
April	9.7	2.86	1.86	41%
May	11.6	4.02	2.29	6%
June	12.7	3.77	2.45	59%
July	13.5	3.66	2.56	47%
August	15.2	2.85	2.80	68%
September	15.9	3.10	2.96	76%
October	17.1	2.63	3.14	57%
November	16.9	2.80	3.12	50%
December	15.2	3.35	2.85	63%

2.5.3.7.3 Future Without Project (FWOP)

Two FWOP conditions were examined based on the final disposition of future diversions. The FWOP includes the baseline conditions, existing diversions at Bonnet Carré and Caernarvon, and planned diversions at Maurepas Swamp, Convent, Hope Canal, Caernarvon, and the CWA Waste Water Treatment Program. Planned diversions from the lower Mississippi River located below the Caernarvon Diversion were not included in the simulation. The Bertrandville Siphon, Bohemia Mississippi River Reintroduction, Delta Building Diversion (North of Ft. St. Phillip), White Ditch, Bayou LaMoque and the Benney's Bay Diversion were deemed to be sufficiently far from the study area to not have a significant influence on salinity conditions in the study area. Also there was little available information as to the proposed operational scheme for these diversions. The diversion input for Bonnet Carré was the same as the calibration/historic run with a maximum flow of 240,000 cfs. The combined diversions into the Maurepas swamp area (Convent Diversion: 500 cfs, Hope Canal: 1,500 cfs and Maurepas Swamp River Reintroduction: 1,000 cfs) have a potential capacity of 3,000 cfs. Considering that these diversions are regulated to keep the salinity in Lake Maurepas below 1 ppt,

The model was operated in the FWOP scenarios to open the diversions when salinity in Maurepas was greater than 1 ppt; if the salinity was less than 1 ppt, they were closed. This results in a condition where Lake Maurepas was always less than 1 ppt. The CWA Waste Water Treatment Program flow totals approximately 300 cfs.

Input flows for the Caernarvon diversion were increased by roughly 25 percent in line with the projected increase in the capacity of the structure. The increase was calculated by increasing the actual flows for 2007 and 2008, in which the structure was operated to pulse large flows, by 25 percent. The resulting flows were then smoothed so as to eliminate rapid changes that might induce numerical instabilities in the model. The resulting smoothed flow was then repeated on that two year cycle over 19 years to examine salinity variability due to the Caernarvon input flows for the 19 year period. The model results indicate that the planned Caernarvon diversion and salinity constraint does modify the salinity regime in the Biloxi Marsh. For the month of April, salinity decreases over the baseline condition and the amount of time that the salinity is under the upper target increases from 41% to 85%. This reduction in salinity from the diversions infers that, on average, additional diversions may not be necessary during April. Consequent of the planned diversions, salinities in the month of May were now met 26% of the time in the simulations. This is a significant increase of 20% over the baseline conditions. This indicates that additional management changes may help meet the targeted goals. This finding also verifies that additional freshwater diversions will be necessary in freshening the Biloxi Marsh to meet the 40% Chatry goal. The FWOP model results are seen in Table 9.

Table 9 Future Without Project (FWOP)

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	10.8	3.32	2.09	99.7%
February	8.1	3.56	1.67	100.0%
March	7.35	3.40	1.54	99.9%
April	7.69	2.49	1.50	84.7%
May	9.11	3.44	1.82	26.1%
June	10	3.32	1.97	94.0%
July	11.1	3.15	2.13	83.9%
August	13.1	2.42	2.44	90.6%
September	14.3	2.78	2.66	91.1%
October	15.6	2.36	2.86	75.9%
November	15.4	2.49	2.84	69.3%
December	13.7	2.98	2.56	82.9%

The second FWOP condition adds in the Blind/Convent River diversion that is in the planning stages. Having conditional approval as an authorized project, the design flow for this diversion is anticipated to be approximately 4,500 cfs. Even though there was a small change in the average salinity, the diversion freshened the FWOP conditions in the Biloxi Marsh area. With Blind/Convent River, salinity targets were met nearly 31% of the time (vs. 26% without the diversion). Table 10 depicts this scenario.

Table 10 Future Without Project Conditions (FWOP1D)

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	10.3	3.09	1.99	99.9%
February	7.81	3.32	1.60	100.0%
March	7.14	3.17	1.48	99.9%
April	7.48	2.31	1.45	88.4%
May	8.82	3.24	1.75	30.7%
June	9.7	3.08	1.89	96.3%
July	10.6	2.90	2.04	89.0%
August	12.6	2.23	2.33	94.4%
September	13.6	2.62	2.53	94.9%
October	14.8	2.20	2.72	84.2%
November	14.6	3.31	2.69	79.3%
December	13	2.77	2.43	89.8%

2.5.3.7.4 Future With Projects/Project Alternatives (FWP)

The FWP scenario includes the closures, diversions outlined in the FWOP conditions, and the a freshwater diversion near Violet, La. All figures for the FWP scenarios are in Appendix E of Annex 1. There were three conditions for diversions as developed in the model. Initially, diversions between 7,000 and 30,000 cfs were discharged to Lake Borgne over the entire year were to investigate the sensitivity to salinity reductions and the ability of a diversion in this area to meet the salinity target or otherwise affect salinity. To discharge this amount of water through the CWA it was physically necessary to anticipate a direct channel through the CWA and through a new structure in the Chalmette levee into the MRGO and Lake Borgne. These higher flows could not be released inside the CWA due to the potential of severe flooding. Alternatives of 7,000; 10,000; 15,000; 20,000; and 30,000 cfs were modeled in this fashion.

To facilitate environmental enhancement of the CWA, a second stipulation was established where discharges of between 1,000 and 10,000 cfs were diverted into the CWA, inundating this area prior to discharging through the Bayou Bienvenue and Bayou Dupre control structures (and potentially a third structure). For these scenarios, a base flow of 1,000 cfs was run for all months except April and May.

In April and May, the flow was increased to 5,000, 7,000, and 10,000 cfs. The 1,000 cfs base flow provides hydration and is expected to create freshwater conditions in the CWA year round. Increased flows in April were included to account for the hydraulic residence time (approximately two weeks) in Lake Borgne to and to establish the freshest conditions possible to help meet the May target.

To improve the flow dispersion to the Biloxi Marsh region these modeling scenarios were also run to include a closure of the MRGO/Lake Borgne connection, forcing additional freshwater south and out through Bayou La Loutre rather than discharging directly through Lake Borgne. The Lake Borgne channel has recently been structurally altered to reduce the opening to a 200m wide channel. In the "closed opening" scenario, this opening is now completely blocked. This closure does not completely block water from moving into Lake Borgne since there are several other smaller channels connecting the MRGO and Lake Borgne.

Table 11 lists the FWP model configurations where the following denotes the type of run:

- A1 – Base flow is 1,000 and flow is increased in April and May. Lake Borgne is open.
- A2 – Base flow is 1,000 and flow is increased in April and May. Lake Borgne is closed.
- A3 – Flow is steady for all months. Lake Borgne is open.
- A4 – Flow is steady for all months. Lake Borgne is closed
-

Table 11 Future With Project Alternatives

Alternative	Base Flow (cfs)	April/May Flow (cfs)	Gap Between MRGO and Lake Borgne – Open/ Closed	Upper Diversion Lake Maurepas
1 - 1A1	1,000	0	Open	<1 ppt
1 - 7A1	1,000	7,000	Open	<1 ppt
2 - 5A2	1,000	5,000	Closed	<1 ppt
2 - 7A2	1,000	7,000	Closed	<1 ppt
2 - 10A2	1,000	10,000	Closed	<1 ppt
3 - 10A3	10,000	10,000	Open	<1 ppt
3 - 15A3	15,000	15,000	Open	<1 ppt
3 - 20A3	20,000	20,000	Open	<1 ppt
3 - 30A3	30,000	30,000	Open	<1 ppt
4 - 7A4	7,000	7,000	Closed	<1 ppt
5 - 7A2D	1,000	7,000	Closed	4,500 cfs
6 - 7A4D	7,000	7,000	Closed	4,500 cfs

The Upper Diversion (Blind/Convent River) for all runs was assumed to be moderated such that the salinity in Lake Maurapas was less than 1ppt except for cases 5 and 6, where runs included the Blind/Convent River at 4,500 cfs. Both the 1,000/7,000 cfs diversion and 7,000/7,000 cfs case at Violet were tested with Lake Borgne closed.

Table 12 depicts the results of project configuration scenarios in terms of % of time salinity met the upper Chatry Salinity. The results indicate that the salinity character of Lake Borgne was affected by which alternative was simulated.

Table 12 – Results of Diversion Scenarios in Terms of % of Time Salinity Meets the Upper Chatry Salinity Limit

			FWOP Scenarios		FWP Scenarios					
Flow (cfs)	Historic	Baseline	Alt - 1 (FWOP1)	Alt - 2 (FWOP1D)	Alt - 1	Alt - 2	Alt - 3	Alt - 4, 7A4	Alt - 5, 7A2D	Alt - 6 7A4D
0	3.90%	6.10%	26.10%	30.70%						
1,000					26.7%					
5,000						33.7%				
7,000					31.7%	36.7%		43.6%	43.0%	48.1%
10,000						41.6%	46.2%			
15,000							55.2%			
20,000							66.3%			
30,000							75.4%			

The results also indicate that the full freshwater diversion over the entire year had a greater impact (approximately 3% increase) on meeting salinity targets in May than just applying a diversion in April and May.

The closure of Lake Borgne affected salinity in the Biloxi Marsh a significant amount. At 7,000 cfs, the Lake Borgne closure was correlated to a 3 to 4% increase in time that the salinity target is met. As hypothesized, more flow moved south in the MRGO channel with the gap closed, discharging to Biloxi Marsh in a more efficient manner than through Lake Borgne alone.

Year-round flows via the Blind/Convent River diversion also impacted salinity in Biloxi Marsh on the order of a 4% increase. The variety of diversion alternatives between 5,000 and 10,000 cfs altered salinity in Biloxi Marsh relative to the 40% target goal. At 5,000 cfs, the salinities were in the range of 32% to 36%. At 7,000 cfs, the range was between 32% and 48%. A flow of 10,000 cfs resulted in a range in meeting the Chatry targets between 38% and over 50%. Choosing 7,000 cfs as a point of reference and omitting the Blind/Covent River as a FWOP condition, the Chatry limits were only met 32% of the time when the diversion was operated at 1,000 cfs year round and 7,000 cfs in April and

May. With Lake Borgne closed, the 7,000 cfs diversion lowered salinity to meet the target 37% of the time. When either adding the Blind/Covent River diversion or allowing the 7,000 cfs flow all year round, the salinity levels met the Chatry target 43% of the time. When including both conditions simultaneously, the target was met 48% of the time. These relationships with a graphic representation of Table 12 are provided in Figure 21.

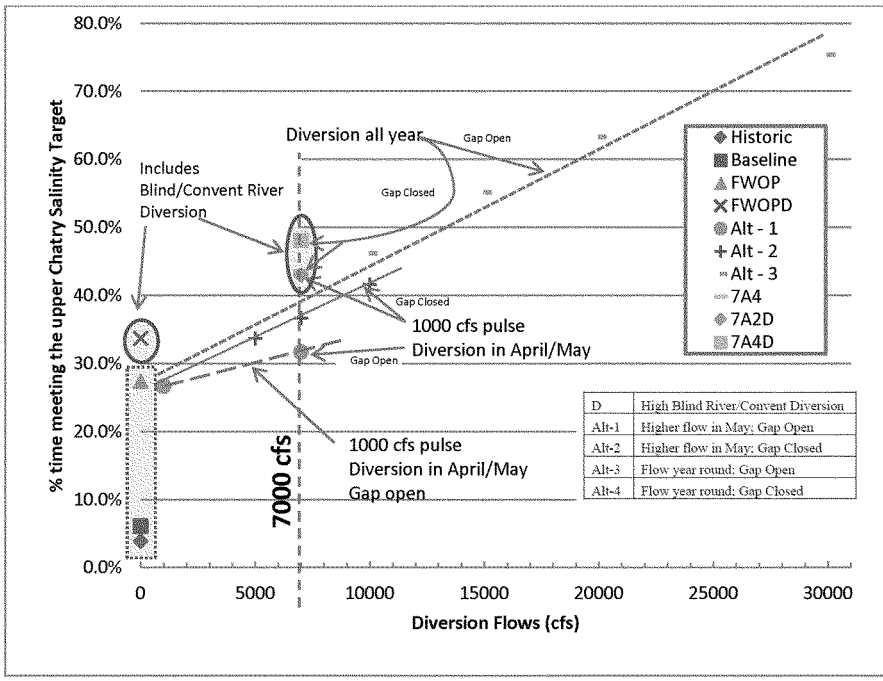

Figure 21. Comparison of alternatives versus % time the scenario meets the upper Chatry limit in Mays.

2.5.3.7.5 Area of Influence / Impacts to Mississippi Territorial Waters

The area of influence of the freshwater diversions is shown in Figure 22. Figure 22 depicts the influence of the 1,000/7,000 cfs diversion including the Blind/Convent River Diversion. In the Biloxi Marsh, there was relatively no salinity change (<0.5 ppt) in the southeast sectors (boxes 74 and 78). Box 73, the region of greatest impact from the diversion alone, was the primary contributor to changes in the salinity target measured at the Chatry Line. It was conclusive from Figure 22 that the Violet diversion most affects Box 78, which is the closest to the CWA and benefits due to the influence of the fresher adjacent regions depicted by Box 8 (Carnarvan) and Box 1 in Lake Borgne. Lake Borgne was significantly impacted by the diversions especially since it is able to trap fresh water behind the raised Biloxi Marsh plateau (which protects this region from the more dense salt water of the Gulf). Box 13 in the Biloxi Marsh was less changed due to the Violet diversion.

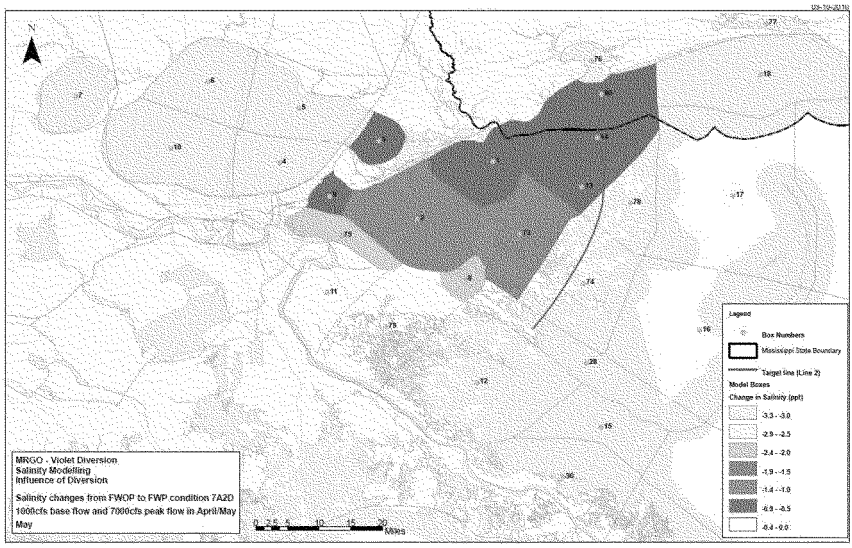

Figure 22 Area of influence of the 7A2D diversion in May (7,000 cfs in April and May with the Gap at Lake Borgne closed and the 4500 cfs diversion at Blind/Convent River)

Influence from the Violet Diversion alone to the Mississippi Coastline and territorial waters was shown to be limited (on average <0.5ppt in May). The salinity reduction is noticeable when including the Blind/Convent River Diversion in addition to the Violet Diversion. Figure 23 is a graphic presentation of all of the diversion combinations that were simulated with the model. The highlighted region represents the range of average salinity change on a month-to-month basis for the various 7,000 cfs diversions. The plot also demonstrates the added salinity reductions along the Mississippi coast for increased diversion flows up to 30,000 cfs.

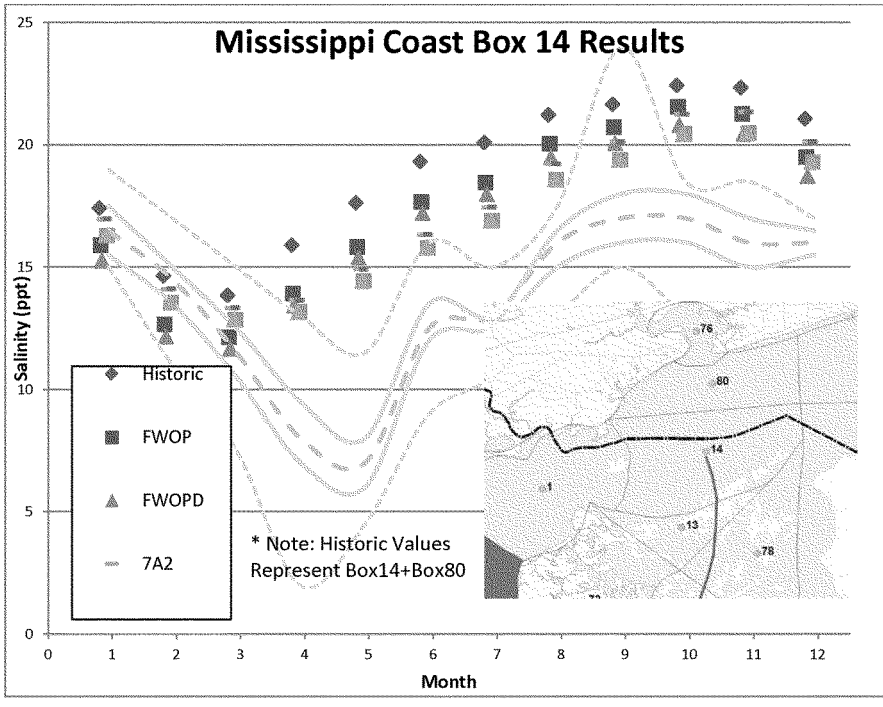

Figure 23 Changes in salinity along the Mississippi Coastal related to diversions near Violet Canal with an inset of the location of box 80 and box 14

2.5.3.8 Conclusions

Several conclusions were obtained in regards to the salinity regime of the Biloxi Marsh as a result of the UNO Mass Balance model simulation. Data and model results demonstrate that the Biloxi Marsh region is, for winter months on average, at or fresher than salinities required for oyster seed production as recommended by Chatry. The spring months of April, May and June have historically been saltier than the optimum salinity ranges. The MRGO closure, the construction of the IHNC barrier, and the Seabrook gate will have an immediate positive impact, in regards to lowering salinities in Biloxi Marsh, relative to these three key months. The baseline condition representing these changes appears to mitigate the long-term impact of salinity intrusion by freshening the system on the order of 1 – 2 ppt in all months. In May for the baseline condition, which includes the major modifications of the system, the probability of meeting the Chatry target is now 6% of the time, which is up from the historic 4%.

The USACE, the State of Louisiana, and others have studied and are implementing a number of planned freshwater diversions. The FWOP scenario adds these new inputs to the system. It is

probable that these diversions would have a significant effect on the year round salinity in Biloxi Marsh, with additional reductions in salinity on the order of 2 ppt. More importantly, it's probable, that there will be a considerable reduction in the salinity in May; the simulations indicating a reduction below the upper Chatry limit 26% of the time. This would be a significant change in the conditions of this area. Considering the Blind/Convent River diversion as a FWOP, the salinity target would be met, on average, 31% of the time.

In general, a new Violet Freshwater Diversion in May is shown to freshen the system. The 1000/7000 cfs diversion scenario without the coincident Blind/Convent River diversion met the upper target in the simulations in May only 37% of the time. It would take about 9000 cfs to meet the 40% criteria under this condition.

When adding the Blind/Convent River diversion to the 1000/7000 cfs Violet Diversion the Chatry limits were met 43% of the time in May. When diverting 7000 cfs yearlong simultaneously with the Blind/Convent River diversion, the salinities in the Biloxi Marsh met the Chatry criteria 48% of the time. Application of much larger diversions (on the order of 20,000 cfs) through the CWA without the benefit of the Blind/Convent River diversion generated even lower salinities and met the May target about 60% of the time. To determine the improvement in the efficiency of delivery of freshwater, another set of diversion alternatives was modeled: constricting the channel between MRGO and Lake Borgne by incorporating a barrier. This forced the freshwater north and south through existing natural channels but more importantly it forced additional water south through the Bayou La Loutre. This created a more direct connection with the Biloxi Marsh than when flows are directed through Lake Borgne and then to Biloxi Marsh.

It should be noted that the Pearl River has a large impact on salinities in Biloxi Marsh. In general, if the Pearl River discharge is unusually low for an extended period, the diversions would be, to a degree, be ineffectual in lowering salinity in the Biloxi Marsh.

2.5.3.9 Sensitivity Impacts to Sea Level Rise

The UNO Mass Balance model was run for two SLR scenarios: 1) a rise of 0.8 m over 100 years, and; a rise of 1 m over 100 years. The model was not modified to consider the effects of progressive land loss over the period of sea level change. The Gulf of Mexico mean stage was raised by 0.8 and 1 m respectively to represent the two SLR scenarios. The main changes that the model responded to were: a) an increase in the depth of the hydraulic links between the boxes and b) an increase in the mean storage in each box. No change in the rainfall-evaporation time series was made.

The example presented here is for the case with the Violet diversion in place at a peak flow of 7,000 cfs in April and May (FWP condition). The model was run for a hydrologic record of years with diurnal lunar tides. The case with no-SLR was run as a basis of comparison [BOC].

Figure 24 shows that the inner boxes of Biloxi Marsh experience little change while the ocean side demonstrates a small increase in salinity. The box that showed the greatest increase was the intermediate marsh in the Caernarvon area. This may be due the width of the direct hydraulic link between the open water and the intermediate marsh. The model showed that, when considering SLR, the Upper Pontchartrain Estuary has a mean salinity slightly less than that for the case of no

sea level rise. Small changes in salinity due to SLR, as depicted by the UNO Mass Balance model, are probably due to the geometry of the system as modified by the condition if it is considered that the Biloxi Marsh will continue to act as a sill, cutting of the salt water flux into the Lake Borgne region. Concurrently, there is a larger reservoir of fresh water because of the increased hydraulic detention times that result from the 0.8 to 1 m increase in depth.

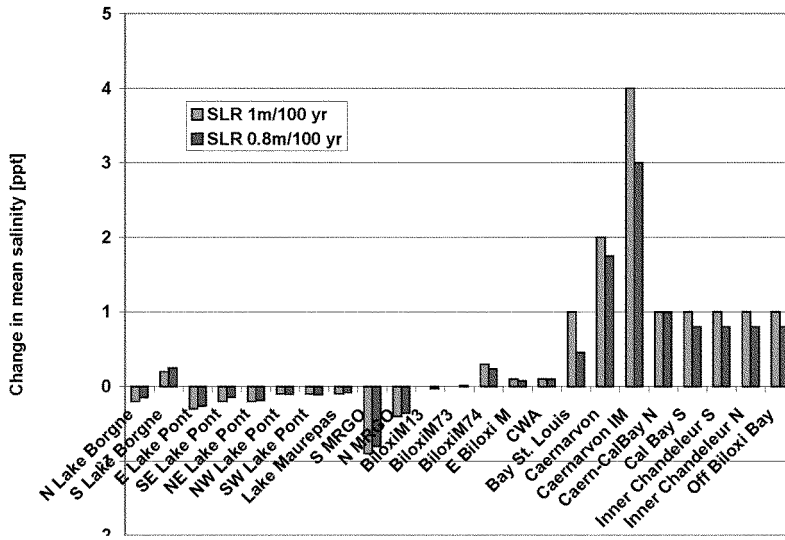

Figure 24 Preliminary Salinity Responses to Relative Sea Level Rise

The UNO Mass Balance model has serious limitations when applying it to predict changes in salinity 100 years into the future. First of all, the model does not take into account the changes in the landform during this period. For example, the increase in the hydraulic conveyance due to erosion is not considered. Secondly, no changes in the hydrologic and meteorological inputs that could significantly impact the Upper Estuary have been considered. The possible increases in wind and wave energies that are often predicted to accompany climate change have been neglected.

2.5.4 Central Wetlands Area – Detailed Modeling

2.5.4.1 General

The Central Wetland Area (CWA) formerly contained an extensive cypress swamp. Re-growth has been hindered by lack of fresh water, nutrients, and sediments. Lack of the natural overbank flow of the river lowers productivity and allows salt stress. The addition of freshwater with accompanying sediments and nutrients through the Violet Diversion would ecologically benefit the CWA. The USACE intends to conduct extensive restoration throughout the CWA. Details of the restoration

project include wetland, marsh, and swamp restoration and creation to restore the CWA to cypress swamp. Preliminary plans for the restoration project are included in Appendix F.

The UNO Mass Balance Model provided generalized hydrodynamic results in the CWA and coarse approximation of the effects of the diversion. To assess the effects and flow characteristics inside the CWA in more detail, the development of a detailed 2-dimensional hydrodynamic model was utilized. The MIKE21-HD (MIKE21) model by the Danish Hydraulic Institute (DHI) is specifically for the purposes of investigating the hydrodynamic effect of the inflow of fresh water into the CWA for existing conditions and for a restored scenario. The impact of the flow through the diversion and how this affects the salinity and circulation in the channels are investigated. The model is used to examine two scenarios, a 1,000 cfs maintenance flow for the purpose of freshening the CWA in support of ecological enhancement of the area by transforming the 48 square miles into freshwater marsh and cypress swamp; and a 7,000 cfs diversion scenario that is the benchmark for freshening the Biloxi Marsh region.

A 1,000 cfs diversion from the Mississippi River was estimated by calculating the inflow from a typical tide through the two navigation gates into the CWA. This order of magnitude of flow generally outlined the magnitude that could be added to the CWA without vastly changing the hydraulic character of the gate. That flow magnitude was carried through and tested as part of the UNO mass balance modeling where FWP scenarios that included the 1,000 cfs diversion indicated that the CWA "box" was adequately freshened by this level of flow.

2.5.4.2 Objectives

The MIKE21 simulation addressed the following questions relating to the diversion of flows through the CWA.

- What is the impact of the base flow through the diversion? How does it affect salinity in the CWA?
- Does the proposed change in topography for the restored marsh impact the base flows, levels and discharges?
- What happens during periods of peak diversion flows? Where does the water go? What is the flow split through the existing structures? Is a new outfall structure needed? How extensive is flooding (frequency, levels, etc) inside the CWA. Are new channels needed within the wetlands?
- What are the impacts of localized flooding due to the new diversions?
- What are the impacts of sea level rise on the marsh?

2.5.4.3 Conventions and Definitions

2.5.4.3.1 Vertical Reference Level

Water levels and depths mentioned in this study are given in feet with reference to NAVD88 (2004.65). However MIKE21 is a European model and works according to international SI

conventions. For this reason some plots direct from the model may be in meters. Special attention to the figure annotation is therefore needed. This is the conversion between feet and meters: 1 meter = 3.281 feet.

2.5.4.3.2 Current Directions

Current directions refer to the direction towards which the current is flowing. Current directions are always given as bearings (clockwise with respect to (wrt) North). The unit is degrees, where 360 degrees cover the circle. For example: current direction 90° means that the current is flowing towards the East.

2.5.4.3.3 Wind Directions

All directions referred to in this study are given in the nautical convention, which means that for winds, the direction refers to the direction where the winds are coming from and is measured positive in degrees from true north. This means that winds from a direction of 0°N are coming from the north and winds with direction 270°N are coming from west.

2.5.4.4 Methodology

2.5.4.4.1 Introduction

MIKE21, a software package from DHI, is a widely used, state of the art integrated modeling package for application in coastal and port areas. The hydrodynamic module solves the shallow water equations, depth-averaged, over a 2-dimensional plane, which implies that the salinity is calculated as a depth averaged concentration. This approach is justified if vertical mixing occurs within short distances of the source and no significant stratification occurs, which is what is expected to happen with the introduction of the near Violet Canal diversion.

2.5.4.4.2 Modeling Scenarios

2.5.4.4.2.1 Baseline Condition – MB

This scenario (MB) reflects existing conditions by including the existing bathymetry, vegetation, control structures at Bayou Dupre and Bayou Bienvenue, and normal tidal flows through the inlets at Bayou Dupre and Bayou Bienvenue. The best available bathymetry was used for this scenario supplemented by specific information on channels and other features that were specifically collected for this effort. Calibration and validation of the model was completed for this scenario and is discussed further in section 5.7. The model domain includes the CWA and extends only as far into the MRGO to enable the flows within the gates to be established.

2.5.4.4.2.2 Baseline Scenario with 1,000 cfs – MB1

The baseline condition with 1,000 cfs (MB1) is the baseline scenario with the existing bathymetry and the addition of a 1,000 cfs base flow from the Mississippi River through the new diversion channel. This scenario investigates the impacts of adding flows to the existing conditions in the CWA. This scenario introduces a new diversion channel that transfers flow into an open water areas of the CWA.

This scenario investigates punching the new diversion channel through a new control structure in the Chalmette levee into the MRGO. For the MB1 run, the flow is split is as shown in Table 13.

Table 13 Loction and Value of Flow for MB1

Location	Flow
New Diversion Channel	870 cfs
Existing Violet Siphon Diversion	100 cfs
WWTPs	30 cft

2.5.4.4.2.3 RESTORED WITH 1000 cfs – MR1

The restored condition with 1,000 cfs (MR1) is the baseline scenario with a restored bathymetry/topography and the addition of a 1,000 cfs base flow from the Mississippi River through the new diversion channel. This scenario investigates the impacts of increasing diversion flows with the restoration of the CWA. The restoration increased the bed levels in local areas and modifies the vegetation according the proposed plans developed by the USACE. The split in flow and configuration of channels and structures is identical to that of the MB1 run.

2.5.4.4.2.4 RESTORED WITH 7000 cfs – MR7

The restored condition with 7,000 cfs (MR7) uses the baseline scenario with the restored bathymetry/topography and the addition of a 7,000 cfs flow in April and May from the Mississippi River through a new diversion channel. This scenario includes a ramping up of flows from the baseline flow condition (1,000 cfs) to the peak over a timeframe of 14 days. It also includes a third control structure into the MRGO with controls to restrict outflow into the MRGO if required. The initial scenario will be established to divert approximately 6,000 cfs through the new control structure. This will force a similar amount of water to exit the Dupre and Bienvenue gates as in the maintenance case.

For the MR7 run, the flow into the CWA is as shown in Table 14.

Table 14 Location and Value of Flow for MR7

Location	Flow
New Diversion Channel	6870 cfs
Existing Violet Siphon Diversion	100 cfs
WWTPs	30 cft

2.5.4.4.2.5 Sea level rise condition – MR1S

The sea level rise condition (MR1S) is the baseline scenario with the restored bathymetry, the addition of a 1,000 cfs base flow from the Mississippi River through the new diversion channel, and accounts for the impact of potential sea level rise on the stage and salinity within the CWA. A mid range Sea Level Rise value of 2.2ft (0.69m) was considered.

2.5.4.4.2.6 Model run MB

2.5.4.4.2.6.1 Flow Distribution

The discharges through the Bayou Dupre and Bayou Bienvenue control structures openings fluctuate with the tide as seen in Figure 25. The maximum discharge through the Bayou Bienvenue structure is much larger (about 1,500 to 3,000 cfs) than through the Bayou Dupre structure (300 -700 cfs).

The average discharges are low, about 9.3 cfs at Bayou Dupre and -19.2 cfs at Bayou Bienvenue. Positive discharge is defined as flowing into the MRGO. Negative discharge is defined as flowing into the CWA. Although the values appear to show a small net inflow into the CWA, this is within the tolerances of the model and is effectively balanced.

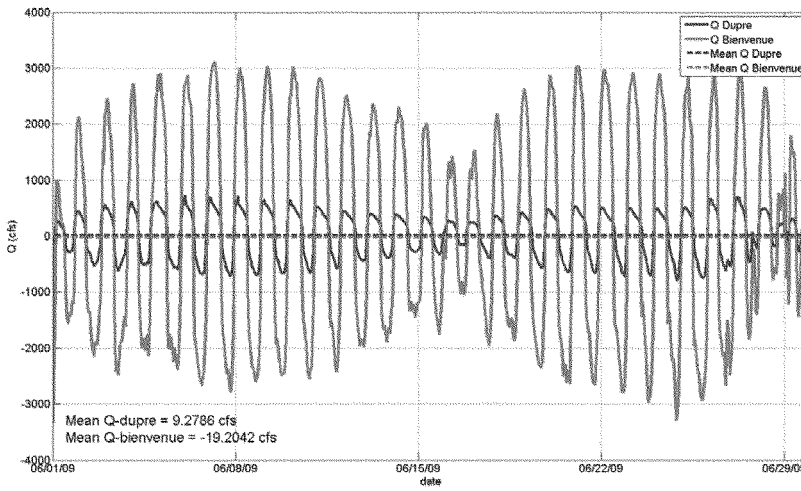

Figure 25 Discharge distribution over the Bayou Dupre and Bayou Bienvenue for the MB scenario

2.5.4.4.2.6.2 Water Levels

The results indicate a small water level gradient from north to south exists with water levels higher near Bayou Bienvenue (maximum at 1 to 1.05 feet) than at Bayou Dupre (maximum at 0.95 to 1.0 feet).

Inside the CWA there is not much variability in water level, except the western part. In that area the maximum water levels are limited to 0.6 to 0.8 feet. These lower water levels are probably due to the effect that Paris Road has on blocking flow into and out of this area.

2.5.4.4.2.6.3 Current Velocities

The maximum current velocities are generally low. The maximum velocities in the channels are low ranging from approximately 0.3 ft/sec to 0.6 ft/s. In the small channels, as well as the open water areas, the current velocities drop to almost 0 ft/s.

2.5.4.4.2.6.4 Salinity

Figure 26 shows the average salinity during the simulation period for the baseline scenario. Within the central wetlands, the mean salinity is typically about 4 ppt. In the Violet Canal the mean salinity drops to 2 ppt in the most western part.

Figure 26 Average salinity in the MB scenario

2.5.4.4.2.7 Model Run MB1

2.5.4.4.2.7.1 Water levels

At the end of the new diversion channel, the water level increases significantly. In the actual situation only during high waters is the area flooded. In the baseline scenario with 1,000 cfs, the water levels increase 0.3 to 1.1 feet and the tidal range is about 0.1 to 0.5 feet at that location.

At Paris Road and at the Bayou Bienvenue structure there is little change in water levels. However, at the Bayou Dupre structure, the water level increases by approximately 0.1 to 0.5 feet and, during high waters, the tidal range decreases by almost 0.3 feet.

The maximum water levels are found in the new diversion channel (above 1.2 feet) and in the adjacent wetlands (1 to 1.1 feet). The mean water level increases in the wetlands by approximately 0.6 feet.

2.5.4.4.2.7.2 Current velocities

The current velocity inside the new diversion channel is approximately 2.5 ft/s. At Paris Road no changes in velocities were observed. At the Bayou Dupre and Bayou Bienvenue structures there are some changes. At Bienvenue the maximum velocity increases by 0.1 ft/s during ebb flow (flow going towards the MRGO). Overall the velocities during ebb flow are larger than during flood flow (flow

going towards the CWA). During flood flow the current velocities decrease by almost 0.2 – 0.3 ft/s at the Bienvenue structure. This can be explained by the extra freshwater outflow from the CWA into the MRGO which increases the ebb flow and decreases the flood flow. At the Bayou Dupre structure flood flow is not easily distinguished due to this freshwater outflow.

Maximum velocities observed in the new diversion channel are on the order of 1.5 ft/s to 2.5 ft/s. In the adjacent wetlands, the maximum velocities are approximately 0.5 ft/s.

2.5.4.4.2.7.3 Salinity

The salinity in the new diversion channel is 0 ppt, whereas in the baseline scenario during high water peaks of 2 – 5 ppt were computed. At Paris Road the salinity fluctuates around 1 to 3 ppt as compared to 4 to 7 ppt in the baseline scenario.

At the Bayou Bienvenue structure, the salinity drops to 1 to 2 ppt during ebb flow (due to fresh water outflow), but does not change (with respect too the baseline situation) at flood flow. In the baseline scenario, values of 6 to 8 ppt were found.

At the Bayou Dupre structure, the salinity drops to almost 0 ppt. Only at high water inflow do the salinity levels increase locally, but do not reach the baseline values of 6 to 8 ppt.

Mean salinity can be seen in Figure 27. Compared to the baseline scenario, the wetland area in the center of the CWA almost becomes fresh with salinity values of 0 to 0.5 ppt. Also, the main channels in the systems become fresh with a mean salinity of 0.5 ppt. Near the Bayou Bienvenue structure, the mean salinity is around 4 – 5 ppt.

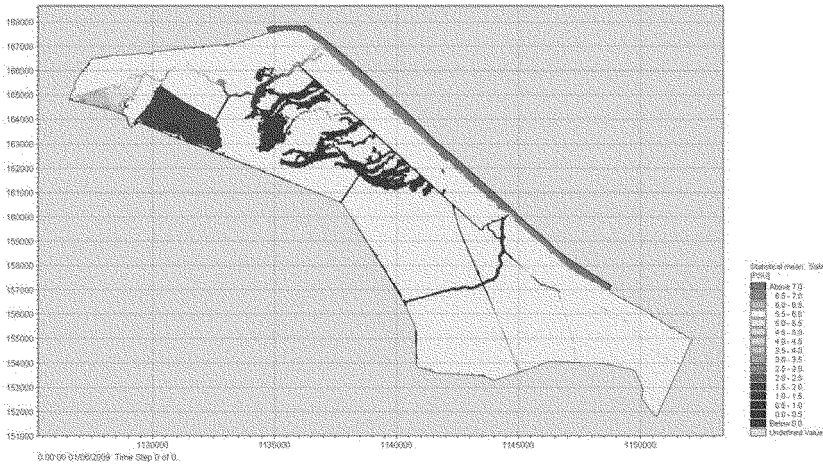

Figure 27 Mean salinity during June 2009 for the MB1 scenario

2.5.4.4.2.8 Model Run MR1

2.5.4.4.2.8.1 Flow Distribution

Figure 28 shows the discharge distribution over the Bayou Dupre and Bayou Bienvenue including the mean discharges. The restored scenario slightly modifies the discharge distribution over the two control structures with 377 cfs (38 %) flowing through the Bayou Dupre structure and 626 cfs (62 %) through the Bayou Bienvenue structure. In the baseline scenario, the ratio was 40 % - 60 %. The discharge through the opening to the MRGO from the new diversion is 0 cfs.

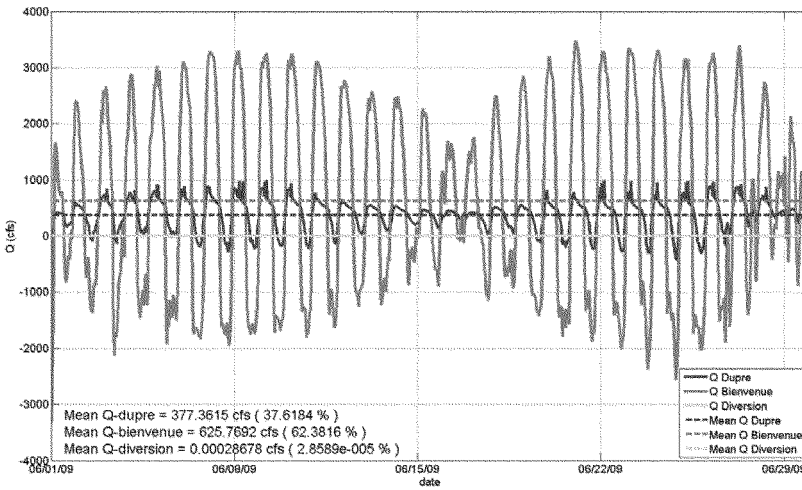

Figure 28 Discharge (cfs) through the Bayou Dupre (Blue), Bayou Bienvenue (red) and new Diversion (green) gates for the MR1 scenario. Dashed line indicate the mean discharge through the gates

2.5.4.4.2.8.2 Water Levels

The results of the water levels are similar to the MB1 scenario. At the end of the new diversion channel the water levels increase to 0.2 to 1.1 feet. The tidal range increases slightly by 0.1 to 0.6 feet.

At Paris Road the tidal range slightly increases by approximately 0.1 to 0.3 over the MB1 results to 0.5 to 1.6 feet. At the Bayou Bienvenue structure, there is little change in water levels. At the Bayou Dupre structure, the water level increases by approximately 0.1 to 0.5 feet and the tidal range decreases by almost 0.3 feet during high waters.

The maximum water levels are found in the new diversion channel (1.1 feet) and in the adjacent wetlands (1.1 feet). Compared to the MB1 scenario, a larger area is affected by the fresh water outflow, but the maximum level in the new channel is lowered by 0.1 feet. The maximum water level in the Violet Canal is 1.0 to 1.05 feet. The mean water level increases in the channel to 0.55 to 0.60 feet and in the wetlands to 0.40 to 0.60 feet.

The higher water levels in the northwestern part of the CWA can the explained by the wastewater outflow, which flows onto a piece of land at a higher elevation and roughness coefficient used in the model. This results in less flow to the neighboring channels and the water is stored in the area.

2.5.4.4.2.8.3 Current velocities

The mean velocity is about 0.3 to 0.35 ft/s at the end of the new diversion channel. Due to the restoration of the wetlands, the velocity also decreases at Paris Road to about half that seen in the baseline scenario.

At the Bayou Bienvenue structure, the same pattern is observed as in the MB1 scenario. The maximum velocity slightly increases by 0.1 ft/s during ebb flow and decreases by almost 0.2 to 0.3 ft/s during flood flow. The velocities during ebb flow are larger than during flood flow.

Compared to the MB1 scenario, the most significant changes are found in the new diversion channel. The maximum velocity is limited to approximately 0.3 ft/s, whereas in the MB1 scenario the maximum velocities were about 1.5 to 2.5 ft/s.

2.5.4.4.2.8.4 Salinity

The water in the new diversion channel is completely fresh, 0 ppt. At Paris Road the salinity fluctuates around 1 to 2 ppt, which is slightly lower than in the MB1 scenario. At the Bayou Bienvenue structure, the salinity drops to 1 to 2 ppt during ebb flow (due to fresh water outflow), but does not change at flood flow. In the baseline scenario values of 6 to 8 ppt were found. At the Bayou Dupre structure, the salinity drops to almost 1 ppt. Only at high water does the salinity increase, but does not reach the value of the baseline scenario of around 6 to 8 ppt.

Figure 29 shows the monthly averaged salinity for the whole area. The overall picture is the same as in the MB1 scenario. The fresh water discharge from the Mississippi River causes a decrease in salinity, not only in the wetland area in the center of the CWA, but also in the main channels like the Violet canal.

Figure 29 Mean salinity during June 2009 for the MR1 scenario

2.5.4.4.2.9 Model Run MR7

2.5.4.4.2.9.1 Flow Distribution

Figure 30 shows the discharge distribution over the Bayou Dupre, Bayou Bienvenue and the new diversion for this scenario, as well as the mean discharges. Due to the opening of the new diversion channel 5,660 cfs flows through the new channel. Approximately 1,260 cfs flows through the other two openings (479 cfs through the Dupre structure and 781 through the Bienvenue structure).

Including a structure at the end of the new channel will potentially result in lower discharges through the channel and will increase the discharge through the Bayou Dupre and Bayou Bienvenue.

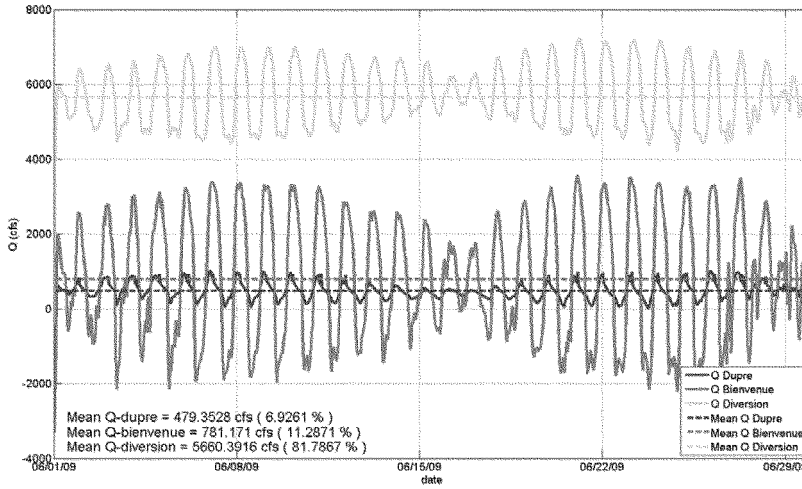

Figure 30 Discharge (cfs) through the Bayou Dupre (Blue), Bayou Bienvenue (red) and new Diversion (green) gates for the MR7 scenario. Dashed line indicate the mean discharge through the gates

2.5.4.4.2.9.2 Water levels

Near Paris Road the water levels increase during high water by about 0.2 to 0.3 feet but decrease during low water (about 0.2 feet) when compared to the baseline scenario. At the Bayou Bienvenue structure a small increase of 0.1 feet was found. At the Bayou Dupre structure, the effect appears to be larger.

The maximum water levels are higher in the new diversion channel (above 1.2 feet) and in the adjacent wetlands (also above 1.2 feet). The extent of the area affected by the freshwater inflow is the greatest in this scenario. Mean water levels in the channel and the surrounding wetlands are above 0.7 feet.

Although the water levels in and near the new channel increase significantly, no flooding of the higher wetlands areas occur. This means that the water levels do not reach the level of the banks of the channel.

2.5.4.4.2.9.3 Current velocities

The current velocity in the new channel fluctuates around 2.5 feet/second, which is almost the same as the velocity in the smaller channel in the MB1 scenario. Although there is a larger discharge, the channel also has larger dimensions which limit the velocities. The current velocities at the other

locations show the same results as in the other scenarios with additional fresh water inflow. Inside the new diversion channel, the flow velocities increase to above 2.1 ft/s, which is significantly larger than in the other channels within the CWA.

2.5.4.4.2.9.4 Salinity

The large fresh water diversion turns the CWA area almost completely becomes fresh. The mean salinity in all major channels and wetland areas is 1 ppt or below. At the MRGO a plume of fresher water is found at the outflow of the new diversion. Only at the main channel near the Bayou Bienvenue structure do higher salinity values penetrate slightly into the area.

At the point in the new channel and near the Bayou Dupre structure, the salinity drops to 0 ppt. At Paris Road the salinity drops to an equilibrium value of 0.2 to 0.3 ppt. At the Bayou Bienvenue structure, the salinity fluctuates with the tide and drops to 1 to 2 ppt during ebb flow (due to fresh water outflow). Salinity does not change noticeably at flood flow. Mean salinities are seen in Figure 31.

Figure 31 Mean salinity during June 2009 for the MR7 scenario

2.5.4.4.2.10 Model Run MR1S

2.5.4.4.2.10.1 Flow Distribution

Figure 32 shows the discharge distribution over the Bayou Dupre, Bayou Bienvenue and the new diversion for this scenario, as well as the mean discharges.

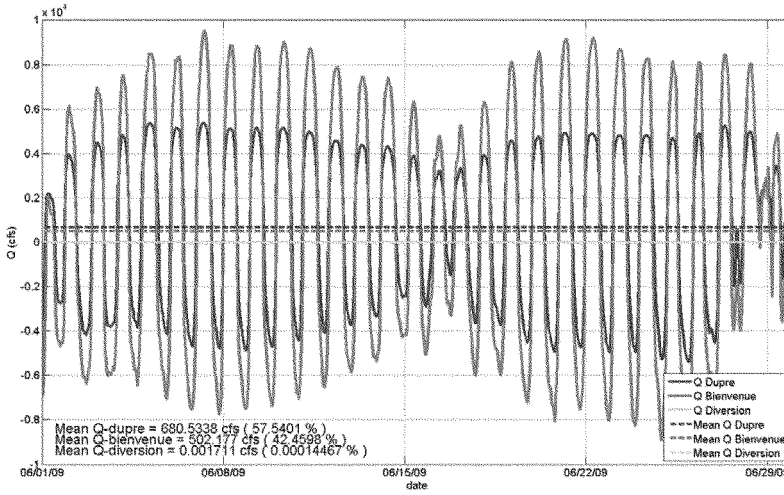

Figure 32 Discharge (cfs) through the Bayou Dupre Structure (Blue), Bayou Bienvenue Structure (red) and new Diversion (green) gates for the MRS1 condition. Dashed line indicate the mean discharge through the gates

Sea level rise affects the maximum discharges through the Bayou Dupre and Bayou Bienvenue structures significantly. Through the Dupre structure, the maximum discharge is to 3,000 to 5,000 cfs or about five times greater than the MR1 results of 600 to 1000 cfs. The maximum discharge through the Bienvenue structure is 5,000 to 9,000cfs when sea level rise is considered. Without the consideration of sea level rise, the maximum discharge is about three times less or 1,500 to 3,500 cfs in the MR1 scenario.

The mean discharges are on the same order as the MR1 scenario regarding no change in total fresh water outflow. However, the flow split over the Dupre and Bienvenue structures changes. When considering sea level rise, 680 cfs flows through Dupre (57.5 %) and 502 cfs flows through Bienvenue (42.5 %). The ratio is 38 % Dupre and 62 % Bienvenue with the MR1 scenario. Sea level rise causes a shift in discharge distribution such that the majority of the discharge is through the Bayou Dupre structure.

The discharge through the opening in the new diversion channel is 0 cfs, as the channel is closed by a weir structure.

2.5.4.4.2.10.2 Water Levels

The water levels increase significantly in this scenario. A large part of the CWA area is flooded due to the 3.7 feet increase of sea level. At all locations the water levels increase by almost 3.7 feet. The

tidal range inside the CWA decreases. In the new diversion channel, the tidal range becomes 0.1 to 0.5 feet. In the MR1 scenario, the tidal range was 0.1 to 0.6 feet.

At Paris Road, the tidal range is completely dampened. It becomes 0.1 to 0.5, whereas it was 0.5 to 1.6 feet in the MR1. This is also the case at Bienvenue where the tidal range in this scenario is 0.2 to 0.8 feet. In the MR1 scenario it was 0.4 to 1.7 feet. The same holds for the Bayou Dupre outflow.

Peak water levels are found at 4.3 - 4.4 feet for all locations.

2.5.4.4.2.10.3 Current Velocities

The current velocities increase at both Bayou Dupre and Bayou Bienvenue. Peak velocities inside the Bienvenue structure are approximately 2.7 ft/s, at Dupre it is 2.1 ft/s. In the MR1 scenario this is respectively 1.5 ft/s and 0.5 ft/s. Inside the Dupre structure outflow the velocities increase significantly. This is also due to the increased discharge through that opening.

Velocities of 0.8 – 1.0 ft/s are found in the channels which run to Bayou Dupre and Bayou Bienvenue. In the remaining portions of the CWA, velocity does not exceed 0.5 ft/s.

2.5.4.4.2.10.4 Salinity

Salinity is able to penetrate more easily into the CWA due to sea level rise.

Figure 33 shows the mean salinity in the CWA. Near Bayou Dupre and Bayou Bienvenue, the mean salinity becomes 4 to 6 ppt. The central CWA is influenced by the fresh water inflow from the new diversion channel and the salinity is 0 to 2 ppt). In the area west of Paris Road, the water becomes saltier with a mean salinity of 3 to 4 ppt.

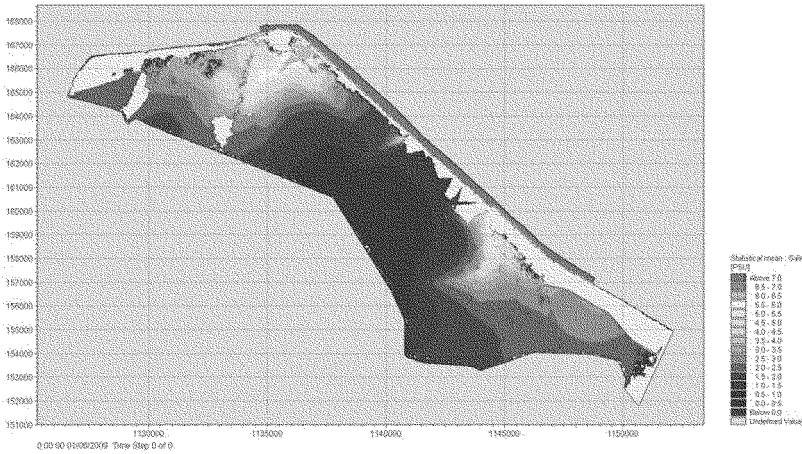

Figure 33 Mean salinity during June 2009, restored scenario with 1000 cfs including Sea level rise

Near Paris Road the salinity fluctuates with the tide. At peak flood the salinity is 6 to 7 ppt and during ebb the salinity drops to 3 to 4 ppt.At both the Bayou Dupre and Bayou Bienvenue structures, the salinity during flood matches the values of the MB scenario at 6.5 to 8 ppt. During low tide the salinity drops at Bayou Dupre to 3 to 4 ppt and Bayou Bienvenue to 4 to 5 ppt.

The salinity inside the CWA fluctuates with the tide. Figures 34 and 35 show the salinity during high water and low water. During high water salinity values of above 7 ppt are found west of the Paris Road. During low water the maximum salinity is approximately 4 ppt. Also notice the number of white cells during low water (Figure 35), which indicates that these cells have become dry.

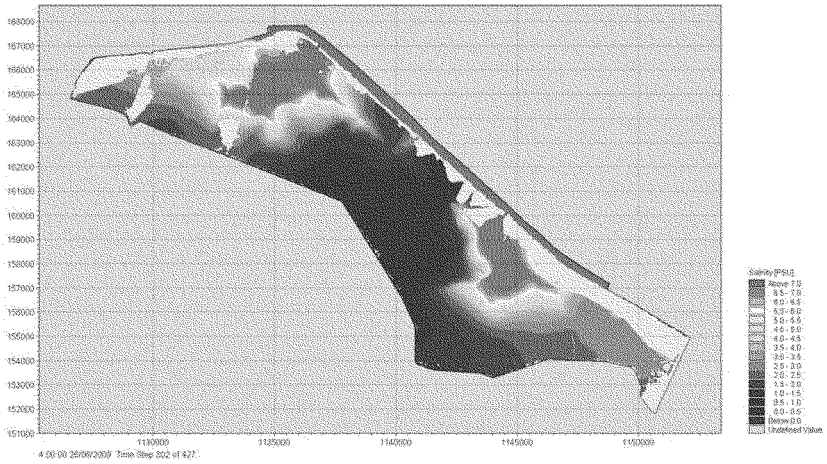

Figure 34 Salinity during high water, 26th June 2009, 4h00

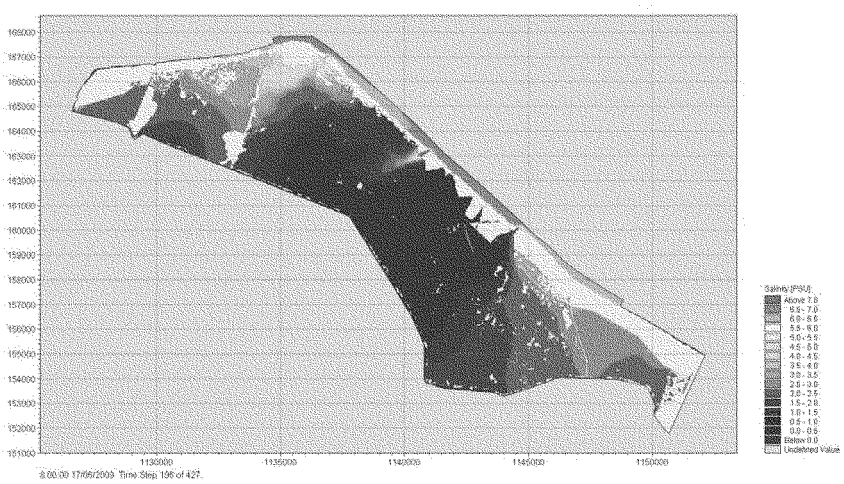

Figure 35 Salinity during low water, 17th June 2009, 8h00

2.5.4.4.3 Summary of Results

The following tables (tables 15 and 16) summarize the MIKE21 results for all scenarios.

Table 15 Discharge Distribution Summary.

	MB	MB1	MR1	MR7	MR1S
Discharge (cfs)					
Dupre	9.3	385	377	479	681
Bienvenue	-19.2	596	626	781	502
Diversion	-	-	-	5660	-
Discharge %:					
Dupre	-	39.2 %	37.6 %	3.9 %	57.5 %
Bienvenue	-	60.8 %	62.4 %	11.3 %	42.5 %
Diversion	-	-	-	81.8 %	-

Table 16 Water levels, current velocities and salinity results summary

	MB	MB1	MR1	MR7	MR1S
Water levels (ft)					
Dupre	-0.55 – 0.9	-0.1 – 0.9	-0.1 – 0.9	-0.2 – 1.1	3.3 – 4.4
Bienvenue	-1.1 – 1	-1 – 1.1	-1 – 1	-1 – 1.1	3.1 – 4.4
Diversion	Dry – 0.9	0.1 – 1.1	-0.15 – 1.1	0.7 – 1.4	3.4 – 4.4
Paris Road	-0.9 – 0.9	-0.7 – 0.95	-1 – 1.1	-1 – 1.1	3.4 – 4.4
Currents (ft/s)					
Dupre	Max 0.5	Max 0.45	Max 0.45	Max 0.55	Max 2.2
Bienvenue	Max 1.4	Max 1.5	Max 1.5	Max 1.5	Max 2.8
Diversion	Max 0	Max 2.7	Max 0.35	Max 2.7	Max 0.3
Paris Road	Max 0.8	Max 0.8	Max 0.55	Max 0.55	Max 0.85
Salinity (ppt)					
Dupre	6 – 8	0 – 7	1 – 7	0	2 – 8
Bienvenue	6 – 8	0.5 – 8	0.5 – 8	0 - 8	3.5 – 8
Diversion	Peaks 2 – 5	0	0	0	0 – 0.5
Paris Road	4 – 7	1 – 3	1 – 2	0.3	1 – 7.5

Conclusions

The following provides responses to the five objectives formulated above relating to the MIKE21 modeling effort.

1. **What is the impact of the base flow through the diversion? How does it affect salinity in the CWA?**

The base flow (1,000 cfs) generally lowers salinity levels within the CWA but raises levels and flow rates to some degree. The increase in water levels is generally less than 0.25ft across the wetlands. See Figure 36.

Figure 36 Comparison of the MB1 and MB Scenarios for Peak Water Level

2. **Does the proposed change in topography for the restored marsh impact the base flows, levels and discharges?**

The change in topography due to marsh and swamp recreation has little impact on the flows, levels and salinity values within the CWA, particularly with the increased channel designed to transfer the higher flows from the Mississippi River to the MRGO.

The water level increase is greatest to the west of Paris Road where the impact of the sewage treatment works discharge is felt together with the increase in marsh and wetland. See Figure 37.

Figure 37 Comparison of MR1 with MB Scenarios for Peak Water Level

3. **What happens during periods of peak diversion flows? Where does the water go? What is the flow split through the existing structures? Is a new outfall structure needed? How extensive is flooding (frequency, levels, etc) inside the CWA. Are new channels needed within the wetlands?**

Initial screening before developing the Mike21 model suggested that a third structure would be needed to prevent excessive flows in the existing channels and extensive flooding.

Therefore during periods of peak flow the water was directed to the MRGO via the new channel. The flow split through the existing structure followed the same proportions as with the 1000cfs background flow. There is some increase in water levels with the 7,000cfs flow in the area immediately adjacent to the new and existing channels when the majority of the flow was passed

directly to the MRGO. See Figure 38. Even at high tide the water levels are below the proposed marsh elevation and will generally in the channels.

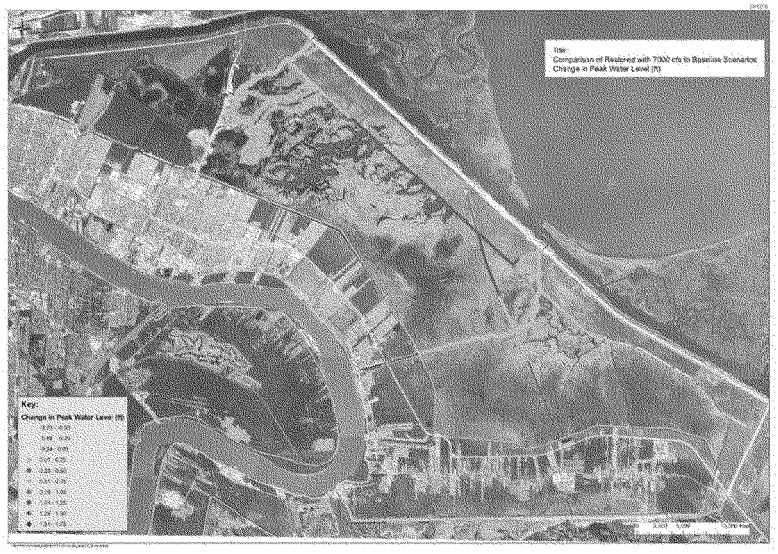

Figure 38 Comparison of MR7 with MB Scenarios for Peak Water Level

Reducing the discharge through the new structure would force water to the Dupre and Bienvenue gates and raise water levels but would increase the velocity through these gates with the increased flows. A variety of scenarios can be generated with the MIKE 21 model to examine impacts to the system by modifying the discharge through the third opening. Water levels would need to be raised on the order of a foot to flood the swamp areas at high tides only. To totally inundate the system the water levels would need to be increased by over 2.5 feet to keep the system we during low tide.

4. What are the impacts of localized flooding due to the new diversions?

The new diversions have little influence on the water levels outside of the channels. For the 1000cfs scenario, in the central area the effect is less than 0.5ft, for the 7000cfs scenario, the effect is less than 1ft. Flow velocities increase within the channels.

5. What are the impacts of sea level rise on the marsh?

About 80% (rough estimate) of the area will flood during high waters for the SLR scenario. This will change drastically the hydrodynamic behavior for the whole area and will likely indirectly induce morphological changes to the area. More areas will experience larger salinity levels.

2.5.5 DETAILED MODELING – FVCOM

The study objectives of the FVCOM modeling effort where to:

1. Better understand and quantify high frequency variability of the salinity field in open water using a numerical model, and
2. To understand the transient salinity field during a transition from low to high hypothetical flow magnitude and distribution between sites at Bayou Bienvenue and Bayou Dupre in the Central Wetlands Area (CWA).

The Finite Volume Coastal Ocean Model (FVCOM) was selected for this study because it is a prognostic, unstructured-grid, finite-volume, free-surface, 3-D primitive equation coastal ocean circulation model developed by Chen et al., (2003). The model consists of momentum, continuity, temperature, salinity, and density equations and is closed physically and mathematically using turbulence closure sub-models. FVCOM is solved numerically by a second-order accurate, discrete flux calculation in the integral form of the governing equations over an unstructured triangular grid. This approach combines the best features of finite-element methods (grid flexibility) and finite-difference methods (numerical efficiency and code simplicity) and provides a much better numerical representation of both local and global momentum, mass, salt, heat, and tracer conservation.

For a more detailed description of model development and other capabilities the reader is directed to Chen et al. (2003). The model was used in three-dimensional mode due to the episodic and seasonal stratification that the estuary experiences (Abadie and Poirrier, 2000; Georgiou, 2002; Li et al., 2008) and to capture additional stratification potentially induced near freshwater input sources. Finally, the freely available source code for FVCOM does not readily offer salinity transport under the two-dimensional mode without code modifications.

A detailed report including the background, model inputs, calibration, verification, and results can be found in Annex 1.

2.5.5.1 Simulation Matrix

The following simulation matrix was considered to address the objectives of this study. First, two simulations, one with wind and one without wind were conducted to compare the high frequency variability in the open water areas of the basin (Lake Borgne and Mississippi Sound in the vicinity of the Biloxi marshes). These simulations were conducted with realistic winds, did not include a closure at the connection between Lake Borgne and the MRGO, and without a new diversion. The second set of simulations, were performed using reconstructed winds, an no closure at the connection between Lake Borgne and the MRGO, and a 7,000 cfs diversion. Lastly, a longer simulation of 45 days was performed to investigate the time-dependent evolution of the salinity field resulting from a diversion of 1,000 cfs (split at 50/50 between Bayou Bienvenue and Bayou Dupre) to 7,000 cfs (with a split of 10/90 respectively). During this simulation, the MRGO closure structures were includes and connection between MRGO and Lake Borgne was closed. Table 17 shows a summary of the FVCOM simulations performed.

Table 17. Case Name and Initial and Boundary Conditions for Each Simulation Performed

Case name	Simulation time (days)	MRGO closure @ La Loutre	MRGO closure @ Bienvenue	Gap @ MRGO and Lake Borgne	Wind stress	Diversion flow
OPT1	5	yes	No	open	Yes, realistic	no
OPT2	5	yes	No	open	No wind	no
OPT3	5	yes	yes	open	Yes, realistic	yes
OPT5	10	yes	yes	closed	Yes, constructed	yes/7,000
OPT6	10	yes	yes	closed	No wind	yes/7,000
OPT7	45	yes	yes	closed	No wind	yes/(1,000-7,000)
OPTF	45	yes	yes	closed	No wind	yes/(1,000-7,000)

2.5.5.2 Model Results and Discussion

2.5.5.2.1 Simulated Salinity Distribution Under Wind Stress

Initially the model was used to investigate the short term high frequency variability in open water (in Lake Borgne and the Mississippi Sound). This was accomplished using realistic wind fields. Two simulations were performed, one with wind and one without wind. Figure 39 shows the depth-integrated distribution of salinity averaged over the 5 day simulation period for the case with wind. Figure 40 shows the same solution without wind. By comparison these two simulations look very similar. An initial conclusion would be to infer that there are negligible changes between the two simulations. When comparing the variance or dispersion in the system, however, by means of calculating the standard deviation of each node (in time) and plotting the results in two dimensions, a different pattern emerges. Figure 41 shows that wind induced circulation within Lake Pontchartrain will cause variation in the salinity near the coastlines where currents are larger. Similarly, higher variability, although small, is observed in the Mississippi Sound near Half Moon Island , at the location of interaction of the Pearl River freshwater plume in that vicinity, and within the Biloxi Marsh area.

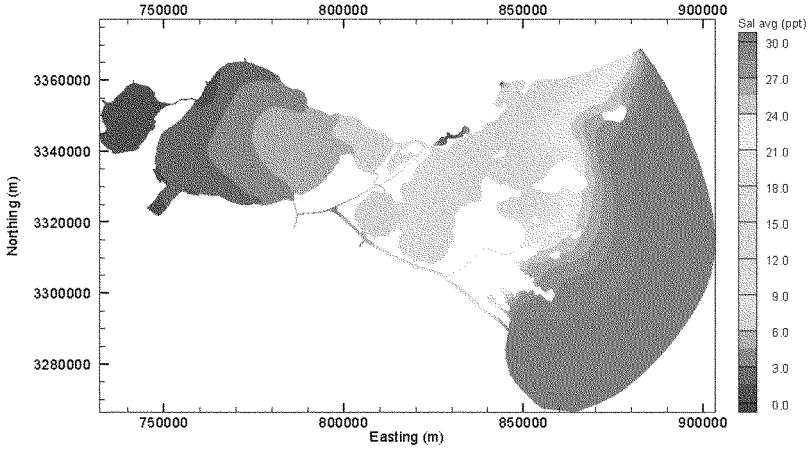

Figure 39 Model simulated depth-integrated salinity distribution averaged over 5 days (case opt1; frontal wind)

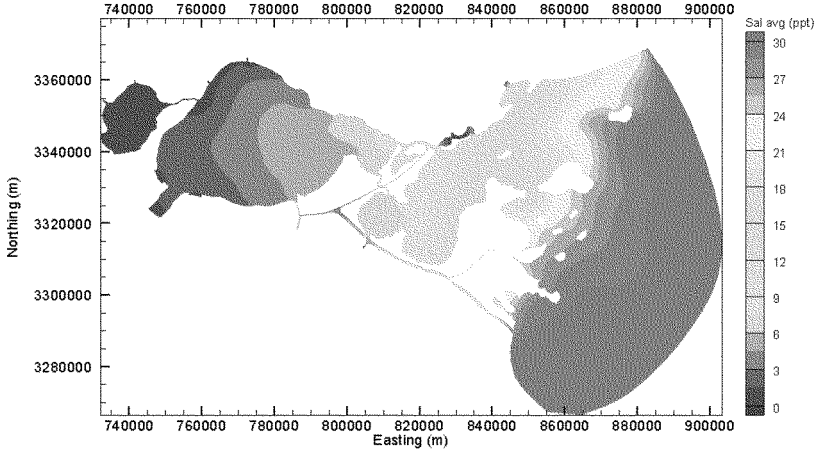

Figure 40 Model simulated depth-integrated salinity distribution averaged over 5 days (case opt2; no wind)

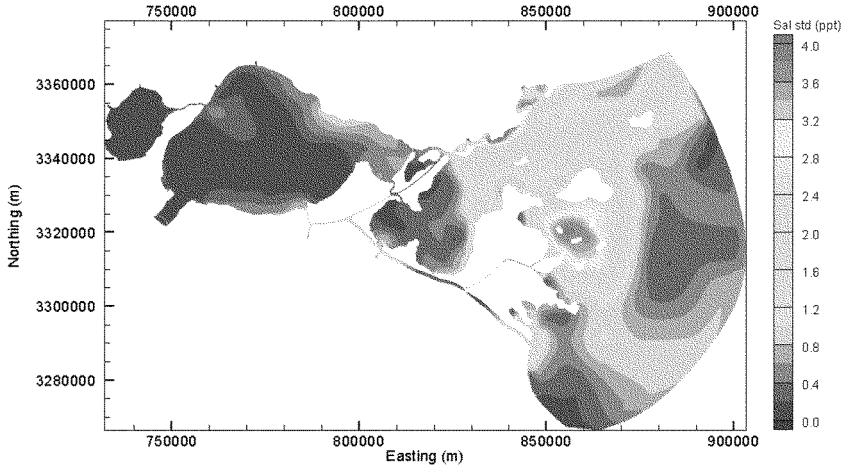

Figure 41. Model simulated depth-integrated standard deviation distribution for 5 days (case opt1; frontal wind)

In an attempt to investigate intermittent or transient conditions, the closure of the MRGO at Bayou Bienvenue was not included in simulations opt1 and opt2. Another simulation was performed (opt3), which was similar to opt1 (i.e., with frontal actual winds, and other boundary conditions), but included the closure of the MRGO near Bienvenue gates. Figure 42 shows that the average depth-integrated salinity for this simulation looks identical to that of opt1. Moreover, the distribution of the standard deviation for scenario opt3, shown in Figure 43, very closely compares to that of the simulation without the closure. Some obvious and expected differences exist between the two simulations and are largely in the MRGO itself, and as a result additional rather small difference in Breton Sound, and within the Biloxi Marshes. The differences however outside the navigation complex are rather small.

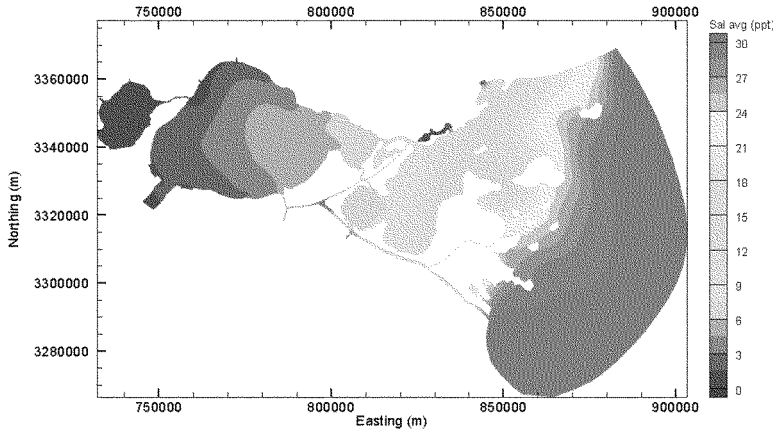

Figure 42 Model simulated depth-integrated salinity distribution averaged over 5 days (case opt1; frontal wind)

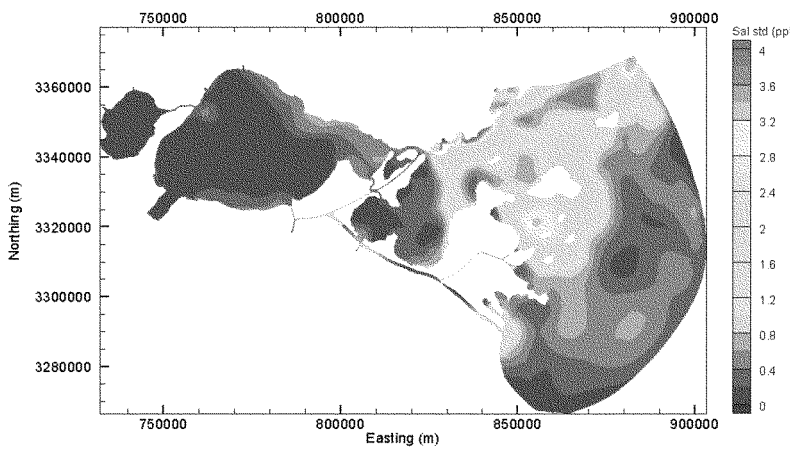

Figure 43 Model simulated depth-integrated standard deviation distribution for 5 days (case opt3; frontal wind)

A second set of simulations with and without winds were conducted with constructed and more persistent west and northwest winds during the post frontal phase of the storm. This wind pattern would have the tendency to push or force water seaward of the Basin, and in the process help

spread and disperse the salinity. As a subsequent result, salinity targets in Mississippi Sound, Biloxi Marshes and other areas of interest could be met faster than anticipated. These simulations, namely opt5 and opt6, have the same initial and boundary conditions as opt1 through opt3, with the exception of the winds which are constructed. An additional difference between these simulations is that there is a diversion at Violet with a constant flow of 7,000 cfs throughout the simulation. These simulations are slightly longer and last for 10 days. Comparatively, Figures 44 and 45 look again very similar, with average depth-integrated salinities fairly similar through the computational domain. When inspected closely, there is a small wind induced variability that shows in the averaged salinity field. This can be seen in Lake Pontchartrain, where the wind induced currents produce more mixing and hence more variability near the coast. Additional differences include small deviations in the Mississippi and Chandeleur sounds; however, when looking at the average salinity field these differences do not appear to be large.

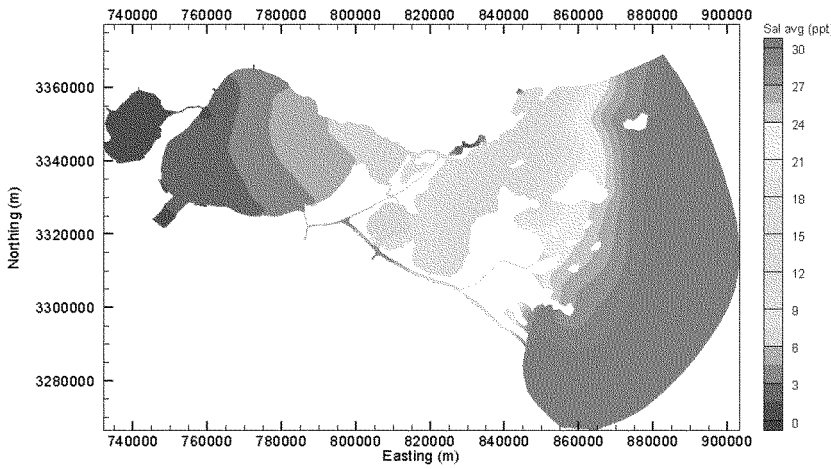

Figure 44 Model simulated depth-integrated salinity distribution averaged over 5 days (case opt5; frontal wind)

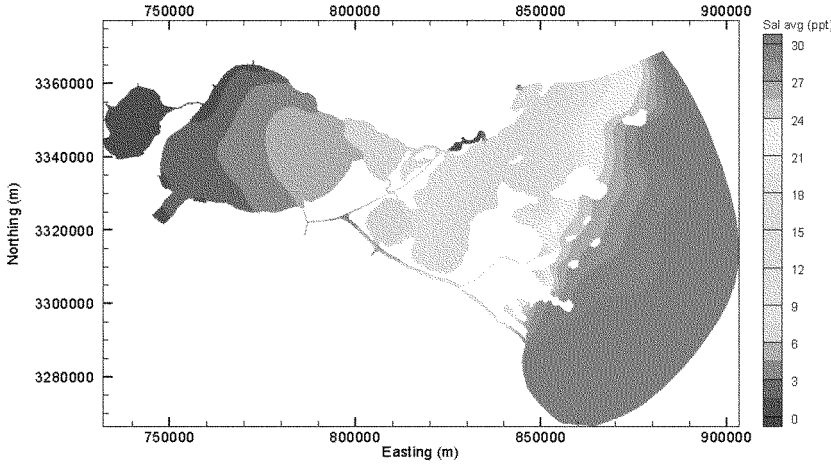

Figure 45 Model simulated depth-integrated salinity distribution averaged over 5 days (case opt6; no wind)

When we examine the variance by looking at the standard deviation in time for every node (Figure 46 and 47), the variability due to wind stress is great. Up-estuary, in Lake Pontchartrain, there appears to be very small variability due to tidal forcing alone (Figure 47). Moreover, in the Mississippi Sound standard deviations are of the order of 3 ppt, and are largely in areas where tidal range is high. In the area of interest, and within the Biloxi Marsh area, there is evident change, although most of this change can de attributed to freshwater input at Violet, which naturally flows seaward through Bayou La Loutre. When we compare Figure 46 to Figure 47 (frontal constructed wind stress), we notice that there is additional variability explained only by high frequency response to wind stress. Wind induced currents within Lake Pontchartrain cause, as previously observed, salinity to respond along the coastline. Furthermore, within the Biloxi Marsh area, the standard deviations appear to rise to 6 ppt or more. Similarly, Figure 46 also shows that open water bodies such as Breton, Chandeleur, and Mississippi Sound respond to wind stress rapidly. The areas, when compared to no wind simulations, showed double the variability in the presence of wind stress.

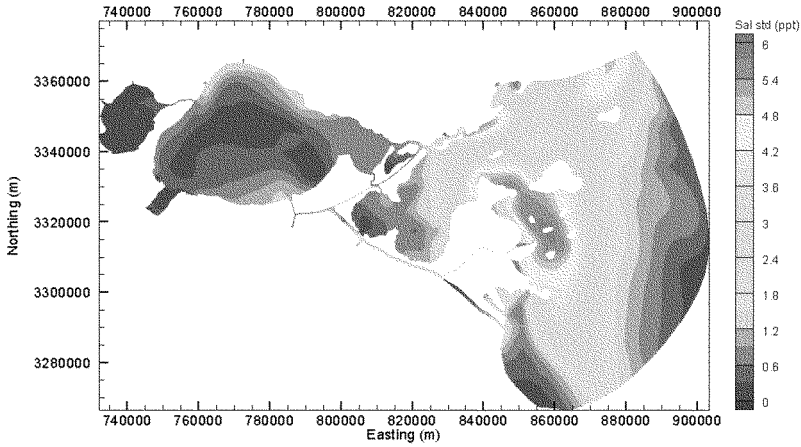

Figure 46 Model simulated depth-integrated standard deviation distribution for 5 days (case opt6; frontal wind)

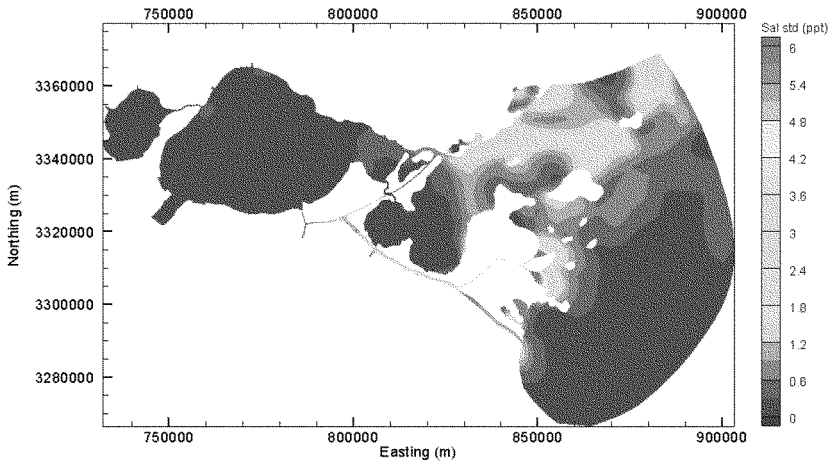

Figure 47 Model simulated depth-integrated standard deviation distribution for 5 days (case opt6; no wind)

2.5.5.2.2 Transient Salinity Response to a Diversion

The second objective of the study was to investigate the transient response of the salinity field from 1,000 cfs to 7,000 cfs during spring, with three closures implemented: (1) MRGO at Bayou La Loutre; (2) MRGO at Bayou Bienvenue; and (3) the connection between Lake Borgne and the MRGO. Two simulations were conducted. The first included the same boundary condition for salinity as in all previous simulations. The second included an open boundary obtained and forced from the UNO Mass Balance model simulations during spring. No wind was considered for this longer 45 day simulation.

Figure 48 and Figure 49 show the average depth-integrated distribution of salinity over the period of the simulation (45 days). The average value for every node (in time) is computed based on the hourly output. It is evident from the average salinity field that up-estuary (such as within Lake Pontchartrain) lower salinities in Breton Sound as a result of diversions in the Caernarvon Basin have little or no impact. This is the same for Lake Borgne and for parts of Biloxi Marsh and the Mississippi Sound. Average salinities however start to be considerably different within Breton Sound, the Chandeleur Sound, and the eastern part of Mississippi Sound. Within the Biloxi Marsh however, the change is rather small, perhaps due to the short simulation period.

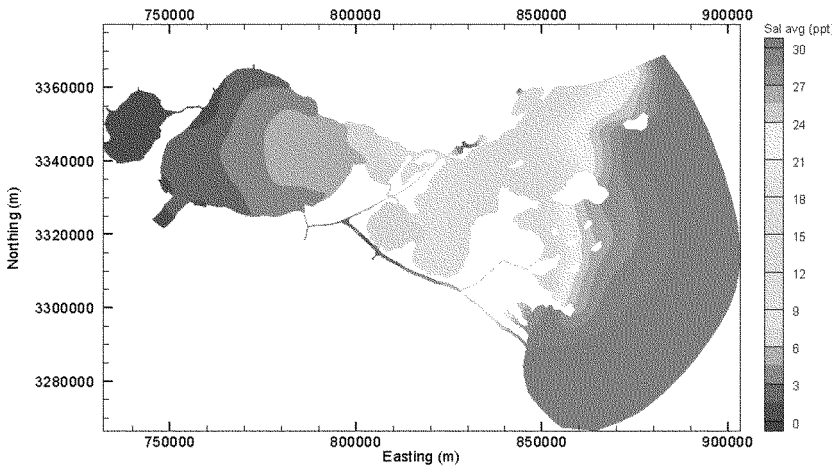

Figure 48 Model simulated depth-integrated standard deviation distribution for 45 days (case opt7; no wind)

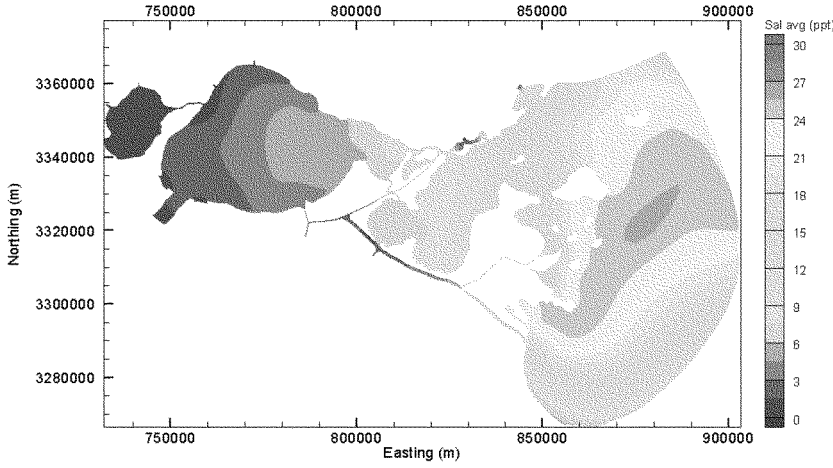

Figure 49 Model simulated depth-integrated standard deviation distribution for 45 days (case optf; no wind)

Looking at Figures 50 and 51, on the other hand, large differences in the standard deviation can be seen, which can explain areas that are more dynamic. For instance, the small and rather insignificant change up-estuary as a result of a diversion in Breton sound directly can be explained easily by direct comparison of Figures 50 and 51, where we see that these two images are very similar. Similarly, the freshwater diversion at Violet (through Bayou Dupre) is unaffected by additional input into Breton Sound. This is explained by the similar standard deviation within the Biloxi Marsh area between Figures 50 and 51. Finally, as expected and as shown to some extend in the average salinity field from Figures 48 and 49, the eastern portion of the Mississippi Sound, Breton Sound, Chandeleur Sound, and the eastern portion of the Biloxi Marsh can be affected by lower salinity in Breton Sound as shown in Figure 51.

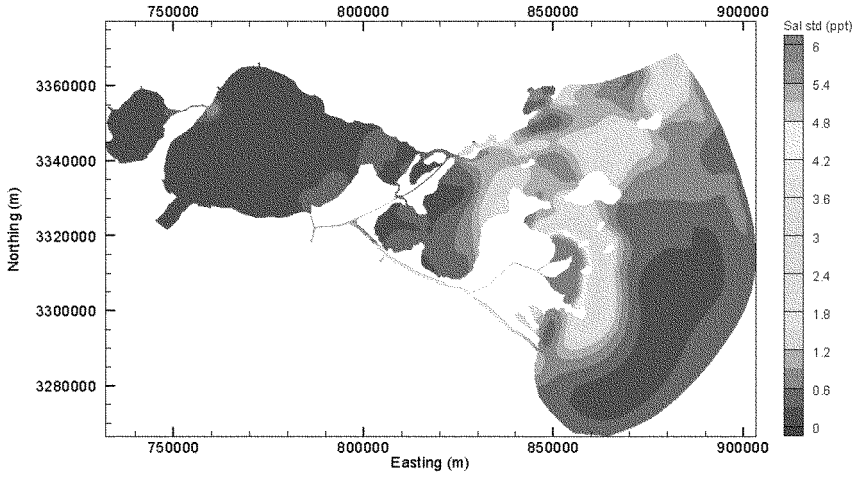

Figure 50 Model simulated depth-integrated standard deviation distribution for 45 days (case opt7; no wind)

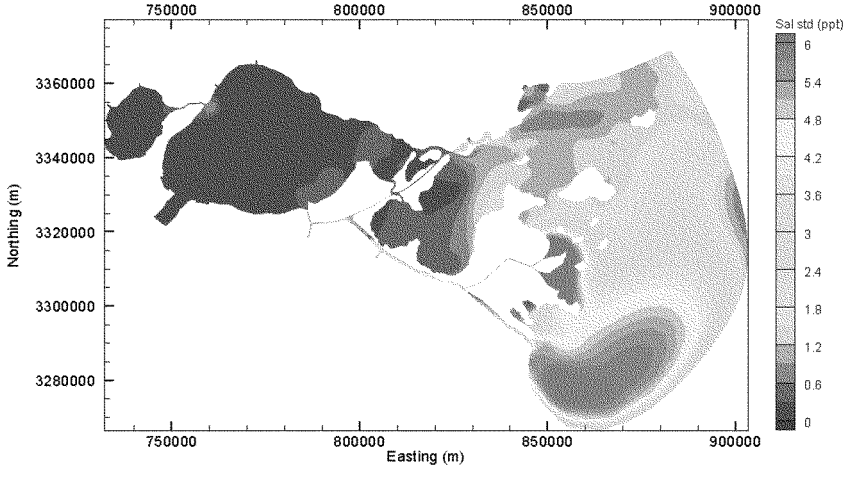

Figure 51 Model simulated depth-integrated standard deviation distribution for 45 days (case optf; no wind)

Most of this change and variability can be explained by either tidally induced circulation or freshwater induced circulation as a result of diversions. The large variation seen in Figure 51 can also be explained relative to the initial condition. Since the initial condition is somewhat saltier than the future and imposed boundary condition, this part of the domain responds to the forcing by rapidly mixing the forced salinity inside the domain. This may be somewhat unrealistic, and will be largely a function of the initial condition. However, the model predicts that this area will respond to a lower salinity in Breton sound, and would in fact, given sufficient time, reach within the area of interest.

Time-series results of the evolution of the salinity field during the longer simulation of 45 days, starting from 1,000 cfs and going through 7,000 cfs are shown in sequential plots in Appendix H of Annex 1 as Figure 22 through Figure 27. The figures show the evolution of the salinity field as a function of time. Figure 52, on the other hand, shows the evolution of an instantaneous surface salinity at two locations, one in the MRGO channel upstream of Bayou La Loutre, and the other in the center of the Biloxi Marsh. The figure shows that initially, when the diversion in the system is of the order of 1,000 cfs using a 50/50 split between Bayou Bienvenue and Bayou Dupre, the instantaneous salinity at both locations is dominated by tidal induced circulation. Both signals respond to tidal forcing by showing diurnal oscillations. The salinity within the MRGO (green solid line), although small, shows some response to diurnal oscillation. This is so small and cannot be seen with the salinity time-series but is seen in the gradient term. The gradient term responds to diurnal oscillations during the low diversion flow but they are rather negligible. However, once the flow starts to rise to 7,000 cfs there is a rather rapid response. The absence of the diurnal oscillation in this term also deems this area now dominated by river-water rather than tides.

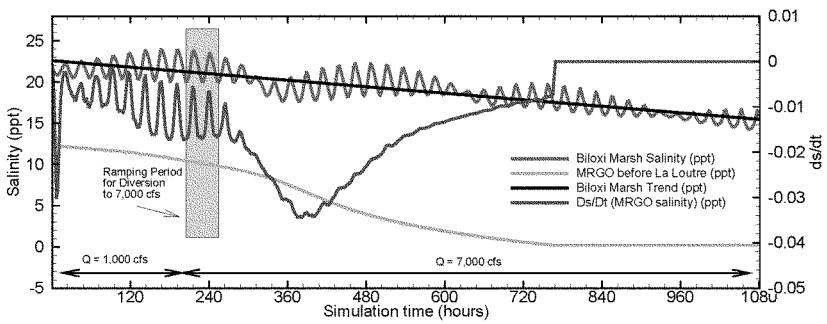

Figure 52 Instantaneous surface salinity for simulation optf, showing the salinity in the central Biloxi Marsh)red line) and within the MRGO channel upstream of Bayou La Loutre (green solid line)

In the Biloxi Marsh, despite the obvious decline in instantaneous salinity as a result of the diversion (black trend line, Figure 52), there seems to be a slightly different response. There is an obvious phase or lag in the system. For example, during the early part of the simulation, the area responds only to tidal forcing, as the local average or trend is a horizontal line up to hour 240 and above. By this time, the diversion has already been operating and is fully ramped to 7,000 cfs, but has not

produced a measurable change in this area. Subsequently, and coinciding with a neap cycle, the system responds with a sudden reduction in the salinity, verifying the small dominance of river-induced circulation in the absence of strong tidal induced flow. By this time, the diversion flow is fully developed and the declining trend in the salinity appears to be linear in time.

2.5.5.3 Conclusions to FVCOM Modeling

The model simulations showed that wind stress resulting from frontal weather can produce high frequency variability in the Pontchartrain Basin within just three days of the application of the wind. In 5 day simulations with half a day of spin up time, the model predicted double the variability. The model also predicted that when only using the averaged salinity field, one would tend to underestimate this variability and high frequency response, primarily because the response is rapid. The model also predicted that in longer simulations, the high frequency response would tend to be smaller due to the natural tendency of wind to cancel this response. This is largely a function of wind climate, basin geometry, duration and intensity of each event, and the relaxation scale of the basin.

Finally, a longer simulation of a diversion from 1,000 cfs to 7,000 cfs showed that the MRGO-La Loutre pathway is largely dominated by tidal currents when the flow is near the low 1,000 cfs magnitude. When the flow is near 7,000 cfs, the basin in this area is dominated by the diversion flow. Furthermore, the model predicted a lag time of the order 4-7 days for this flow to reach the Biloxi Marsh area through this direct route. It is emphasized that for this simulation, the Lake Borgne connection to the MRGO was closed, which further ensures that the conveyance is maximum through this pathway. The model also showed that the Biloxi Marsh area is largely tidally influenced when the flow at Violet is near 1,000 cfs. Although tidal flows continue to cause strong diurnal oscillations in the salinity, when the flow reaches 7,000 cfs and dynamic equilibrium after the lag period, there is a steady decline in the salinity.

2.5.6 HYDRAULIC DESIGN FRESHWATER DIVERSION

2.5.6.1 Preliminary Alternative Analysis

2.5.6.1.1 Channel and Culvert Design

Four alternative locations for the Violet Freshwater Diversion Canal for the subject project were investigated. The analysis was not an optimized design, but was done to compare the 4 alternative diversion alignments.

At the point when the alternatives were considered, it was projected that 15,000 cfs of freshwater would need to be diverted from the Mississippi River in order to achieve the Chatry line salinity targets. This amount was selected based on earlier designs for the Violet Diversion Project.

Figure 53 displays and labels the 4 diversion locations that were investigated for this effort. Figures 54-56 depict the cross section needed to convey the design flow for each alternative. Table 18 depicts the Invert Elevations of each Channel and Culvert. Table 19 shows the culvert dimensions for each culvert.

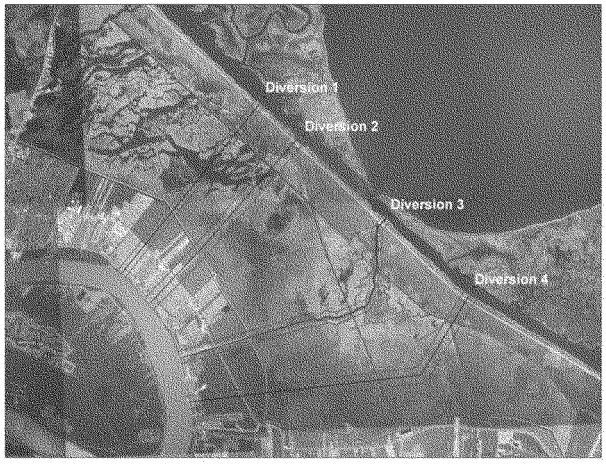

Figure 53 Alternative Diversion Locations

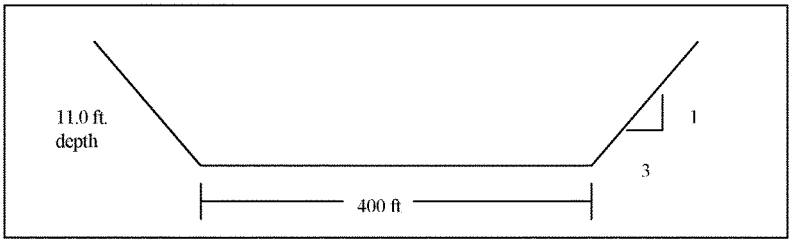

Figure 54 Diversions 1 & 2 Cross Sections

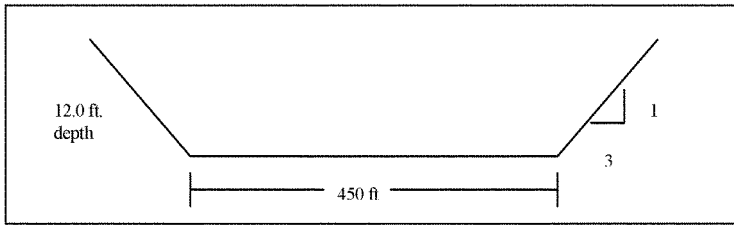

Figure 55 Diversion 3 Cross Section

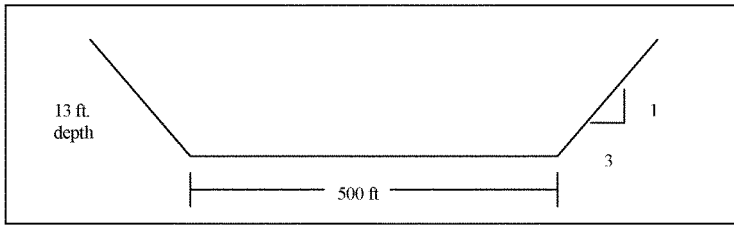

Figure 56 Diversion 4 Cross Section

Table 18 Design Invert Elevations

Diversion	Invert Elevation- Upstream Side of Culvert	Invert Elevation- Downstream Side of Culvert	Invert Elevation- After Culvert Flow is Expanded	Invert Elevation- Discharge of Diversion
1	-5.1	-5.6	2.7	-15.3
2	-5.1	-5.6	2.7	-15.3
3	-3.2	-3.7	2.7	-16.3
4	-2.5	-3.0	2.8	-15.8

Table 19 Culvert Dimensions

Diversion	Diversion Culvert - Assumed Length, ft.	Diversion Culvert, Dimensions (Each Box), ft.	Discharge Culvert – Assumed Length, ft.	Discharge Culvert, Dimensions (Each Box), ft.
1	400	35 x 15	400	25 x 15
2	400	35 x 15	400	25 x 15
3	400	40 x 15	400	30 x 15
4	850	50 x 15	400	35 x 15

2.5.6.1.2 Assumptions-Methodology

Similar to the design of the Davis Pond Diversion, 4-box culverts were utilized in the design for conveying flow under the railroad and Hwy 46, and also to avoid subjecting the diversion canal to the stages in the Mississippi River. The box culverts were assumed to be 400 feet long for Diversion 1, 2, and 3. The assumed length of Diversion 4 was 850 feet long to account for the wider widths between the diversion point, the railroad, and Hwy 46. The culvert was sized on the criteria not to allow significant backwater stages.

It was assumed that the maximum allowable velocity for the diversion is 4 ft. /sec., except in the vicinity of the contraction/expansion zones of the culverts.

The channel was designed with 1:3 side slopes. This may or may not be acceptable in accordance with soil conditions.

The channel depths were obtained by adding 1 ft. of freeboard to the maximum water surface along the channel for the design flow.

An n-value of 0.035 was used for the channel. This means that in order to maintain the design flows, the channel would have to remain reasonably clear of vegetation and debris.

The 95-percentile stage (Elev. 12.0 NAVD 88 2004.65) of the Mississippi River was used to determine the amount of head available to convey flow down the diversion. The data used was available daily gage data recorded at 8:00 AM each day for the period 3/20/1987 – 6/2/2009. Rather than breaking the data down on a temporal scale, all of the data was taken as one set.

For the discharge side of the diversion, the 70-percentile stage (Elevation 0.5 NAVD 88 2004.65) of the NOAA gage located at Shell Beach was used as downstream stage. Data used for this gage was at 8:00 AM for the period 6/03/2006 – 06/02/2009. There was a much more extensive record of data available, however this data was not used since it was not verified. The 70-percentile stage was used throughout the simulations. This stage was assumed to be the same at all diversion locations.

2.5.6.1.3 Further Analysis (Sensitivity)

Other percentile stages of the river were analyzed to illustrate what quantities of flows other than the design flow would be conveyed through the diversion. All stage data of the river were used as one set, and were not broken down on a temporal scale. To accomplish this, Elevation 0.5 NAVD 88 2004.65 was used (as in the primary analysis) as a downstream stage. Table 20 is a depiction of these results.

Based on the results of this investigation and other factors such as existing infrastructure, location on the river length of outflow channel and potential for influencing the Central Wetlands alternative Location 1 was selected as part of the TSP. Further plan selection details can be found in the main report.

Table 20 Diversion Flows

Diversion Flows				
Percent Exceedance – Stage, NAVD 88 2004.65	Diversion Flows, cfs			
	1	2	3	4
5% - 12	15000	15000	15000	15000
10% - 10.7	12300	12300	12100	11900
15% - 10.2	11350	11350	11050	10850
20% - 9.6	10300	10300	9850	9500
25% - 8.7	8700	8700	8100	7600
30% - 7.6	6900	6900	6200	5400

Based on the results of this investigation and other factors such as existing infrastructure, location on the river length of outflow channel and potential for influencing the Central Wetlands alternative Location 1 was selected as part of the TSP. Further plan selection details can be found in the main report.

2.5.6.2 Detailed Design of Violet Diversion

2.5.6.2.1 General

For the detailed design of Location 1, it became apparent that the design of the freshwater diversion consisted of several unique problems that needed to be addressed, revolving mainly around the stages in Lake Borgne vs. the stages in the Central Wetlands. Because the Central Wetlands are

proposed to not merely serve as a means of transmitting Mississippi River water but also as a receiving area, the question as to what happens with the stages and flow between the two areas is of great concern in the design. Figures 57 and 58 depict the nature of the water flow and discharge in the scenario of the familiar freshwater diversion operation, vs. the scenario that would persist routinely in the case of the Violet Diversion.

Figure 57 Continuous Diversion

For a continuous diversion (without gaps), Lake Borgne always contains the lowest stages in the system, thus water will always flow as intended (river to outfall area).

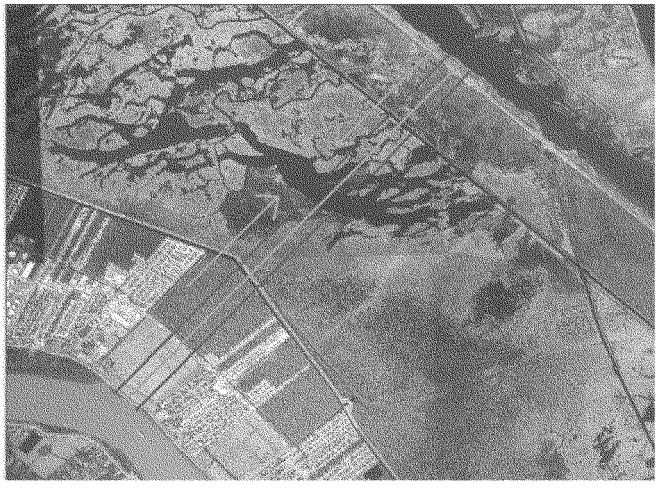

Figure 58 Proposed Violet Diversion

Depending on the Lake Borgne stage, the Central Wetlands are routinely the lowest stage in the system, resulting in the situation where the water from the river and water from Lake Borgne converges into the Central Wetlands.

To remedy the problem, there are at least several possible "solutions", detailed below.

1. Only operate the diversion during ebb (outgoing tide), since the Central Wetlands stages are higher than the Lake Borgne stages in this case. This would require either one-way flap gates (to allow only outgoing flow) or the constant closing and opening of the sluice gates with each tidal cycle. The issue would be exacerbated due to sea level rise if the stages in the Central Wetlands were required to remain similar to current stages.

2. Place pumps at the MRGO outfall to account for the negative head differential when flow is needed out into the Lake Borgne. The diversion would then be able to operate continuously.

3. Have the channel operate by discharging all flow into Lake Borgne, instead of discharging some into Lake Borgne and some into the Central Wetlands. Since this alternative was not acceptable to the project managers, a hydraulic analysis was not completed for this alternative.

Most of the following dialogue and figures are centered around Solution 1. Three scenarios of SLR were considered in the analysis: Low, Medium, and High. It should be noted that the channels in the detailed design are significantly narrower because 7,000 cfs was determined (by that point) to be the flow necessary to achieve the Chatry salinity limits.

2.5.6.2.2 Channel Designs, Assuming No Pumps Are Used

2.5.6.2.2.1 Low SLR

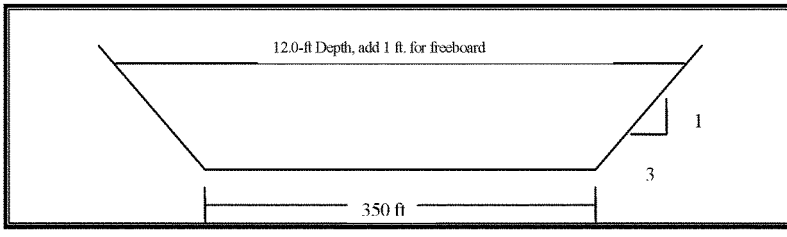

Figure 59 Channel Section

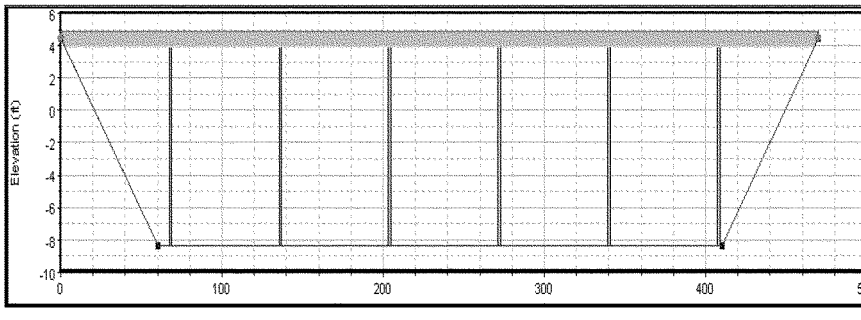

Figure 60 Judge Perez Bridge Section

Culvert Specs. Concrete box culverts with wingwalls angled between 30° and 75° to the barrel. Figure below shown to display wingwalls only (not culvert barrel).

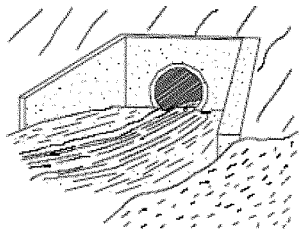

Figure 61 Culvert Specs

Table 21 Culvert Data

Culvert Location	Invert Elevation-Upstream Side of Culvert	Invert Elevation-Downstream Side of Culvert	# of Barrels	Dimension of Each Barrel	Total Flow Area of Culvert
Upstream	-12.3	-12.3	4	13' x 13'	676 ft^2
40-Arpent Levee	-13.3	-13.3	5	13' x 13'	845 ft^2
Downstream	-14.9	-14.9	8	13' x 13'	1352 ft^2

Note in the profile depiction that there are 500' transitions at each face of each culvert to the normal channel profile. For all cases, the upstream culvert encompasses the Mississippi River Levee, St. Bernard Highway, and the railroad.

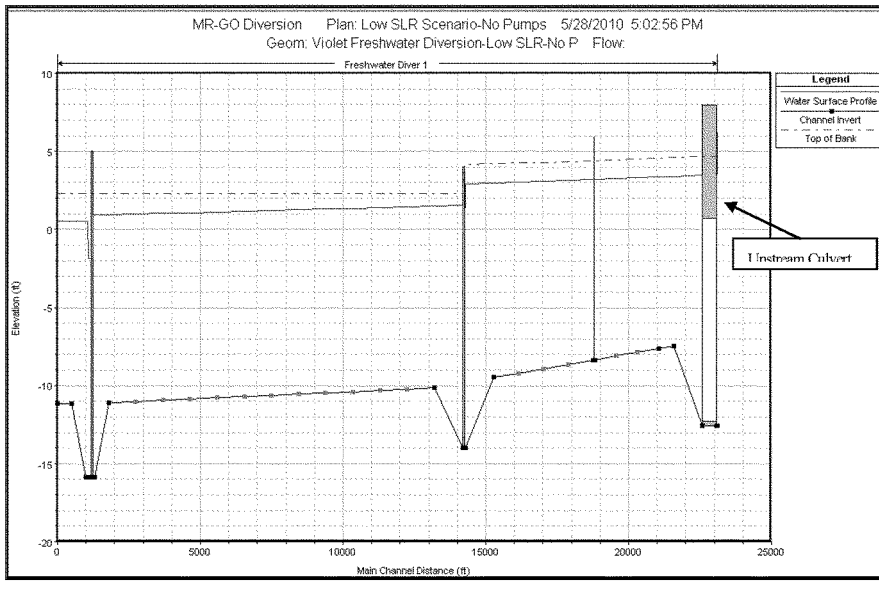

Figure 62 Channel Profile

Using an estimated Central Wetlands marsh elevation of Elev. 1.3 NAVD 88 2004.65, 1-ft (above marsh elevation) guide levees are needed between the Mississippi River and 40-Arpent Levees.

2.5.6.2.2.2 Medium SLR

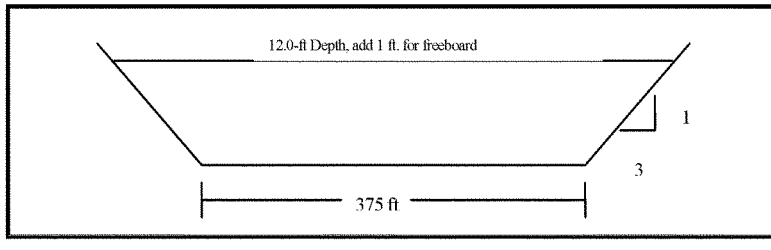

Figure 63 Channel Section

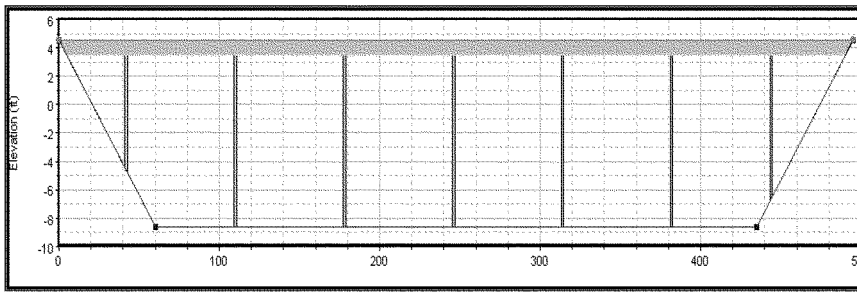

Figure 64 Judge Perez Bridge Section

Table 22 Culvert Data

Culvert Specs – Same as with low SLR scenario.					
Culvert	Invert Elevation- Upstream Side of Culvert	Invert Elevation- Downstream Side of Culvert	# of Barrels	Dimension of Each Barrel	Total Flow Area of Culvert
Upstream	-11.8	-11.8	4	13' x 13'	676 ft^2
40-Arpent Levee	-12.8	-12.8	5	13' x 13'	845 ft^2
Downstream	-14.4	-14.4	8	13' x 13'	1352 ft^2

Note in the profile depiction that there are 500' transitions at each face of each culvert to the normal channel profile.

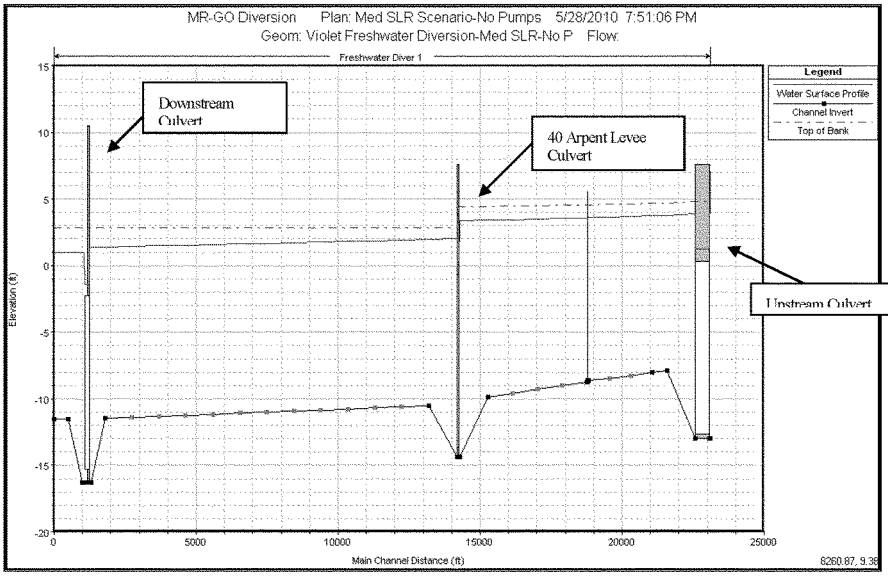

Figure 65 Channel Profile

Using an estimated Central Wetlands marsh elevation of Elev. 1.3 NAVD 88 2004.65, 1.5-ft (above marsh elevation) guide levees are needed between the Mississippi River and 40-Arpent Levees.

2.5.6.2.2.3 High SLR

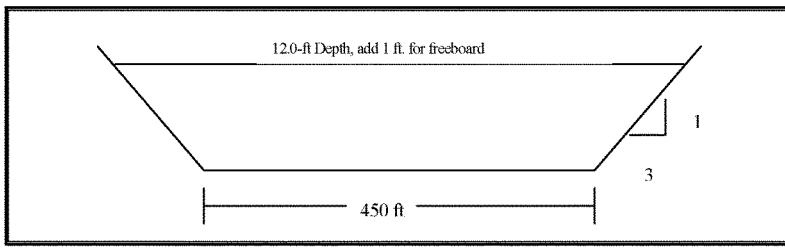

Figure 66 Channel Section

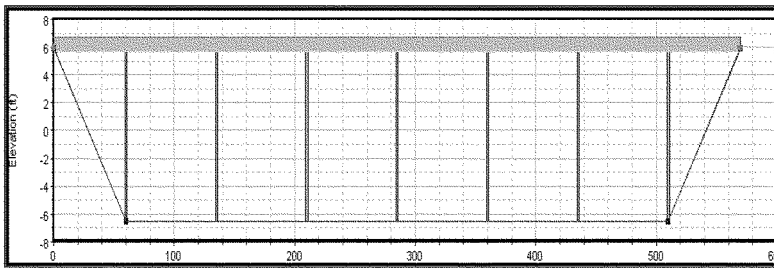

Figure 67 Judge Perez Bridge Section

Table 23 Culvert Data

Culvert Specs – Same as with low SLR scenario.					
Culvert	Invert Elevation- Upstream Side of Culvert	Invert Elevation- Downstream Side of Culvert	# of Barrels	Dimension of Each Barrel	Total Flow Area of Culvert
Upstream	-10.5	-10.5	4	13' x 13'	676 ft^2
40-Arpent Levee	-11.5	-11.5	5	13' x 13'	845 ft^2
Downstream	-13.1	-13.1	8	13' x 13'	1352 ft^2

Note in the profile depiction that there are 500' transitions at each face of each culvert to the normal channel profile.

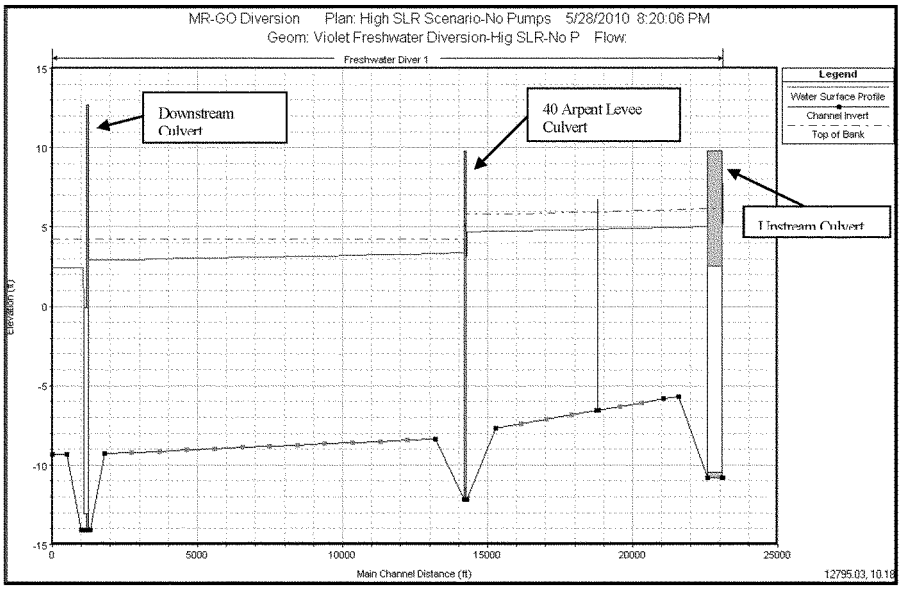

Figure 68 Channel Profile

Using an estimated Central Wetlands marsh elevation of Elev. 1.3 NAVD 88 2004.65, 3.1-ft (above marsh elevation) guide levees are needed between the Mississippi River and 40-Arpent Levees.

2.5.6.2.3 Channel Design Assuming Pumps are Used

As mentioned before, any case of sea level rise (and present conditions, for that matter) would require pumps if the diversion is to push water into Lake Borgne continuously and not be dependent of tidal fluctuations. The pumps generally do not change the design of the channel if they are sized to meet the flow demands at that point in the channel. However, oversized pumps can be used to lower the water stages in the channel if so desired. This would however increase flow rates and also velocities significantly. Oversized pumps located at the MRGO levee could also allow the channel to have a smaller cross section-footprint. For instance, a pump capable of pumping 6000 cfs at a -1.5 head would allow a 250 width bottom width channel.

2.5.6.2.4 Earthen Weirs

The diversion is proposed to operate at design level by depositing 1,000 cfs into the Central Wetlands and the other 6,000 cfs. into Lake Borgne. To do this, earthen weirs must be constructed at the intersections with existing open channels. Otherwise the 7,000 cfs will discharge into the Central Wetlands. Unless these weirs are adjustable, 1000 cfs can only be discharged into the Central Wetlands by manipulating the gates at the MRGO and Mississippi River levees. The concept is to keep stages in the diversion channel high enough to where flow is discharged from the channel

into the Central Wetlands. For Feasibility-Level design purposes the crest of the weir should be set at Elev. 0.5 (NAVD 88 2004.65) for the low SLR scenario, Elev. 0.9 for the medium scenario and Elev. 2.4 for the high scenario.

For the purposes of this design, the weirs are broad-crested. Maximum velocities of 2 ft/sec were calculated over the crest of the weirs. Consequently, the weirs would not have to be protected from scour.

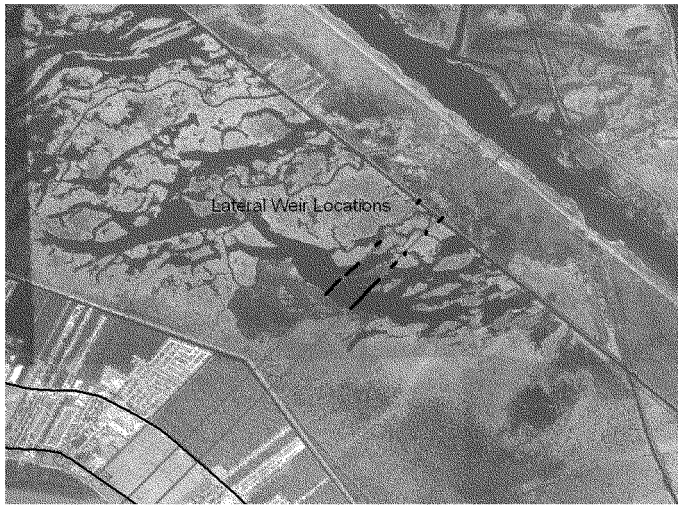

Figure 69 Lateral Weir Locations

2.5.6.2.5 Rip Rap

2.5.6.2.5.1 Culverts

Channel flow near the culverts presents the major concern for channel velocities. All SLR scenarios produced similar velocities for the transitions into and out of the culverts. Therefore, the rip rap gradations necessary to protect the channel and structures are listed below for each SLR scenario. The gradations were determined assuming placement in the dry. Tables 24 to 27 show riprap designs for each structure.

Table 24 Mississippi River Structure Riprap

Upstream, Weight, lb		
20" Layer Thickness		
Percent Lighter by Weight, 20" Thickness	W_{max}	W_{min}
100	400	160
50	160	80
15	80	30

Table 25 40 Arpent Levee Structure Riprap

40-Arpent Levee, Weight, lb		
12" Layer Thickness		
Percent Lighter by Weight, 20" Thickness	W_{max}	W_{min}
100	90	40
50	40	20
15	20	5

Table 26 MRGO Structure Riprap

Downstream, Weight, lb		
12" Layer Thickness		
Percent Lighter by Weight, 20" Thickness	W_{max}	W_{min}
100	25	10
50	10	5
15	5	2

Table 27 Placement Distance

Rip Rap Placement		
	Distance in Feet Upstream	Distance in Feet Downstream
Upstream	205	410
40-Arpent Levee	200	400
Downstream	190	380

2.5.6.2.6 Judge Perez Highway Bridge

During design flows, the average cross-sectional velocities at the upstream face of the bridge are 1.6 ft/sec. The velocities in the immediate vicinity of the piers are expected to be higher (as the HEC-RAS model is a 1-D model, not capable of modeling the flow around the piers unless a scour analysis is completed). Since soil borings along the channel were not yet available, it was estimated that scour protection would be needed around the bridge even though the velocities do not increase significantly as in the cases near the culverts. It was decided that it would be sufficient for the purposes of feasibility level study to utilize the design used for the Hwy. 90 Bridge for the Davis Pond Diversion, since Davis Pond has similar velocities. The gradations for the bridge assume placement in the wet. Rip rap extends 20 ft. upstream and downstream of the bridge. The design is sufficient for the case of with or without pumps, as in both cases the average velocities in the cross section remain below 3.0 ft/sec. Table 28 shows the riprap design for the Judge Perez bridge.

Table 28 Judge Perez Bridge Riprap

Rip-rap placement, Judge Perez Bridge		
Percent Lighter by Weight, 18" Thickness	W_{max}	W_{min}
100	25	10
50	10	5
15	5	2

2.5.6.2.7 Design Criteria

- Design flow of 7000 cfs total (6,000 cfs into Lake Borgne, 1,000 cfs into the Central Wetlands)
- A channel length of 22,000 ft.
- Sides slopes are 3H:1V
- Assume manning-n of 0.038

- Channel flows at a maximum depth of 12 feet.
- Assume a maximum permissible velocity of 4.0 ft/s for the channel.
- Data for "Mississippi River at Carrollton", "Mississippi River at Venice", and "Lake Borgne at Shell Beach" gages.
- All elevations-stages referenced to NAVD 88 (2004.65).
- A 500 linear foot culvert needed at the upstream end of the diversion (this culvert will flow under the MRL levee, St. Bernard Hwy and railroad).
- Assume (based on a 10 ft height and 12 foot crown) a 72 foot linear foot culvert needed at the 40-arpent levee.
- Six sets of 75-foot bridge bents at Judge Perez Drive. Three foot-diameter piles.
- 500 cfs needed to each side of channel through a lateral weir continuously.
- Assume a 150 foot culvert needed at the downstream end of the diversion (this culvert will flow under the HSDRRS floodwall).

2.5.6.2.8 Culvert Design

The bridges and culverts were placed into the model, submerging the culverts so the top is at a depth of at least ½ of the diameter/height. This is to help prevent formation of hydraulic jumps inside or near the culvert and to help prevent sedimentation around the culvert).

The culvert analysis consisted of sizing the culverts so that most of the head is lost at the upstream (Mississippi River) culvert. This would allow stages through the channel to remain relatively low (necessitated by the fact that the criteria was not to have guide levees in Lake Borgne and also to facilitate the lowering of stages as the channel traverses through developed areas) since significant backwater profiles wouldn't occur along the length of the channel. The culvert depth was determined from taking into account the types of culvert flow classifications that would occur depending on the parameters involved in the design. It was determined that a Type IV classification would be desirable since a hydraulic jump would not occur in this case and also because concerns of sedimentation occurring in the culvert. For this reason, the culvert invert is located lower than the rest of the channel invert.

2.5.6.2.9 Further Analysis-Sedimentation

In general, a sediment analysis of the channel should be performed in design phase in order to determine the actual maximum velocities and how the channel will perform under the sediment load presented by the river. In general, the slope and cross section must be designed such that the

channel does not have excessive depositional/erosion tendencies. If the channel does not have stable parameters and it is unlined, extensive deposition or erosion could occur at undesired locations, resulting in unexpected maintenance costs. Should the channel be found to convey extensive amounts of sediment, then a sediment basin will be recommended and designed to be constructed at the upstream end of the channel. Due to the extensive scope of a sediment analysis, this is recommended for the design phase of the study.

2.5.7 SHORELINE PROTECTION DESIGN

2.5.7.1 General

The proposed shoreline protection consists of rock breakwater located along several reaches in the Lake Borgne/Lake Pontchartrain Basins. This is a synopsis of design parameters and design methodology. Figure 70 depicts the proposed shoreline protection locations and the wind fetches which were used to determine wave heights to which these reaches are exposed to.

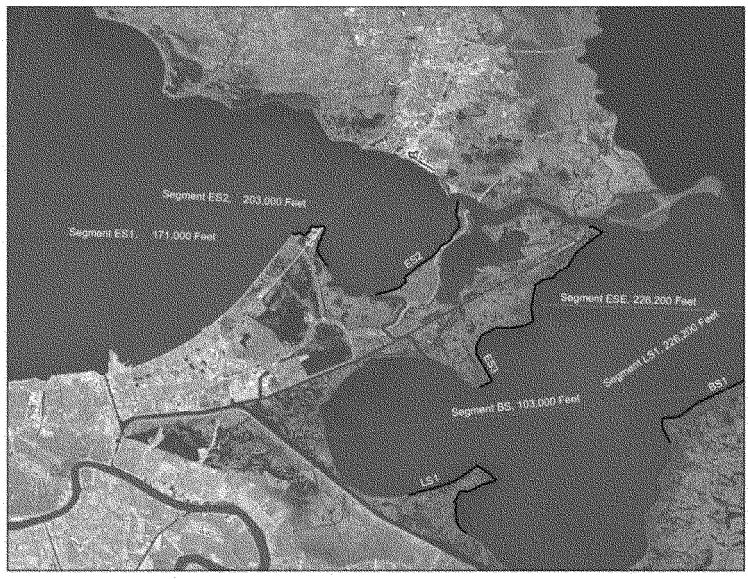

Figure 70 Shoreline Protection Reaches and Fetch Distances

2.5.7.2 Design Specifications

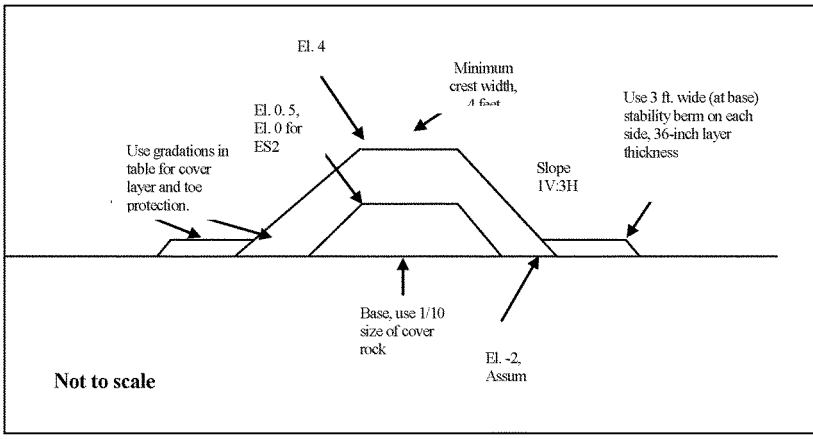

Figure 71 Cross-Section for Segments LS1, ES3, ES1, BS1, ES2

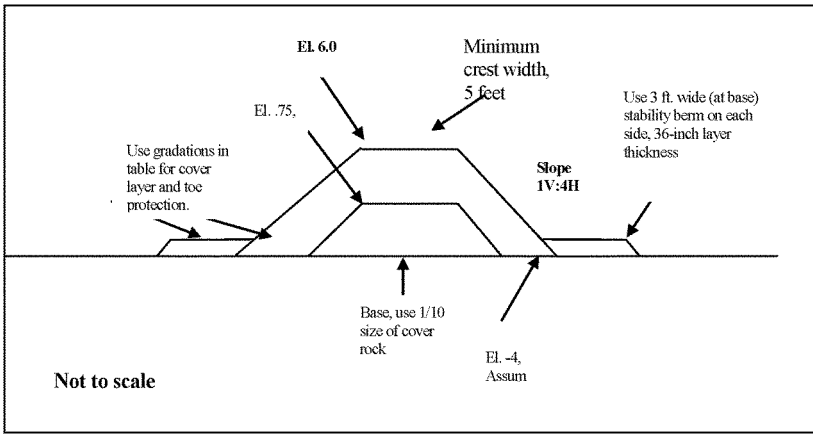

Figure 72 Cross-Section for Segments JS1, and BS2

Table 29 Stone Gradations for Areas LS1, ES3, BS1 and ES1		
42-Inch Layer Thickness Minimum		
Percent Lighter By Weight	Required Gradation, Percent Lighter by Weight, lbs	
	Upper Limit	Lower Limit
100	1000	400
50	430	200
15	210	60

Table 30 Stone Gradation for Area ES2		
48-Inch Layer Thickness Minimum		
Percent Lighter by Weight	Required Gradation, Percent Lighter by Weight, lbs	
	Upper Limit	Lower Limit
100	1500	600
50	650	300
15	330	100

Table 31 Stone Gradations for Areas JS1 and BS2		
63-Inch Layer Thickness Minimum		
Percent Lighter by Weight	Required Gradation, Percent Lighter by Weight, lbs	
	Upper Limit	Lower Limit
100	3500	1400
50	1500	700
15	700	200

2.5.7.3 Design Points

- A geotextile material shall be placed under the base of the structure.
- The stability berm shall have the same gradation as the cover layer of the main structure.
- The structure shall be placed where there is a maximum 125 ft. distance between the shoreline and the toe of the stability berm.

- Rough, angular rocks are more stable than smooth, round rocks and are recommended.

2.5.7.4 Design Assumptions

- For rock stability, design for the 90% case, a SWL at 3 ft, and a SWL at 6 ft. The SWL's were derived from stage-frequency curves formulated for ADCIRC modeling completed for USACE New Orleans District's Hurricane and Storm Damage Risk Reduction System (HSDRRS).

- For design crest elevation, design for mean higher high water and accompanying conditions.

- Design breakwater to have no overtopping for daily wave attack. The structure would be submerged during a low frequency event (the structure still will provide some wave attenuation).

- Assume that the base of the structure is at -2 NAVD 88 2004.65 for all segments except JS1 and BS2. For JS1 and BS2, assume a base elevation of -4 NAVD 88 2004.65. This may or not be the case. However, the crest elevation should be as given in the figures.

2.5.7.5 Design of Areas LS1, ES3, and BS1

2.5.7.5.1 Determine Structure Crest Elevation

- Design elevation (peak crown elevation) = Design High Water (DHW) + Set-up + run-up + freeboard + SLR.
- Use Mean Higher High Water for Shell Beach Gage for DHW (in this case 1.5 ft. MLLW = 1.95 NAVD 88). The DHW was obtained from a November 2008 NOAA tidal bench mark report. The conversion to NAVD 88 was obtained from the IPET Report, Volume III.
- Set-up happens when after incoming waves break, the average level of the water surface inside the surf zone to the beach is set up higher than the sea level offshore from the breaker zone. Assume set-up = 0 because it's a sloped structure
- Run-up is the maximum vertical point on the dike face that a breaking wave travels as its energy is dissipated.
- Use a sea level rise rate of 10.24 mm/yr. Taken over a ten year design life, total sea level rise is 102.4 mm = .34 feet = 4 inches

Due to depths in Lake Borgne, the waves are shallow water waves. A wave height is needed for each segment. For the winds, an analysis where the Coastal and Hydraulics Laboratory at

Vicksburg, MS reconstructed hourly wind records from 1980 to 1999 for various stations along the Gulf coast was used. The wind rose in Figure 4 for station 142 at 29.83N 88.67W (70 miles east of Lake Borgne) shows that prevailing winds come from the north, east, and southeast. High winds however, usually come from the north. The wind field was transferred from over 70 miles offshore without any reduction for terrestrial friction and is very likely higher than what might be expected over Lake Borgne. From looking at the wind distribution graph, it is evident that the distribution of winds coming from the northeast is similar to the winds coming from the southeast. For this reason, the same winds from 359° to 89° (ES3 and LS2) were used for the winds from 90° to 179° (BS1). The 90-percentile wind speed was used for each segment.

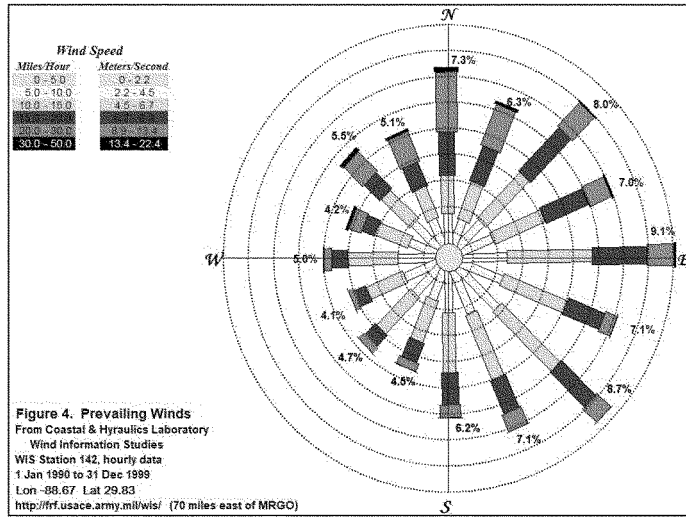

Figure 4

A 5-hour average wind speed was used because it requires about that long for waves over a 25-mile fetch to become fully developed. The hindcast maximum 5-hr wind speed was 50.8 mph from 45 degrees. The 90th percentile velocity is 21.5 mph. This 90-percentile case was adjusted to obtain the wind speed wind averaged over the length of the fetch. These windspeeds were used with the fetch distances (contained in Figure 5) in the shallow water wave prediction tables contained in SPM 1984. Table 4 depicts the windspeeds, periods, and design wave heights used for each segment. The broken wave heights were obtained using Figures 7-2 and 7-3 and Equation in SPM 1984.

Table 32 Design Period and Breaker Heights for 90-percentile case

Segment Corresponding to Section	Segments LS1, ES3	Segment BS1
90 Percentile Wind Speed mph	21.5	21.5
Duration-Averaged Windspeed mph	18.5	19.2
Wind-Stress Factor miles/hr	21.4	22.4
Fetch Length, feet	156000	103000
Depth of Fetch, feet	20	20
Design Wave Height	2.5	2.1
Design Period	3.5	3.1
Maximum Breaker Height (.4*D)	2.0	1.9

To determine crest height, the following example for Segments LS1 and ES3 are shown.

To determine run-up, use a van der Meer equation, located in the CEM 2003.

According to van der Meer (1988)

$R_u/H_S = a\xi_m$ for $\xi_m < 1.5$ Eq. 1

$R_u/H_S = b\xi_m^c * \lambda$ for $\xi_m > 1.5$ Eq. 2

where

R_u = Runup Level

H_S = Significant Wave Height

ξ_m = Surf similarity parameter $= \tan\alpha / \sqrt{H_s/L_m}$ Eq. 3

(where L_m is the deepwater wave length for the deepwater period, T_m and α is the structure slope)

a and *b* are defined in Table 33

λ = Reduction Factor, defined in Table 34

Table 33 Ru Exceedance Probability (%)

R_u exceedance probability (%)	*a*	*b*	*c*	*d*
0.1	1.12	1.34	0.55	2.58
2	0.96	1.17	0.46	1.97
5	0.86	1.05	0.44	1.68
10	0.77	0.94	0.42	1.45
50	0.47	0.60	0.34	0.82

Table 34 Reduction Factor

	Reduction factor (γ)
Smooth impermeable (including smooth concrete and asphalt)	1.0
1 layer of stone rubble on impermeable base	0.8
Gravel	0.7
Rock rip-rap with thickness > $2D_{50}$	0.5-0.6

Smooth impermeable rock is assumed for a reduction factor of 1.

- $\xi_m = \tan 17^o / \sqrt{2.0/62.7}$ [1]

  $= 1.7$

- $R_u = (.6)(2.0)(1.7)(1) = 1.9$ ft.

- Design Crest Elevation = 1.95 ft. + 1.9 ft. + .4 = **4.0 ft. NAVD 88 2004.65**

2.5.7.5.2 Determine Required Rock Sizes for Stability (selected size in bold)

- Check for 90 percentile case using Hudson's Equation. Equation shown for example case

$$W_{50} = \frac{w_r H^3}{K_D (S_r - 1)^3 \cot\theta}$$

where w_r = unit weight of stone

W = Weight in pounds of median stone size

H = Design wave height of site

K_D = Stability Coefficient

θ = Angle of structure slope from horizontal

S_r = Specific gravity of stone

Using these parameters in the Hudson equation for Segments LS1 and ES3,

$$W_{50} = \frac{(155\ \text{lb/ft}^3) * (2.0\ \text{ft.})^3}{1.2\ (2.5 - 1)^3 \cot 3} = 102\ \text{lbs}$$

Table 35 Rip Rap Calculations Using Hudson Eq.

Segment Corresponding to Section	Segment LS1, ES3	Segment BS1
Design Wave Height	2.5	2.3
Maximum Breaker Height - Check (.4*D)	2.0	1.9
W_{50} lbs	102	87

- Check for SWL at 3 feet, use a wind stress factor of 1.4 times 90-percentile case and a depth of 27-feet (must be interpolated) in the shallow water wave tables in SPM 1984. Using the Hudson Equation,

Table 36 Hudson Formula-Wave Table

Segment Corresponding to Section	Segments LS1, ES3	Segment BS1
Wind-Stress Factor miles/hr	30	31.4
Fetch Length, feet	156000	103000
Design Wave Height	3.5	3

Design Period	4.2	2.8
Maximum Breaker Height – Check (.4*D)	2.5	2.3
W50	200	155

Check required size for a SWL level of 6 feet, assuming a design wind of 60 mph. Using the shallow water wave equations for a depth of 30 feet, the wind, and design sizes and weights determined for each segment are listed in Table 37.

Table 37 Rip Rap Calculations

Segment Corresponding to Section	LS1, ES3	BS1
60 mph windspeed converted to factored windspeed, mph	48.0	50.2
Wind-Stress Factor miles/hr	69.0	72.9
Fetch Length, feet	226201.0	103000
Design Wave Height	7.0	6.5
Design Period	6.0	5.5
Maximum Breaker Check (.4*D)	4.1	4.0
D_{50} (feet)	1.1	1.1
W_{50}	**200**	**200**

The D_{50} size was determined with the van der Meer equation for submerged structures.

$$h'_c / h = (2.1 + 0.1S) \exp(-0.14 N^*_s) \qquad \text{Eq. 4}$$

where h'_c = Height of structure over seabed level

h = Water depth

S = Relative eroded area

N^*_s = Spectral Stability Number

For further explanation of this equation and its constituents, see Chapter VI-5 of the CEM. A spreadsheet table was made of the equation, and displayed here as Table 38, solving for the D_{50} (this is a metric table).

Table 38 Rip Rap Calculations Using van der Meer Equations

van der Meer 1991, Page VI-5-68		
Water depth	h	2.4
Relative Eroded Area	S	6.0
D50 Size	D_{50}	0.3
Deepwater Period	T	6.0
Specific Gravity		2.5
Wave Height	H	1.2
Local Wave Steepness	s_p	0.020632937
Height of structure over seabed level	h'_c	2.0

2.5.7.5.3 Determine Recommended Crest Width

The recommended crest width of the structure is dependent on the amount of allowable overtopping. Placement of rock in these locations along the shoreline will probably result in a high degree of overtopping. The Coastal Engineering Manual's equation VI-5-116 (Eq. === below) was used to calculate the crest width. The calculated crest width =

$$B = n\, k_\Omega (W/w_a)^{1/3}\text{, where}$$

B = Crest width

n = number of stones (n = 3 is recommended minimum)

k_Ω = layer coefficient from Table VI-5-51

W = primary armor unit weight

W_a = specific weight of armor unit material

Using the W_{50} of 200 lb, B = 3*1*(200 lb / 155 lb/ft^3)$^{1/3}$ = 3.2 ft., **use 4.0 ft.**

2.5.7.6 Design of Areas ES1 and ES2

2.5.7.6.1 Determine Structure Crest Elevation

- As in above, use Mean Higher High Water for Shell Beach Gage for DHW (in this case 1.5 ft. MLLW).
- Assume set-up = 0
- Use a sea level rise rate of 4 inches.

- A wave height is needed for each segment. For all segments, the NW Quadrant winds were used to determine wave heights and periods. The 90-percentile wind speed was used for each segment.

The fastest mile wind windspeed for the 90-percentile case (24.1 mph) was adjusted to obtain the wind speed wind averaged over the length of the fetch. These windspeeds were used with the fetch distances (contained in Figure 5) in the shallow water wave prediction tables contained in SPM 1984. Table 39 depicts the windspeeds, periods, and design wave heights used for each segment (assuming an average water depth of 20 feet). Using the same methodologies as used to obtain run-up for sections LS1, ES3, and BS1.

Table 39 Run-up Calculations

Segment Corresponding to Section	Segment ES1	Segment ES2
90 Percentile Wind Speed mph	24.1	24.1
Duration-Averaged Windspeed mph	20.8	21.5
Wind-Stress Factor miles/hr	24.6	20.4
Fetch Length, feet	171000	203000
Design Wave Height	2.5	2.3
Design Period	3.5	3.5
Maximum Breaker Check (.4*D)	2.0	2.0
Surf Similarity	1.7	1.7
Runup	1.9	1.9
Sea Level Rise	0.4	0.4
Design Crest, NAVD 88 2004.65	4	4

2.5.7.6.2 Determine Required Sizes for Rock Stability

- Check for 90 percentile case using Hudson's Equation.

Table 40 Rip Rap Calculations Using Hudson Equation

Segment Corresponding to Section	Segment ES1	Segment ES2
Design Wave Height	2.5	2.3
Maximum Breaker Height - Check (.4*D)	2.0	2.0
W_{50} lbs	102	102

- Check for SWL at 3 feet, use a wind stress factor of 1.4 times 90-percentile case and a depth of 17 feet (must be interpolated) in the shallow water wave tables in SPM 1984. Using the Hudson's Equation,

Table 41 Rip Rap Calculations Using Hudson Equation

Segment Corresponding to Section	Segments ES1	Segment ES2
Wind-Stress Factor miles/hr	34.4	28.6
Fetch Length, feet	171000	203000
Design Wave Height	3.7	4
Design Period	4.0	4.5
Maximum Breaker Height – Check (.4*D)	2.5	2.6

W50	**200**	**224**

-
- Check for a SWL level of 6 feet, assuming a design wind of 60 mph. Using the shallow water wave equations for a depth of 20 feet, the wind, and design sizes and weights determined for each segment are listed in Table 42 (obtained with the van der Meer equation).

Table 42 Rip Rap Calculations Using van der Meer Equation

Segment Corresponding to Section	Segment ES1	Segment ES2
60 mph windspeed converted to factored windspeed, mph	49	48.5
Wind-Stress Factor miles/hr	70.6	69.8
Fetch Length, feet	171000	203000
Design Wave Height	5.8	6
Design Period	5.3	5.5
Maximum Breaker Height – Check (.4*D)	3.9	4.0
D_{50}	1.0	1.0
W_{50}	111	111

2.5.7.6.3 Determine Recommended Crest Width

For ES1, use same crest width (4 ft) as LS1, ES3, and BS1, since the W_{50}'s are the same. For ES2, use $3*1*(224\ lb / 155\ lb/ft^3)^{1/3} = 3.39$ ft. **(use 4 ft.)**

2.5.7.7 Design of Areas JS1 and BS2

2.5.7.7.1 Determine Structure Crest Elevation

- Use Mean Higher High Water for Shell Beach Gage for DHW (in this case 1.5 ft. MLLW).
- Assume set-up = 0
- Use a sea level rise rate of 4 inches.
- Use a slope of 1:4 in order to have less runup.
- Use all fully-developed, depth-limited waves.
- R_u = (.6)(1.8)(3.2)(1) = 3.5 ft

Table 43 Run-up Calculations

Segment JS1, BS2	
Maximum Breaker Height – Check (.4*D)	3.2
T_{90} sec.	5.8
Runup	3.5

Table 43

Design Crest Elevation = 1.95 ft. + 3.5 ft. + .4 = 6.0 ft. NAVD 88 2004.65

2.5.7.7.2 Determine Required Sizes for Rock Stability (required W_{50} size in bold)

- Check for 90 percentile case using Hudson's Equation (Table 44).

Table 44 Rip Rap Calcuations Using Hudson Equation

Segment Corresponding to Section	Segment JS1, BS2
Design Wave Height	3.2
W_{50} lbs	418

- Check for a SWL level at 3 feet. Using a period of 6.0 sec, the design breaking wave from one wavelength away from structure is = 3.7 ft. The design is depicted in Table 45.

Table 45 Rip Rap Calculations Using Hudson Equation

Segment JS1, BS2	
H	3.7 ft
W_{50}	**646 lb**

- Check for a SWL level of 6 feet. Using a period of 6.4 sec, the design breaking wave from one wavelength away from structure is = 5.0 ft. Using the van der Meer equation.

Table 46 Rip Rap Calculations using van der Meer Equation

Segment JS1, BS2	
H	5.0 ft
T	6.4 sec
W_{50}	536 lb

2.5.7.7.3 Determine Recommended Crest Width

Use $3*1*(646\ lb / 155\ lb/ft^3)^{1/3}$ = 4.8ft. **(use 5 ft.)**

2.5.8 SYNOPSIS OF RELAVANT HISTORICAL STUDIES

2.5.8.1 Dortch, M. S., M. Zakakhani, M. R. Noel, S. Kim. 2007. Application of a Water Quality Model to Mississippi Sound to Evaluate Impacts of Freshwater Diversions. U.S. Army Corps of Engineers, Engineer Research and Development Center.

The study, completed under the MSCIP (Mississippi Sound Coastal Improvements Program), entails the development and application of a water quality model (WQM) of the Mississippi Sound region is an evaluation of various freshwater diversion alternatives.

The objective of this study was to develop and apply a water quality model of the Mississippi Sound and surrounding region to provide key information for a screening level evaluation and improvement alternatives for coastal restoration. The study used a previously developed, three-dimensional hydrodynamic and WQM. The model domain included a portion of Mississippi Sound to aid the Mobile District in evaluating dredging and dredge material disposal impacts resulting from channel widening and/or deepening for the Port of Gulfport, Mississippi (Bunch et al. 2005). The CH3D-Sigma model code was used for the hydrodynamic model (Chapmanet al. 1996), and the CE-QUAL-ICM (ICM) model code was used for water quality. In this original study, the domain extended from east of Mobile Bay (including Mobile Bay), south to the Chandeleur Islands, and west past the mouth of the Pearl River into eastern Lake Borgne. For the MSCIP study, the domain was extended southward beyond Chandeleur Islands and further west to include all of Lake Borgne and Lake Pontchartrain, the Inner Harbor Navigation Channel of New Orleans, and the Mississippi River Gulf Outlet channel

The following variables were activated in the model: temperature, salinity, fixed solids (inorganic suspended solids), dissolved oxygen (DO), dissolved organic carbon (DOC), Particulate Organic Carbon (POC), Ammonium (NH4) Nitrogen, Nitrate + Nitrite Nitrogen (NO3), Dissolved Organic Nitrogen (DON), Particulate Organic Nitrogen (PON), Total Phosphate or Total Inorganic Phosphorous (TIP), Dissolved Organic Phosphorus (DOP), Particulate Organic Phosphorus (POP), and Phytoplankton Carbon. For many of the rivers, assumptions were made to fill data gaps for state variables that were not available. Organic nutrients and organic carbon loads from the river are assumed to be comprised of mostly dissolved forms. Thus, TOC was assumed to be comprised of solely dissolved organic carbon (DOC), and particulate organic carbon (POC) was assumed to be zero. Similarly, total organic nitrogen (TON) was assumed to be dissolved organic nitrogen (DON), and particulate organic nitrogen (PON) was assumed to be zero. TON was computed by subtracting NH_4 from TKN. PO_4 was assumed to represent total inorganic phosphorus (TIP), the model state variable. Several other similar methods were utilized to estimate constituent loadings.

Loadings for all sources of nutrients and sediment must be specified for the model. These include loadings from inflowing rivers, atmospheric deposition, and other sources, such as local distributed runoff and major point source (e.g., wastewater discharge) loadings. Some of the riverine and atmospheric loadings had to be estimated by several methods (part of the reason that this is a screening level study). However, the majority of the data was collected and analyzed.

A partial model calibration was performed due to the limited scope of this study. Hydrodynamics from CH3D were supplied to the WQM for March through September 1998 conditions. The WQM was executed for the period April through September 1998 for calibration.

2.5.8.2 Mississippi-Louisiana Estuarine Area Study, Salinity and Circulation at or Near Bay Boudreaux in Biloxi Marshes Eastern Louisiana

This report is part of a long-term study conducted by the US Army Engineer District (USAED), New Orleans, concerning the feasibility of diverting fresh water into Lakes Pontchartrain and Borgne basins from the Mississippi River to increase fish and wildlife productivity.

2.5.8.3 EA Engineering, Science, and Technology. 2006. Proposed Reintroduction of Mississippi River Water at Violet, Louisiana. Preliminary Hydrologic Modeling to Support Environmental Benefits Estimates and Project Planning. Draft Technical Memorandum submitted to the U.S. Department of Commerce

The purpose of this study is to conduct a reconnaissance-level analysis to obtain a characterization of expected hydrologic and salinity changes in the project area. Hydrodynamic modeling of the study area was performed with the Surfacewater Modeling System (SMS). SMS is a graphical user interface that contains the U.S. Army Corps of Engineer's Waterways Experiment Station (USACE WES) two-dimensional finite-element models RMA2 (for hydrodynamics), and RMA4 (for water quality). The modeling was used to simulate tidal and diversion scenarios and to assess the resulting salinity conditions within the marsh area.

Modeling the study area was a several step process. First, the hydrodynamic model was executed to simulate the tidal and freshwater inflow conditions. This modeling was performed for multiple tidal cycles. A hydrodynamic solution file was then produced over a tidal cycle. RMA4 was then run for multiple tidal cycles to reach an equilibrium condition for the constituent of concern. For the Violet study, RMA4 was used to simulate the salinity interaction between Bayou Dupre and Bienvenue and the Mississippi River diversion at Violet.

The Violet study area was modeled for a base case scenario representing the existing siphon and for three alternative diversion scenarios. The base case scenario used a diversion flow of 200 cfs and alternative diversion flows of 1,000 cfs, 3,000 cfs, and 5,000 cfs were modeled. A mean 1.2 ft tide range was used for all scenarios. RMA4 was executed to simulate salinity within the Violet study area.

Three input salinity levels were modeled for each diversion scenario. These included mean annual level (10 ppt), mean salinity during the growing season (12.6 ppt), and maximum salinity level input during the growing season (20 ppt). At diversion rate of 200 cfs salinity levels vary from 0.5 ppt to 7.0

ppt along Violet Canal for average annual conditions. Salinity levels up to 9.0 ppt were noted at the northern marsh boundary. Under diversion of 1,000 cfs maximum salinity of 5.0 ppt was noted at the outlet of Violet Canal. Salinity levels of 9.0 ppt were still evident at northern marsh boundary. Diversion of 3,000 cfs results in 0.0 ppt salinity level along Violet Canal and a reduction to approximately 6.0 ppt at the northern marsh boundary. Salinity levels are reduced to approximately 2.0 ppt at northern boundary with diversion of 5,000 cfs.

2.5.8.4 Tate, J., A. Carrillo, R. C. Berger, and B. J. Thibodeaux. 2002. Salinity Changes in Pontchartrain Basin Estuary, Louisiana, Resulting from Mississippi River-Gulf Outlet Partial Closure Plans with Width Reduction.

This report presents the results of a numerical model investigation used to further study the average salinity changes that would occur in the Lake Pontchartrain Basin as a result of varying the level of closure of the Mississippi River- Gulf Outlet below Lake Borgne, LA.

A hydrological background is first given in the report. In the background, a comparison was made of salinities made at several locations within the Pontchartrain Basin pre-and post MRGO construction. The report then addresses the modeling effort. TABS-MDS, a three-dimensional finite-element code, was the numerical model used for this investigation. TABS-MD models three-dimensional hydrodynamics and salt transport accounting for unsteady river inflows, tides, wind effects, and density-driven circulation.

The boundary conditions (tides, freshwater inflows, wind) and initial conditions were then addressed. The base condition of a 47 ft-deep MRGO cross-section, and three combinations of depth and width closure were modeled. The proposed closure would consist of a sill across the LaLoutre Ridge in the MRGO and a section of surface width reduction at approximately the midpoint of the length of the ridge and extending for 300 ft along the ridge.

The experimental conditions were as follows:

- Base: Maximum depth in the cross section is 47 ft.
- 200-ft by -20-ft Plan: Closed to within 20-ft depth and 200-ft width.
- 160-ft by -16-ft Plan: Closed to within 16-ft depth and 160-ft width.
- 125-ft by -12-ft Plan: Closed to within 12-ft depth and 125-ft width.

The numerical model was used to calculate water-surface elevations, current velocities (three-dimensional components), and salinities at each node every 60 min for the 10-month period of simulation between January 1 and October 31. Those data were processed to provide average monthly salinity contour plots for base conditions and for each plan for April, May, September, and October.

The study concluded that the depth and width closure would produce a decrease in the salinity values at locations of interest. In general, the partial width/depth closure plans reduce salinity in Lake Pontchartrain and Lake Borgne, and their reductions are less than that of complete closure. The most severe partial closure plan (125 ft by -12 ft), as expected, produced the changes most nearly like that

of complete closure. The least severe partial closure plan had the least impact. All of the results resulting from the closure are given quantitatively in the report.

2.5.8.5 McAnally, W. H. and R. C. Berger. 1997. Salinity Changes in Pontchartrain Basin Estuary Resulting from Bonnet Carre Freshwater Diversion: Numerical Model Investigation. U.S. Army Corps of Engineers, Waterways Experiment Station.

This report entails the use of a numerical model to predict salinity changes that will occur in Lake Pontchartrain Basin estuary, Louisiana and Mississippi, as a result of proposed Mississippi River Freshwater Diversions at Bonnet Carre Spillway. A Bonnet Carre Freshwater Diversion would divert water through the existing Bonnet Carre Spillway to reduce salinities within the Lake Pontchartrain Basin. This study is of interest because it identified some target salinities as a result of the project. These salinities, called Chatry salinities in the report, were first defined in the Chatry Report (1983). They consist of a constricted band of optimum salinities and a broader band of "range limits." The optimum range represents plus or minus one standard deviation about the monthly mean observed salinities that correlated with The goal of the project is to achieve the target salinities on average every other year. The Chatry salinities were accepted by the Salinity Working Group (SWG) as the target salinities for the Ecosystem Restoration.

The Pontchartrain Basin was modeled using the TABS-MD model suite. The model grid is shown in Figure 73. The boundary conditions included were the tides at the Gulf of Mexico, freshwater inflows, and wind. Of particular note is the fact that the only freshwater inflow model was that of Pearl River. The model was used to compute instantaneous water levels, salinities, and velocities.

Four conditions were modeled for April through August of a typical year: a base condition with no diversion, a plan with freshwater diversion flow up to 20,000 cfs (called Plan RT), a plan with freshwater diversion flow up to 8,500 cfs (called Plan MPB5), and a plan with no freshwater diversion but with the connection between Lake Borgne and MRGO closed (called Plan LBC1)

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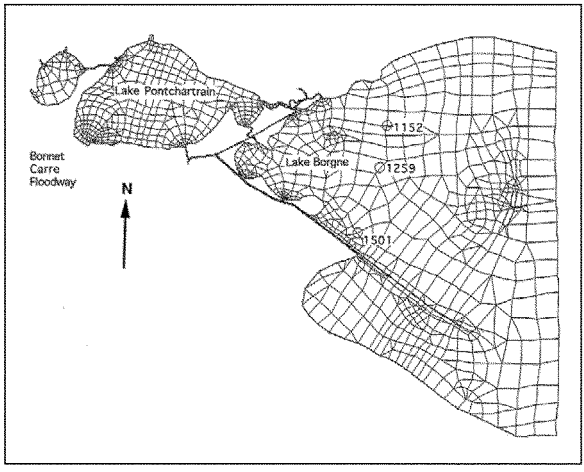

Figure 73 Model Grid

The model was verified by modeling two periods, March – July 1982 and March – May 1994, with a comparison of field data to literature. Salinity and stage were the main comparisons made in the verification. The salinity data used was gathered from the Biloxi Marsh area by the Louisiana Department of Fisheries and Wildlife.

Table 47 depicts the model output of the three plans.

Table 47 Salinity at Node 1259

Month	Base	Plan RT		Plan MPB5		Plan LCB1	
		ppt	Change, ppt	ppt	Change, ppt	ppt	Change, ppt
Apr	13.4	10.2	3.2	11.4	2	11.4	2
May	13.5	9.9	3.6	11.4	2.1	11.4	2.1
Jun	14.4	11	3.4	12.4	2	12.2	2.2
Jul	15.7	12.2	3.5	13.2	2.5	13.2	2.5
Aug	17.2	13	4.2	13.8	3.4	13.9	3.3

A regression analysis was used in order to determine salinities throughout the year and for other diversion scenarios at Node 1259. The end result was Eq 1, which is reliable for a Bonnet Carre Diversion up to 20,000 cfs and 50 percent exceedance tributary discharges.

$$S = -0.844\, Ln\,(P') - 2.68\, Ln\,(LP') + 26.4 \qquad \text{Eq. 1}$$

where:

S = Average Monthly Salinity at Node 1259

P' = Lagged, weighted, and normalized Pearl River monthly discharges

P = Lagged, weighted, and normalized Lake Pontchartrain monthly discharges

Several conclusions can be derived and from the modeling effort:

A. The Pontchartrain Basin salinities respond slowly to change. Salinities in the Biloxi Marshes showed a reduction, maximum effects, then a declining but noticeable affect at 30, 60, and 120 days, respectively.

B. It may be impossible for average monthly salinities to fall within the Chatry optimum limits for every month in any given year. The basin's slow response time and persistence of fresh water in the system may mean

C. Salinities in the target area respond nonlinearly, in that each succeeding salinity decrease requires more proportionally than the last decrease required.

D. Plan LCB1 confirms the significant role that the MRGO plays in altering salinities in the basin.

2.5.8.6 El-Sayed, Sayed Z., 1961. Hydrological and Biological Studies of the Mississippi River Gulf Outlet

The report summarizes a study conducted by the Department of Oceanography and Meteorology of the Texas Agricultural and Mechanical College under a contract entered with the Fish and Wildlife Service. The contract required the study team to establish hydrological boundaries between sub-areas and determine the interaction between these areas.

2.5.8.7 U.S. Army Corps of Engineers, Waterways Experiment Station. 1963. Effects on Lake Pontchartrain, LA., of Hurricane Surge Control Structures and Mississippi River-Gulf Outlet Channel: Hydraulic Model Investigation. Technical Report No. 2-636.

The report summarizes a model study proposed to determine the impacts on the salinity and hydraulic regimes of Lake Pontchartrain and its connecting water bodies due to New Orleans hurricane barriers. The proposed structures in the study were located in Chef Menteur Pass, the Rigolets, the Inner Harbor Navigation Canal, and the Mississippi River-Gulf Outlet. The model, which included the entire Lake Pontchartrain Basin, was equipped to reproduce and measure tides, tidal currents, salinity, freshwater inflow, etc. It was model utilized model-to-prototype ratios of 1:2000 horizontally and 1:100 vertically. Figure 74 depicts the general layout with all proposed modifications.

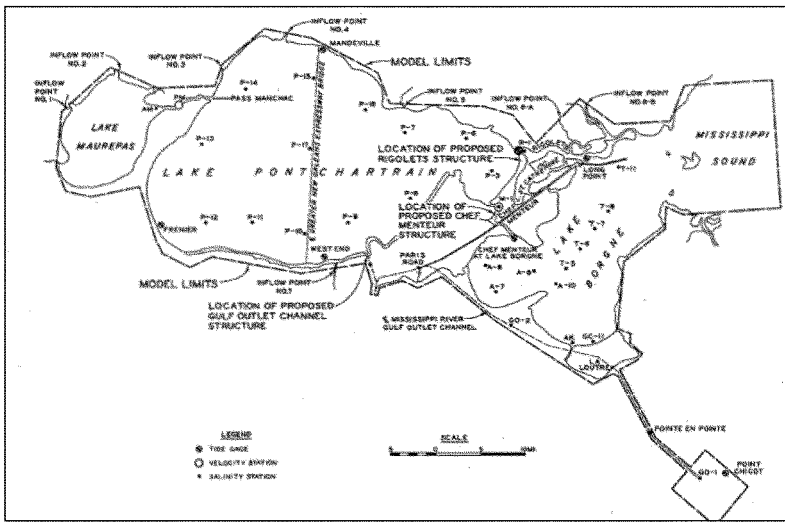

Figure 74 General Layout

The model was verified in two phases: hydraulic verification and salinity verification. Model base tests (tests of existing prototype conditions) were performed, and then tests were performed with the MRGO channel and hurricane surge barriers in place. The following conclusions were drawn from the analysis:

a. Gated structures at Chef Menteur and Rigolets Passes would cause no appreciable change in the salinity of Lake Pontchartrain, although reducing the cross-sectional areas by 25%, while raising the average water surface elevation Lake Pontchartrain by 0.1 ft and 0.4 ft, the latter being if there is a 250,000 cfs diversion flow at Bonnet Carre.

b. The MRGO channel resulted in a 5.0 ppt increase (1.1 to 6.1 ppt) in average salinities in Lake Pontchartrain for high freshwater inflow, a 5.9 ppt increase (3.2 to 9.1 ppt) for low freshwater inflow, with a 5.5 ppt average increase due to the addition of the channel. These results are all with gates in place at Chef Menteur and Rigolets Passes. Further tests indicate that the any desired degree of salinity can be obtained in Lake Pontchartrain by adding a gated structure at the entrance of the MRGO channel.

c. Operation of the Bonnet Carre Spillway at design flow with MRGO channel and gates in place raises the high-water elevation in the lake to a 1.4 ft. msl maximum.

2.5.8.8 Rounsefell, G. 1964. Preconstruction Study of the Fisheries of the Estuarine Areas Traversed by the Mississippi River-Gulf Outlet Project. Bureau of Commercial Fisheries, Louisiana Fish and Wildlife Service, Fisheries Bulletin, 63 (2): 373-393.

The report summarizes a study intended to address the biological and environmental concerns prevalent prior to the construction of the MRGO channel. Sampling stations for salinity, water temperature, dissolved oxygen, inorganic phosphates, turbidity, and currents were set up. Figure 75 depicts the project area with all sampling stations.

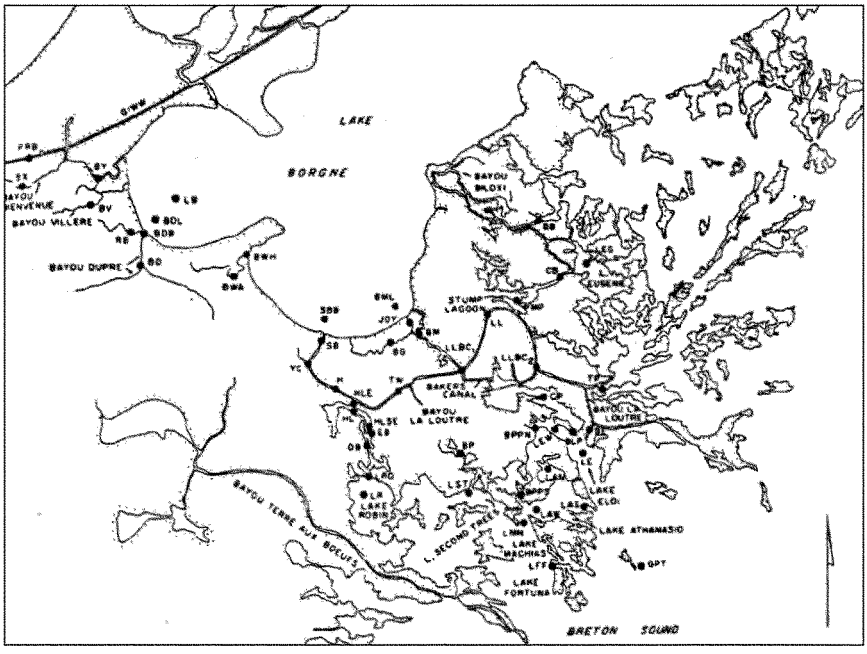

Figure 75 Sampling Stations

Table 48 depicts a summary of mean salinities for all stations.

Table 48 Mean Salinities

Station	24-month average	1959 Apr.-May	1959 June-July	1959 Aug.-Sept.	1959 Oct.-Nov.	1959 Dec.-Jan.	1960 Feb.-Mar.	1960 Apr.-May	1960 June-July	1960 Aug.-Sept.	1960 Oct.-Nov.	1960 Dec.-Jan.	1961 Feb.-Mar.	Mean of two bimonthly periods: High	Low	Difference
BX	1.62	1.32	1.03	0.91	2.54	1.89	0.91	1.03	1.78	2.22	1.77	2.91	1.19	2.72	0.91	1.81
FRS	2.06	1.74	1.46	1.18	2.91	2.10	1.34	1.16	1.90	2.46	(2.24)	(3.70)	(1.51)	2.59	1.17	2.42
BD	2.39	2.00	1.52	1.50	2.93	2.68	1.60	1.19	2.38	1.09	3.24	3.92	1.56	4.00	1.34	2.66
BV	2.45	(1.87)	(1.43)	(1.48)	3.64	2.71	1.86	1.20	1.58	3.74	3.19	4.46	2.20	4.30	1.32	2.78
BY	2.51	1.92	1.46	1.52	3.76	2.51	1.47	1.38	2.11	3.92	3.33	4.85	1.88	4.38	1.42	2.96
RB	2.73	(2.12)	(1.52)	(1.60)	3.86	2.80	1.57	1.38	2.44	4.14	3.47	5.30	2.44	4.72	1.42	3.30
SOB	2.78	2.16	1.64	1.62	4.02	2.83	1.64	1.43	2.43	4.57	3.54	5.20	2.28	4.88	1.52	3.36
BDL	2.95	2.44	1.82	1.76	4.26	2.86	1.78	1.34	2.59	4.78	3.81	5.62	2.47	5.30	1.55	3.65
LB	3.04	(2.51)	(1.88)	(1.81)	(4.38)	2.66	1.68	1.23	2.88	5.26	3.78	5.72	2.74	5.30	1.46	4.04
BWA	3.24	2.63	2.12	2.04	4.82	3.44	2.41	1.70	2.62	4.12	(4.01)	(6.22)	(2.74)	5.52	1.87	3.65
BWH	3.26	2.63	2.09	1.97	4.99	3.58	2.40	1.54	2.54	4.33	4.04	5.26	2.76	5.62	1.76	3.86
SBB	3.77	3.60	2.81	2.65	5.68	3.84	2.44	1.92	3.40	4.86	4.06	6.29	3.68	5.98	2.18	3.80
SB	4.03	3.46	3.29	2.84	5.76	4.14	2.46	2.04	3.10	4.90	4.93	6.28	4.22	6.02	2.25	3.77
JDY	4.09	(4.74)	(3.36)	(2.37)	5.28	3.90	2.74	2.10	4.54	5.15	4.08	6.22	4.61	5.75	2.24	3.51
BML	4.11	4.94	3.22	2.47	5.54	3.83	2.60	1.90	4.06	5.25	4.14	6.64	3.95	6.24	2.18	4.06
BO	4.31	4.44	3.40	2.88	5.72	4.00	2.40	2.90	5.16	5.43	4.20	6.19	5.01	5.96	2.64	3.32
YC	4.44	5.68	3.36	2.56	5.30	4.00	2.47	3.59	6.29	5.46	4.14	6.00	3.50	6.53	2.52	3.86
BM	4.47	3.16	3.66	2.59	5.74	3.82	2.84	2.79	5.86	5.51	4.18	6.55	4.96	6.20	2.89	3.53
Bapedale	4.94	6.12	4.36	3.80	5.48	4.15	3.19	4.29	6.02	6.55	4.40	6.22	4.96	6.38	3.43	2.93
HLE	5.34															
HL	6.20	5.50	6.92	4.73	5.48	4.91	3.29	5.11	9.28	6.41	4.80	6.59	6.30	8.94	4.01	4.93
TW	6.22	8.30	4.48	4.86	5.78	5.90	4.26	5.24	10.72	6.50	4.43	8.38	5.93	9.55	4.34	5.21
HLSE	6.81															
LLBC	7.08	11.12	8.03	6.06	5.90	5.61	3.22	6.54	11.94	7.63	3.17	7.14	6.58	13.53	4.42	7.11
EB	7.11															
LL	7.17	10.64	8.73	7.70												
BB	7.24	10.20	8.15	7.86												
OS	7.55	9.96	8.54	8.69	6.94	6.10	4.75	8.62	11.32	11.94	5.70	7.37	7.80	13.18	5.22	5.96
MP	7.92	11.25	9.78	9.18												
LRO	8.32	11.08								9.58						
CB	8.69	11.54	10.34	9.60												
LR	8.82	10.66	7.04	7.95	7.94	6.98	7.90	7.46	12.96	12.24	6.97	8.75	5.94	12.60	6.98	5.62
LEG	8.90	12.10	10.98	9.18												
CP	9.85									9.96	5.69	8.82	9.06			
LLBC	9.94	14.38	12.84	8.60	8.32	8.71	5.84	8.82	15.54	9.55	(6.08)	(10.53)	(9.87)	15.06	5.96	9.10
BP	11.47	14.30	11.94	9.08	10.86	10.74	10.68	9.76	15.19	11.64	7.92	14.55	10.80	14.82	8.50	6.32
BPPN	11.61	16.77	13.86	10.38	10.28	10.20	6.96	10.60	17.48	11.50	9.04	11.68	11.74	16.88	8.00	8.88
TF	12.21	17.04	16.32	12.38	11.32	10.37	6.84	10.94	16.50	12.26	(7.48)	(12.94)	(12.30)	16.77	7.16	9.61
LST	12.22	15.10	13.58	10.64	12.19	9.30	10.62	10.40	16.22	13.43	8.56	15.57	11.02	15.90	8.93	6.97
LE	13.42	18.80	15.53	14.85	13.42	11.64	9.00	11.58	17.82	12.64	8.22	14.22	13.32	18.31	8.61	9.70
BPPS	13.90	17.22	15.76	13.43	12.90	12.38	10.90	10.80	18.68	(15.29)	(9.74)	(17.70)	(12.52)	17.89	10.27	7.62
LAW	14.53															
LAN	14.60	(15.20)	(15.62)	(13.68)	13.13	12.93	11.06	12.32	18.78	12.66	(8.66)	(15.64)	(12.59)	17.21	9.66	7.35
LMN	14.73	(19.72)	(16.94)	(14.84)	13.85	12.84	11.42	12.40	19.53	13.70	10.04	17.02	14.71	19.62	10.73	8.89
LAS	15.50	(20.60)	(17.70)	(15.50)	15.02	13.80	11.76	14.58	21.58	14.86	9.80	17.71	14.26	21.09	10.78	10.31
LFF	16.96	(22.69)	(19.49)	(17.06)	(17.16)	14.73	13.06	15.74	21.66	15.84	10.70	21.56	15.87	22.18	11.88	10.30
GPT	17.27										10.52	20.06	18.41			

There are several conclusions drawn from the observation and collection of this data. Relevant points are:

1. Large, short-term fluctuations in salinity are explicit in the bayous that form part of the water exchange route between Lake Borgne and Breton Sound.
2. Salinity levels in Lake Borgne are mainly controlled by freshwater input (of which the Pearl River discharge was used for this study) modified by winds.
3. Pearl River discharge and wind intensity require time, on the order of several weeks, to affect salinities in the western end of Lake Borgne.

2.5.8.9 Bretschneider, C. L., and J.I. Collins. 1966. Storm Surge Effects of the Mississippi River-Gulf Outlet. Study A.

This report was based on a study which determined the storm surge elevations of Hurricane Betsy at several locations along the MRGO channel and IHNC. The results were then used to predict surge levels for six synthetic hurricanes and evaluate the effects of the MRGO channel on hurricane storm surge. The storm surges were computed using the bathystrophic storm tide theory. The study area with points of interest (lettered A-F) is depicted in Figure 76.

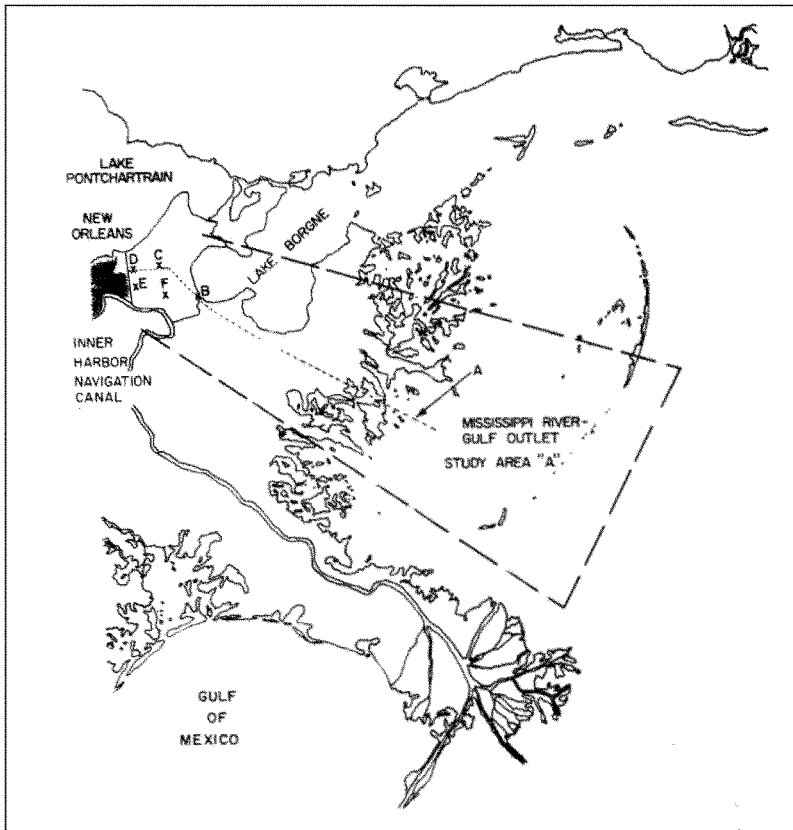

Figure 1
General location map of area under study

Figure 76 Study Area

The main relevant conclusion from the study is that the MRGO channel is almost negligent for all large hurricanes accompanied by slow rising storm surges. The channel would have a more relevant role in promoting surge in a storm producing a rapidly rising surge, but a storm of this type would not produce as high of a tide.

2.5.8.10 Sikora, Walter B. and B. Kjerfve. 1985. Factors Influencing the Salinity Regime of Lake Pontchartrain, Louisiana, a Shallow Coastal Lagoon: Analysis of a Long-Term Data Set. *Estuaries copyright 1985.*

The purpose of this study is to obtain an understanding of Lake Pontchartrain's salinity regime over the past three decades, to determine whether the long-term salinity has been affected by the MRGO channel, and to determine which environmental factors control the lake's salinity regime. The report first gives a detailed description of all data sets, which cover 36 years (from 1946 to 1982). The data used includes river discharges, rainfall, and salinities in the lake. Hourly salinity measurements were within 0.5m from the surface, which was acceptable since the salinities are well-mixed vertically within the water column in the lake. Because of the tidal variability, hourly (instead of daily) salinity measurements were taken with a mean salinity and root mean square deviation determined. In order to obtain freshwater inputs, correction factors were applied to the observed values since the gages were located upstream of the discharge. The report points out that the mean annual discharge of all freshwater inputs into the lake is 188 m^3 with a coefficient of determination of 184%.

The report asserts that the actual average increase in salinities in the lake was less than 2%, even though a 5% increase was expected. This increase was 2% in the eastern portion of the lake, but was substantially less in the western portion. Furthermore, it is suggested that salt water intrusion caused by the MRGO channel is short-lived. Table 49 depicts the mean salinity increases resulting from MRGO Channel construction.

Table 49 Mean Salinity Increases

	Before 1963	After 1963	Increase
Chef Menteur	3.2	5.8	2.6
Rigolets	3.8	5.8	2.0
North Side	2.6	3.9	1.3
Little Woods	3.2	4.8	1.6
Pass Manchac	1.2	1.4	0.2

There was not found to be a change in the variance in salinity pre- and post- construction. According to the study, freshwater discharge is the most important factor controlling lake salinities, the salinity signal has remained constant since the construction of the MRGO channel, and the channel is not responsible for the depletion of freshwater swamps and the retreat of lake shorelines. The study also finds that although the lake becomes fresh within a few days of opening the Bonnet Caree Spillway, long-term variations in salinity were not impacted by the spillway.

The study examines the effects of the MRGO channel on Lake Pontchartrain Basin salinities and oyster production by monitoring hydrological and biological parameters, pre- and post-construction. The study was conducted mainly by utilizing historical data and studies. The results maintain that the construction of the channel had a pronounced effect on salinities.

The report first gives a historical account of the MRGO channel, and also describes the following features of the study area: the areas considered to be affected by the channel, the historical impacts of Mississippi River alleviation regime, the tidal regime, the type of marsh, and past biological and hydrological studies completed in the study area by the Department of Wildlife and Fisheries. A list of the data sampling stations used in these studies is given in the report.

The conclusions maintain that there have been very pronounced salinity changes in the MRGO areas since the completion of the channel. In general, the report goes into detain in describing findings from historical studies. Some of the major assertions are that Fontenot and Rogillio (1971) and Rogillio (1975) reported an increase in Biloxi marsh salinities, there was a significant increase in salinity towards the northern end of the estuary, and the cypress swamp in the area between Lake Pontchartrain and Lake Maurepas was degenerated. The major cause of salinity increase was attributed to the saturation of the upper zone in the area just west of the MRGO.

2.6 BORROW PIT IMPACTS ASSESSMENT

A wave model of Lake Borgne was developed to determine the impact on wave climate due to the excavation of borrow pits proposed to be used for marsh and swamp restoration and nourishment. A summary of the results of this analysis is shown below. A detailed report of this analysis is included as Annex 2.

An unstructured SWAN model was chosen to provide high resolution wave calculations in the area of interest. For the with- and with-out borrow pit scenarios, simulations were performed for 24 wind directions, with 4 different wind speeds, and two water levels. This set of simulations is meant to provide an estimate of the impact for "normal" or "non-storm" conditions, where waves are locally generated by wind. A total of 120 simulations were performed for the with and without borrow pit scenarios. These scenarios are listed in Table 50.

Table 50 Borrow Pit Simulation Scenarios

Simulation Set	Wind Speed (mph)	24 Wind Directions (Nautical deg.)	Water Level (ft. NAVD88)	Number of Simulations
W20	20	[0:15:345]	0.92	24
W30	30	[0:15:345]	0.92	24
W40	40	[0:15:345]	0.92	24
W50	50	[0:15:345]	0.92	24
W30H	30	[0:15:345]	2.5	24

An additional ADCIRC+SWAN simulation of Hurricane Gustav was conducted to show the impact of the borrow pits for a recent high impact storm. Gustav has been chosen due to the unprecedented amount of observational data, and strong validation of the modeling. Peak water level, water velocity, significant wave height were determined for the with and without project conditions.

Very little difference in significant wave height and mean wave period was attributed to the proposed borrow pits along the Lake Borgne shoreline for the simulated "non-storm" conditions. We have calculated a 0 to 4% increase in significant wave height and a 0 to 3% increase in mean wave period along the shoreline. Within the borrow pits, there can be substantial increases: 3 to 39% increase to significant wave height and up to a 10% increase in mean wave period.

With the full-scale ADCIRC+SWAN simulation of hurricane Gustav, very little change in peak surge elevation was observed. The perturbation to the bottom bathymetry is not enough to significantly alter surge levels in the region of interest. However, the change in peak velocity surrounding the borrow pits is significant. We see a change of up to 0.7 ft/s at the Lake Borgne shoreline, which could be significant in terms of erosion and deposition patterns. The simulation of hurricane Gustav shows relatively large significant wave heights forming in Lake Borgne, at about 5.5 ft with a depth of about 18.0 ft. When we add the borrow pits and re-run the simulations, we see a relatively large increase in significant wave height within the borrow pit areas, at about 10 to 20%, or almost 1.0 ft higher. For this simulation, the larger waves that are developing within the borrow pit areas do not propagate far from the borrow pit areas, apparently due to depth limitation. The largest increase is about 0.2 ft, a 3% increase.

2.7 WATER QUALITY

An assessment of the potential water quality impacts of the proposed freshwater diversion was performed. The results of this assessment are included as Annex 3. An assessment of the existing water quality and potential impacts of the tentatively selected plan and other project alternatives is included in Sections 3.7 and 4.4 of the Environmental Impact Statement.

3.0 SURVEYS

Surveys for the shoreline protection, marsh creation, ridge restoration and diversion features have been taken for use in the design of the TSP. Existing survey information such as LIDAR and recent surveys taken for other projects in the area was also used.

Surveys for shoreline protection elements are approximately 500' in length and consist of a top of bank shot, water's edge shot, and 20' shot intervals to the required offshore distance. Periodic shots extend to the -8.0 contour (or to deepest available water) to determine the need for flotation access dredging. Surveys for marsh creation elements consist of transects along the marsh/swamp creation/restoration features in the TSP.

4.0 GEOTECHNICAL

4.1 GEOLOGY

4.1.1 Regional Geologic Setting

The geologic development of coastal Louisiana is closely related to shifting Mississippi River courses since the slowing of Holocene post-glacial sea level rise (Fisk, 1955; Frazier, 1967; and Coleman and Gagliano, 1964). The Mississippi River has changed its course several times during the last 7,000 years, leading to the development of the Mississippi River deltaic and chenier plains. The deltaic plain is composed of several major delta complexes, two of which (the Plaquemines/Modern and Atchafalaya) are still active (Fisk, 1955; Frazier, 1967; and Coleman and Gagliano, 1964). Dominant physiographic features of the deltaic plain include abandoned courses and distributaries and their associated natural levees, swamps, marsh, hundreds of lakes and bays, and barrier islands.

Recognition that the deltaic plain is formed by an orderly progression of events related to shifting Mississippi River courses led to the identification and characterization of the "delta cycle" (Scruton, 1960; Frazier, 1967). The "delta cycle" is a dynamic and cyclic process that alternates between periods of progradation and a subsequent transgression of deltaic headlands as deltas are abandoned and reworked by marine waters (Penland et al., 1988; Roberts, 1997). Throughout most of the last 7000 years the "delta cycle" has created more land by building deltas (regressive phase) than was destroyed by relative sea level rise and erosional processes (transgressive phase). Since the early 1900's man has had a major influence on many of the key elements controlling the "delta cycle". The Old River Control Structure has eliminated the delta switching process by maintaining the Mississippi River in its present course. Flood protection levees confine the flow of the Mississippi River eliminating overbank flooding and the nutrients and sediments that accompany these floods. Also, the suspended sediment load of the Mississippi River has declined by approximately 50 percent between the 1930 to 1952 period and the 1963 to 1982 period (Kesel, 1988). This decline has been attributed to bank stabilization by revetments, dams constructed on the Missouri River and other large tributaries, and other erosion control measures (Kesel, 1988).

As the natural delta-building process was restrained, relative sea level rise and erosion (transgressive processes) began to dominate the coastal landscape. Within this environment of diminished delta building, man began a period of extensive development in the coastal zone beginning in the early 1900's. Man-made alterations to the natural landscape such as dredging of navigation and access canals, construction of roads and levees within the wetlands, and drainage projects altered the natural hydrology compounding the negative effects of relative sea level rise and wetland erosion.

Coastal Louisiana is characterized by depositional environments and shoreline configurations representing various phases of the "delta cycle". Presently, most of the Louisiana coastal zone is in the marine-dominated, transgressive phase of the "delta cycle". Only the Modern and Atchafalaya Deltas are in the fluvially-dominated, regressive phase.

4.1.1.1 Geologic Setting of Study Area

The study area is part of the St. Bernard delta complex which began depositing deltaic sediments in the study area approximately 4000 years ago (Frazier, 1967). Prior to the initiation of delta growth, the entire study area was open water. Major distributaries of the St. Bernard Delta which contributed sediment to the study area were Bayous Bienvenue, LaLoutre, Sauvage, and Terre Aux Boeufs. Dominant physiographic features include Lakes Pontchartrain and Borgne, Bayous Sauvage and LaLoutre abandoned courses and their associated natural levees, the Chandeleur Island chain, swamp, marsh, and bays.

The entire St. Bernard delta is in the marine domininated/transgressive phase of the "delta cycle". During this phase, delta abandonment takes place and the processes of subsidence, erosion, and marine transgression dominate the landscape. The result is land loss, submergence, habitat change (driven mainly by elevation decrease and salinity increase), and an increase in water area. The St. Bernard delta complex has been in this marine dominated/transgressive phase since approximately 2000 years ago when the Bayou La Loutre course was abandoned, eliminating the major source of sediment for this delta (Frazier, 1967).

The surface and shallow subsurface is generally characterized by natural levee, swamp, and marsh deposits separated by abandoned distributaries. Natural levee deposits are generally characterized by medium to stiff clays and silt. Swamp and marsh deposits consist mainly of very soft clays and organic clays with peat. Natural levee, swamp, and marsh deposits are generally less than 20 feet thick. Beach deposits composed mainly of fine sand and shell are found at the surface along the Chandeleur Islands, a long arcuate-shaped barrier island chain located at the eastern boundary of the study area. Interdistributary deposits are located beneath natural levee, swamp and marsh deposits. Interdistributary deposits consist of very soft to medium clays with minor amounts of silt, shell fragments, and organics. Prodelta deposits, characterized by medium clays, underlie interdistributary deposits. Prodelta and interdistributary deposits vary widely in thickness throughout the study area, but generally thicken from west to east. Bay-sound deposits underlie the interdistributary and prodelta deposits. Bay-sound deposits are predominantly homogeneous fat clay with some lean clay and sand, with shells. Beneath the bay-sound deposits are Pleistocene deposits characterized by oxidized, stiff to very stiff clays and silty clays with areas of silty sand and sand, and concretions. Pleistocene deposits range from approximately -25 feet in elevation in Lake Maurepas to -150 feet in elevation in Chandeleur Sound.

4.1.1.2 Soils

The study area is characterized mainly by 4 soil types. The northwestern portion of the study area contains Maurepas and Barbary-Sharkey soils. Maurepas soils (Pt) are level, very poorly drained, organic soils that are mucky throughout. Barbary-Sharkey soils (OH,MH,CH,CL)are frequently flooded, clayey soils. The marshes in the central and eastern portions of the

study area generally contains Lafitte-Clovelly and Scatlake soils. Lafitte-Clovelly soils (Pt, MH, ML, CL, CH) are level, very poorly drained soils that have a thick or moderately thick, mucky surface layer and clayey underlying material, in brackish marshes. Scatlake soils (OH, MH) are level, very poorly drained soils that are clayey throughout, in saline marshes.

4.1.2 BORROW SOURCES

4.1.2.1 General

Approximately 150,350,000 cubic yards of dredged material will be required for swamp and marsh restoration features. The ridge restoration feature requires approximately 400,000 cubic yards of silty sand material.

4.1.2.2 Potential Borrow Sources

Potential borrow sources for swamp and marsh restoration features include the Mississippi River, the Inner Harbor Navigation Channel (IHNC) / Gulf Intracostal Waterway (GIWW), the former MRGO, Lake Pontchartrain, Lake Lery, Lake Borgne, Breton Sound, and offshore sources including the former MRGO offshore dredged material disposal site (ODMDS). Barges could be used to bring material from other locations in the region; however, the cost of transporting material by barge is generally much more expensive that pumping material via pipeline for a nearby source. Therefore, other sources of material from outside of the study area were not considered a practicable option due to the costs associated with obtaining, transporting, and stockpiling the needed volume of material.

4.1.2.3 Viable Borrow Sources

4.1.2.3.1 Mississippi River

The cost per unit associated with moving sediments from the river to restoration areas is significantly higher than using sediments from the nearest source. All things being equal, using river sediment for a restoration area with an average pumping distance of 20,000 feet (3.8 miles) would cost approximately 25 to 30 percent more than using material from Lake Borgne. However, all of the proposed marsh and swamp restoration features are significantly farther away from point bar deposits of river sediment than the nearest borrow source. Because dredging at depths greater than 70 feet necessitates costly modifications to dredging equipment, it is not feasible to dredge the nearest location on the river. It is possible to load dredged river sediment onto barges and transport it to a restoration site. However, this process costs at least twice as much as dredging and distributing via pipeline. Other factors influencing the feasibility of using Mississippi River sediment include considerations for laying pipe across levees and land, rather than water, and potential impacts to navigation.

Mississippi River sediment was determined to be feasible for construction of the proposed ridge restoration feature at Bayou La Loutre (BR1). Dredged material from between Miles 83 and 85 of the river would be transported approximately 52 miles via barge to this site.

4.1.2.3.2 Lake Lery

Lake Lery is in the vicinity of some of the proposed project features and could be a cost effective source of borrow. A number of other restoration plans currently under development are considering the use of Lake Lery as a borrow source. Because of the uncertainty associated with the use of Lake Lery as a borrow site in the future, Lake Lery is not considered to be the source of borrow materials for any of the TSP features.

4.1.2.3.3 Breton Sound

It is not practicable to use material from Breton Sound for TSP features because of distance.

4.1.2.3.4 GIWW/ Michoud Canal

Measure CM2 would utilize sediment from the adjacent GIWW channel between miles 66 and 60. The channel would be dredged to its authorized depth to provide material for this restoration feature. This feature would also utilize sediment from the Michoud Canal. The material needed to construct this feature would exhaust the supply from these sources for use elsewhere in the near-term.

4.1.2.3.5 MRGO ODMDS

This site is not a practicable site for marsh and swamp restoration features, because it is located over 30 miles away from the nearest restoration sites and 50 to 70 miles from other features.

4.1.2.3.6 MRGO Channel

Legally, it is unclear whether dredging the MRGO channel for non-navigation purposes is contrary to the Congressional intent. However, public preference for filling in the channel and restoring the area to historic conditions is documented in the Scoping Report for this study and numerous other public documents. The practicability and acceptability of the use of the MRGO must also be considered. The purpose of the study is to restore areas affected by the MRGO. The area that was dredged to create the channel is the most directly affected area. Dredging the channel would not restore the area to a more natural condition: it would alter conditions further. Therefore, dredging the channel would be contrary to the study purpose and is not a practicable alternative.

Degrading the MRGO spoil banks south of the Chalmette Loop Levee to marsh elevation was considered as a restoration feature that would also provide material. This alternative was rejected by the majority of the PDT, because the spoil bank provides more storm surge protection than it would as marsh.

4.1.2.3.7 Lake Pontchartrain

Lake Pontchartrain is a viable borrow source for features located on the East Orleans Landbridge. Like Lake Borgne, the portion of Lake Pontchartrain closest to these features is designated critical habitat for Gulf sturgeon. However, the sandy bottoms of Lake Pontchartrain were identified as preferred foraging habitat for this species. Therefore this borrow source was not considered further as other sources that are not preferred foraging habitat were identified closer to proposed restoration features.

4.1.2.3.8 Lake Borgne

Based on borrow borings taken at two potential borrow sites, the sediment in Lake Borgne can be characterized as primarily organic clay and clay with minor amounts of silt and fine sand. There are some concerns about the use of material dredged from the bottom of Lakes Borgne. Dredging in these areas may result in temporary adverse impacts to benthic resources, plankton, and other

marine wildlife. There are long-term concerns regarding potential impacts to Essential Fish Habitat and Gulf sturgeon critical habitat. Also, there may be unknown indirect impacts of deepening lake bottoms that have limited natural replenishment sources

4.1.2.4 Borrow from Critical Habitat

Lake Borgne water bottoms were determined to be the most cost-effective and feasible borrow source for construction of the remaining restoration features requiring sediment. To limit potential impacts to critical habitat, areas determined to have shell or hard bottoms were removed from consideration as borrow sites.

Borrow sites would be located a minimum of 3,000 feet from the Lake Borgne shoreline to minimize potential impacts to hydraulic conditions (e.g., wave climate), as well as to avoid existing oyster leases to the maximum extent practicable. Borrow material would be excavated with a hydraulic dredge and transported via pipeline to wetland creation and nourishment sites. Designated borrow areas are estimated larger than needed for each feature to ensure that adequate material is available in the event that environmental or cultural resources are discovered during construction that require avoidance. Borrow areas would be designed to minimize hypoxic (lack of dissolved oxygen) formation.

A phased implementation plan is proposed to remove borrow material from Lake Borgne. Borrow would be removed from the lake gradually over 10 implementation cycles that would allow no more than 2.5 percent of the lake bottom to be impacted during any given implementation cycle. The borrow plan limits dredging to one lobe of Lake Borgne per implementation cycle, therefore isolating increased turbidity to one lobe of the lake. As a new implementation cycle is being initiated, the borrow areas disturbed in the previous cycle for that lobe would have recovered sufficiently to support foraging and to allow benthic species to recover between implementation cycles.

To ensure that water quality is not sacrificed within Lake Borgne, MVN has included two years of water quality monitoring into the proposed action. Three test borrow pits would be constructed in implementation cycle number 1. The first pit would be constructed to 15' deep below the water surface, the second pit would be constructed to the proposed depth of 20' deep below the water surface, and a third pit would be constructed to approximately 25' deep below the water surface. After the borrow pits are constructed, monthly water quality monitoring would be used to determine if hypoxia formation was occurring within the borrow pits. Once the two years of monitoring is complete, the remaining borrow pits would be adjusted to ensure that hypoxia formation would not result within the remaining borrow pits. The MVN believes that the design of the borrow pits, coupled with the proposed water quality monitoring, would ensure that the proposed action would only temporarily impact the water quality of Lake Borgne.

4.2 GEOTECHNICAL DESIGN

4.2.1 General

Geotechnical investigations and analyses consider two distinct aspects of the MRGO Ecosystem Restoration Project, namely; the Shoreline Protection components and the Violet Diversion

components. In general, the field investigations and analyses completed for these separate components do not overlap, technically, and are discussed separately in the following paragraphs.

4.2.2 Design Reaches

Due to the vast project expanse, the project was initially divided into nine design reaches, with the Violet Diversion considered Reach 2. These reaches are shown on Figure ED-F-1 Sheet 2. These reaches were chosen based on location of existing borings, location of planned work, and sub-surface geology. Reaches 3 and 4 were added to the study after borings and CPTs were underway, therefore at this time no subsurface investigations have taken place in the area. A rock dike located between the two reaches located at Bayou Chevee and built under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) has been used in conjunction with the minimum hydraulic requirements to design the shoreline protection for Reaches 3 and 4. Further analysis determined that Reaches 5 and 6 were impractical based on costs associated with the amount of required rock. These rock dike features were replaced by three reaches of sheet pile wall along the eastern banks of the MRGO.

4.2.3 Field Investigations

4.2.3.1 Shoreline Protection Work

In conjunction with 19 historical borings, 23 undisturbed, 5-inch borings and 32 Cone Penetrometer Tests (CPTs) were completed in approximately two to three feet of water along the project shoreline as illustrated in Figure ED-F-2. Along the investigation alignments, undisturbed borings and CPT locations alternated at 2000-foot spacing and completed to sixty feet depth. Individual logs of undisturbed borings and CPT soundings are provided as Annex 4 and Annex 5, respectively. Ground surface cross sections at 1-mile intervals along the project shoreline provide topographic control.

4.2.3.2 Violet Diversion Channel

Subsurface investigations completed along the Violet Diversion alignment comprise ten 5-inch, undisturbed-type borings. The western half of the proposed Violet Diversion alignment consists of relatively large concrete structures such as concrete culverts; therefore, borings were completed to about 100-feet depth. The eastern half of the project is proposed as open channel with guide levees; therefore, borings were completed to about 60-feet depth.

This phase of geotechnical investigation was initiated in mid-April 2010 and completed in June 2010.. Analyses presented herein are based on historic borings completed in the general project area and will be reevaluated during additional studies to be done at a later date and documented in a separate report.

4.2.4 Laboratory Testing

Subsurface material collected from all undisturbed borings was submitted to a geotechnical laboratory for visual classification, index, strength and consolidation testing. All delivered samples

were visually classified at the laboratory. Visual classification logs are submitted to USACE for review and selection of specific samples for further testing. Select soil samples were identified by USACE for index testing consisting of: a) natural moisture and density; b) grain size analysis; c) Atterberg Limits; and, d) specific gravity. Select cohesive samples were assigned for strength testing, namely: a) unconfined compressive strength; and, b) unconsolidated, undrained triaxial compressive strength. Additional materials were assigned consolidation testing.

Annex 6 provides laboratory testing results and lab summary sheets, where available. Completed boring logs provided as Annex 4.

4.2.5 Geology

4.2.5.1 Shoreline Protection Geology

4.2.5.1.1 Rock Dike Section

Reaches 1, 8, and 9 are located in the eastern portion of the Mississippi River deltaic plain along the shoreline of Lake Borgne, north of the Mississippi River Gulf Outlet. This is an area of low relief averaging near sea level.

Based on subsurface boring information, the Reaches are characterized by a sequence of marsh, interdistributary, and Pleistocene deposits (see Figure ED-F-3). In addition, intradelta deposits are present in Reaches 1 and 9 and prodelta deposits are present in Reach 9. Marsh deposits generally consist of very soft to soft, organic clay with peat and lenses of silt. These deposits are approximately 10 to 15 feet thick. Interdistributary deposits underlie marsh deposits and consist of very soft to medium fat clay interbedded with occasional lenses of very soft to medium lean clay, silt, silty sand, and sand. These deposits are approximately 40 feet thick. Intradelta deposits are located within interdistributary deposits in Reaches 1 and 9. Intradelta deposits consist of silt and silty sand interbedded with occasional layers and lenses of sand and clay. Intradelta deposits are approximately 10 to 20 feet thick. Prodelta deposits underlie interdistributary deposits in Reach 9 and are composed predominantly of medium clay. Prodelta deposits were not fully penetrated by the borings, but are at least 10 feet thick. Pleistocene deposits were encountered in Reaches 1 and 8. They consist of interbedded, stiff to very stiff, oxidized, fat and lean clays, silt, silty sand, and sand. The surface of the Pleistocene deposits averages -50 feet in elevation and these deposits extend to an unknown depth.

4.2.5.1.2 Sheet Pile Wall Section

The MRGO Walls are located in the eastern portion of the Mississippi River deltaic plain along the northern shoreline of the MRGO. This is an area of low relief averaging near sea level.

Based on subsurface boring information, the Wall reach is characterized by a sequence of swamp/marsh, interdistributary, nearshore gulf, bay-sound, and Pleistocene deposits (see Figure ED-F-3). Swamp/marsh deposits generally consist of very soft to soft, organic clay with peat, wood, and lenses of silt. These deposits are approximately 15 feet thick. Interdistributary deposits underlie swamp/marsh deposits and consist of very soft to medium clays interbedded with occasional lenses

of silt, silty sand, and sand. These deposits are approximately 30 to 40 feet thick. Nearshore gulf deposits are located beneath interdistributary deposits and generally consist of silt and silty sand with shells. These deposits are approximately 5 feet thick. Bay-sound deposits are located below nearshore gulf deposits. They are approximately 15 feet thick and are composed of soft to medium clays with some silt and silty sand lenses, and shells. Pleistocene deposits underlie nearshore gulf deposits. They consist of interbedded, stiff to very stiff, oxidized, fat and lean clays, silt, silty sand, and sand. The surface of the Pleistocene deposits ranges from approximately -50 feet in elevation at the northern end of the reach to approximately -85 feet at the southern end. These deposits extend to an unknown depth.

4.2.6 Soil Design Parameters

4.2.6.1 General

Generalized soil profiles were developed for the design components based on laboratory geotechnical data specifically completed for this project, or in the absence of recent, site specific data, estimated from nearby borings. Values of soil cohesion and total unit weight assigned as material properties in the analyses are presented Figure ED-F-4. Development of material properties for the generalized soil profiles followed standard USACE procedures and guidelines.

4.2.6.2 Soil Conditions – Shoreline Protection Work

Review of completed subsurface investigations and laboratory testing reveal that all project reaches consist of very soft to medium fat clay interbedded with small silt layers to depth. Borings near the three sheet pile reaches also show isolated layers of very soft to medium fat clay interbedded with small silt layers and sand layers with large sand layers present at the bottom of all three reaches. For simplicity of design, the small silt and sand layers were excluded from the generalized soil profiles but the large sand layers remain included. Results of geotechnical investigations and laboratory testing are provided as Annex 6.

4.2.7 Stability Analyses

4.2.7.1 Shoreline Protection Work – Rock Dikes

Generalized cross-sections of the rock dike sections, suitable for wave energy dissipation, were provided by the Hydraulics Branch, MNV for evaluation with respect to slope stability. The Geotechnical Branch adjusts this generalized cross-section in order to provide an established reserve of safety with respect to slope stability. These typical sections are presented in Figure ED-F-5. Slope stability analyses were completed using the USACE Method of Planes and checked against a Spencer's method analyses. The resultant rock dike section consists of: a top elevation at 4.0-feet*, crown width of 5-feet, and side slopes of 1V:2H providing the required 1.30 factor of safety. Results of these analyses are presented in Figures ED-F-6, ED-F-8, ED-F-9, and Annex 7.

*All elevations in N.A.V.D 88

4.2.7.2 Shoreline Protection Work – Sheet Pile Walls

Slope stability of the sheet pile walls, with respect to overturning, was determined using an anchored bulkhead design option in the USACE program CWALSHT. A generalized soil profile was developed for the Reach 1 wall section and, due to the lack of site specific subsurface data, used in the stability analysis for all three sheet pile wall reaches. The results of the CWALSHT analyses are provided as Annex 8.

Topographic surveys in the area indicate a flood side elevation of -6.0-feet and a protected side elevation of 4.0-feet. The MRGO low water level of elevation -2.0-feet was used in the analyses.

Based on the estimated soils strength, surface water level and assumed construction loading conditions, the sheet pile needs to be driven to a minimum of elevation -40-feet The sheet pile wall will be further supported by a counterfeit frame with a horizontal wale bolted to vertical timber piles on the flood side and battered timber piles on the protected side. Additional pile analyses indicate the supporting timber piles need to be driven to elevation -70-feet.

4.2.7.3 Violet Diversion

Project planning to date indicates that the eastern half of the Violet Diversion channel will consist of a 375-foot bottom width open channel with guide levees between the Mississippi River levee and the 40-Arpent canal and through the Central Wetlands. Because the guide levees and channel are not directly related to flood protection, a minimum factor of safety of 1.30 was established for all water elevation (loading) conditions.

Based on hydraulic requirements and the results of slope stability analysis, the open channel between the Mississippi River levee and the 40-Arpent canal has a bottom elevation of -10.0-feet with 1V:3H side slopes ascending to the natural ground at elevation 2.0-feet for a total depth of 12-feet. Guide levees must be located a minimum of 20-feet from the channel and require 4H:1V side slopes and a maximum height of 6-feet above the ground surface. The guide levee crown width will be determined based on the amount of fill excavated from the channel.

The portion of the channel within the Central Wetlands has a bottom elevation of -11.7-feet with 1V:4H side slopes ascending to the natural ground at elevation 1.3-feet for a total depth of 13-feet. Based on the results of slope stability analysis, guide levees must be a minimum of 60-feet from the channel with 1V:3H side slopes and toe berms with 1V:4H slopes. The guide levee height above the ground surface should not exceed 6.5-feet.

Due to the remote location of the Central Wetlands portion of the proposed Violet Diversion, the guide levees will be used as haul roads during construction and require sand fill and 1,000 pounds/inch geotextile for stability. Results of these analyses are presented in Figures ED-F-7 and Annex 7.

4.2.8 Settlement

Immediate settlement of the rock dikes during construction is conservatively estimated to be 80-percent. Consolidation settlement has not been calculated at the time, but will be evaluated for the final project report.

4.2.9 Pile Foundations

4.2.9.1 Sheet Pile Wall

Based on the ease of use, relatively low cost and availability, timber piles with a 7-inch diameter tip and 12-inch diameter butt were chosen for the deep foundation components of the sheet pile wall system. Ultimate compression and tension pile capacities were developed based on nearby geotechnical borings, namely: LCAMN-2U, LCAMN-3U, LCAMN-4U, LCAMN-5U, LCAMN-10NU, LPV-145-52U, LPV-145-69U, LPV-145-70U and LPV-145-72U.

In determining pile capacities, overburden stress was limited to 3,500 psf. Soil unit weight and strength values were developed from the noted borings. Pile design soil coefficients used in developing ultimate pile capacities are presented in tables 35 and 36.

4.2.9.2 Violet Diversion

At this stage in the design process it was assumed that Violet Diversion Channel structures will be founded on 14-inch by 14-inch concrete piles. Accordingly, ultimate compression and tension pile capacities were developed based on database geotechnical borings. Three historic borings, R-85.5-LU, 1-AU-A, and LPV-145-10TU were used to develop design strengths at structure locations at the Mississippi River, 40-Arpent Canal and Mississippi River Gulf Outlet sites, respectively.

In determining pile capacities, overburden stress was limited to 3,500 psf. Soil unit weight and strength values were developed from the noted borings. Pile design soil coefficients used in developing ultimate pile capacities are presented in tables 51 and 52.

Table 51 Undrained Conditions (Q-case)

Soil Type	Friction Angle (phi)	Kc	Kt	Nc	Nq
Clay	0	1	1	9	1
Silt	15	1	0.5	12.9	4.4
Sand	30	1.25	0.7	0	22.5

Table 52 Drained Conditions (S-case)					
Soil Type	Friction Angle (phi)	Kc	Kt	Nc	Nq
Clay	23	1	0.7	0	10
Silt	28	1	0.5	0	19.5
Sand	30	1.25	0.7	0	22.5

Results of design pile load versus tip elevation are illustrated in Figure ED-F-10 and computer software output files are presented as Annex 9. At this stage of project development, a factor of safety of three should be used in determining appropriate pile lengths for both compression and tension piles.

During construction, test piles will be loaded for determining final recommended capacities and lengths for project service piles. The information presented here is preliminary and will be further refined upon completion of the site specific subsurface geotechnical investigations and further analyses.

5.0 DESIGN

5.1 MARSH CREATION/NOURISHMENT, SWAMP CREATION AND RIDGE RESTORATION

5.1.1 General

Marsh restoration involves the placement of dredged material in shallow open water areas and extensively broken marsh to raise the area to marsh elevation. Following compaction and dewatering, the area is planted with marsh vegetation. Retention dikes and/or closures may be used to contain material within the restoration area. Dredged material is allowed to overflow to nourish and consolidate existing marsh vegetation within the restoration area.

Marsh nourishment refers to the placement of a thin layer of dredged material into broken marsh. The placement of this material facilitates the recruitment and consolidation of marsh vegetation after dewatering. No plantings are associated with marsh nourishment features.

Swamp restoration involves the placement of dredged material, similar to marsh restoration described above. Swamp restoration features would have a higher elevation than marsh restoration features to support cypress trees.

Swamp nourishment is proposed for areas that are currently at marsh elevation, and consists of placing a thin layer of dredged material to nourish the area, raise elevation, and encourage the recruitment of cypress-tupelo community species.

Historically, ridges were formed as natural levees of major and minor distributary channels that diverge from larger distributaries as they trend toward the outer coast. Ridge restoration would consist of the placement of dredged material to a height suitable for upland habitat.

5.2 MARSH CREATION/NOURISHMENT

5.2.1 General

Due to the overall magnitude of the study area, funding was provided to obtain what was determined to be the minimum cross section and profile data that would be needed to reasonably scope out and quantify the work required for the numerous marsh and swamp features that were to be assessed under this study. Due to limited funds as well as time, geotechnical investigations of the marsh and swamp features, as well as the borrow pit locations, were not performed during this study phase. Instead, it was determined that these efforts would be performed during the PED phase. In the meantime, existing data would be used, as well as knowledge of the project area that had been obtained during prior O&M dredging of the MRGO, performed prior the de-authorization of the MRGO Reach 2 (reach southward from the intersection of the MRGO with the GIWW at approximate Mile 60 and in the vicinity of Michoud) in 2008.

5.2.2 Field Data and Design Assumptions

Surveys of the numerous marsh and swamp restoration and nourishment features, as well as the Bayou La Loutre ridge, were performed in 2010 and 2011. These surveys, consisting of cross sections and profiles, were used to determine the average elevations of the existing marsh and swamp, as well as the areas to be occupied by dredged fill for restoration and nourishment. In conjunction with these surveys, aerial photography was used to determine/verify the feature boundaries that had been proposed by the PDT and determine the acres and cubic yards of dredge fill that would be required to construct each feature. Profiles were taken at select locations where retention and closure features would be required in order to assure that the dredge material was retained within the feature boundaries. Perimeter retention features, consisting of earthen retention dikes, as well as earthen and vinyl sheetpile closures were estimated and quantified based off of elevations obtained from the surveys. In addition to these perimeter retention features, some project features also included the construction of internal earthen weirs which were used to maximize retention of dredge solids while also allowing for the finer sediments to flow over the weirs and nourish the adjacent marsh/wetlands. In areas where depths were determined to warrant non-earthen closures due to potential retention and constructability issues, vinyl sheetpile closures were planned, with timber piles spaced 6' to 8' along the closures also included. Dependent upon the existing depth at each closure location, an embedment depth factor of between 3 to 4 times the exposed piles was used in determining the required vinyl and timber pile lengths.

The marsh and swamp features were designed based off of the data obtained from the surveys mentioned in the above paragraph, as well as historical dredge fill elevations that were used during past maintenance dredging events along the MRGO prior to the de-authorization of Reach 2 in 2008. In the past, a maximum slurry elevation of +4.0' Mean Low Gulf (MLG) was successfully used in the creation of marsh along both the north and south banks of the MRGO channel. For this study, all survey data was referenced to NAVD88 (2004.65) datum. Thus, in order to properly quantify the cubic yards and borrow required for this study, a correlation between the old vertical datum of MLG and NAVD88 (2004.65) was required. The following was derived from information received from CEMVN's Survey Section and used to determine the relationship between MLG and NAVD88 in the MRGO - Lake Borgne area. This information was based off of gage information provided by the District's Operations Division/ Tech Support Branch which is in charge of the District's channel condition surveys.

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a. From Ops Survey File: mi020311.raw

Gage used: 2.14
2/3/2011. MICHOUD.
Seas: Calm.
BYBIENVENUE E STAFF:
0.15 NAVD +1.21 (NAVD88 TO NGVD) +0.78 (NGVD TO MLG) = 2.14 MLG

Based off of the above, this states that at the Bayou Bienvenue Flood Gate,

0.0 MLG = -1.99' NAVD88

=> +4.0' MLG (old MRGO Slurry Elevation used for Marsh Creation) = +4.0-1.99' NAVD88

= +2.01' NAVD88; say +2.0' NAVD88

b. From Ops Survey File: am071910.raw

Gage used: 2.45
7/19/2010. MRGO SHEET 1.
Seas: Calm.
GAUGE = 2.45 MLG
Gauge =0.60(NAVD88) + 1.05(conversion) = 1.65(NGVD29) +.78(conversion) = 2.43 MLG @ IHNC LOCK

Based on the above, this states that at the IHNC,

0.0 MLG = -1.83' NAVD88

=> +4.0' MLG (old MRGO Slurry Elev used for Marsh Creation) = +4.0-1.83' NAVD88

= +2.17' NAVD88; say +2.2' NAVD88

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In order to account for potential subsidence, as well as potential future epoch adjustments between now and construction, an elevation of +2.5' NAVD88 was used for the maximum slurry elevation for the MRGO marsh creation/restoration features, and +3.0' NAVD88 for the swamp creation/restoration features. This half-foot difference in elevation between the marsh and swamp restoration features was provided to the New Orleans District's Engineering Division by the environmental PDT for use in developing quantities.

Retention features will be required for each feature and will vary from features requiring 100% containment to others requiring partial containment. As stated earlier, retention features will consist of earthen dikes and closures, as well as non-earthen features such as vinyl sheetpile, supported with timber piles. Borrow for earthen dikes and closures will be obtained from within the area to be occupied by the dredged material, or in the case of earthen closures from within the adjacent waterway. As borings of the wetland restoration and nourishment sites were not obtained during this study phase, borrow to fill ratios varying from 2:1 to 3:1 were used in order to estimate the amount of borrow required for the earthen retention features. Also, for earthen dikes, side slopes of 1V on 3H were used, and for earthen closures 1V on 4H side slopes were used in determining the borrow quantities for these earthen features. These slopes are in line with those that could be anticipated within the MRGO area based off of the geology of the project area as well as prior dredging work performed in this area.

For project features calling for marsh nourishment, a 1' to 1.25' initial layer of fill, to consolidate to between 0.75' to 1.0', was used in determining the amount of borrow required for marsh and swamp nourishment. This is in line with criteria that had previously been approved by various

agencies and successfully implemented for marsh nourishment performed during previous O&M dredging events along the MRGO.

Also, when determining the amount of borrow (CYS) required to construct each feature, initial consolidation of the dredge fill was accounted for. This initial consolidation would occur within the first 6-12 months after pumping had ceased within the restoration sites. For the swamp and marsh creation/restoration features, 1-foot of initial dewatering/consolidation was accounted for when computing the CYS required, and ¼ to ½ foot used for the marsh and swamp nourishment features. Below are some of the factors considered in determining the amount of borrow material (CYS as well as acreage) required for each project feature.

- Average elevation within each project feature - based off of surveys
- Design fill elevations for marsh and swamp restoration and nourishment features - (previously addressed in this section)
- Cubic yards of borrow required - based off of surveys
- Average lake bottom elevation – based off of NOAA Charts
- Maximum borrow depth below lake bottom (12' except for test pits for Features LM 1 and LM 2)
- Borrow acres required, using a 2:1 Borrow to Fill ratio, and accounting for 1V on 3H side slopes
- Other sources of borrow to be used: Mississippi River, between Miles 83 and 85 along the right descending bank, and the GIWW/ MRGO Reach 1 (Miles 66 to 60) and the Michoud Canal project

It should be noted that a 2:1 borrow to fill ratio was used to determine the potential acres of borrow required within Lake Borgne. This 2:1 factor was used due to the fact that cultural surveys of the lake borrow sites have not yet been performed. These surveys will be performed during the PED phase. This ratio will account for any potential anomalies and pipelines not listed in current pipeline databases, and which would have to be avoided, as well as allowing for a (+)vertical working tolerance to assure that no dredging is performed below the specified/allowable borrow depths for each feature. Also, based upon a few isolated borings that were taken of four (4) potential borrow pits in Lake Borgne (1 pit in the northwest lobe and 3 in the southeast lobe) back in 2007 for the MRGO 3rd and 4th Supplemental work, the material consisted predominately of soft clays with some thin, isolated, interspersed layers of sands/silts. Additional borings will be required to verify the classification of the material within the borrow pits proposed within Lake Borgne.

5.2.3 Borrow

A borrow plan was developed for the TSP identifying borrow areas for each of the features. Borrow locations are shown on plate C-01 and described for each of the features in the descriptions below. Features LM 1, LM 2 and LM 4, which all call for borrow to come from Lake Borgne, will be

constructed initially. The borrow pits for each of these features will be dredged to different depths and monitored for a two (2) year period in order to determine the maximum allowable borrow depth for the remaining marsh and swamp features. Additional details on the borrow plan for Lake Borgne can be found in Section 4.1.2.4 of this appendix.

As cultural surveys, including magnetometer surveys, of the borrow sites have yet to be performed, a 2:1 borrow to fill ratio was used for this study in determining the acres of borrow that could possibly be required. This ratio also assures that the allowable borrow depth will not be exceeded. (I.e. a vertical working tolerance) It also accounts for other unknowns such as the existence of unknown anomalies (i.e. pipelines, sunken vessels, reefs, etc) that would have to be avoided. Due to these unknowns, the potential acres of borrow to be cleared within Lake Borgne are addressed in Table 53. These acreages also account for side slopes of 1V on 3H and a maximum borrow depth below the lake bottom of 12', except for features LM 1 and LM 2 where the maximum borrow depths would be approx 17' below the midline (25' below the water's surface) for LM 1 and approx 6.5' below the midline (15' below the water's surface) for LM 2.

Table 53 Potential Acres of Borrow Within Lake Borgne

FEATURE LABELS	**POTENTIAL ACRES OF BORROW FROM LAKE BORGNE** (2:1 BORROW TO FILL TO ACCOUNT FOR UNKNOWN P/L'S, CULTURAL FINDS,ETC)
LM 1	1075
LM 4	132
LM 2	860
CM 2	503
TM 1	396
TM 2	930
HM 1	469
M 5	322
M 8	385
EM 1	857
M 7	180
BM 1	1160
LM 3	669
TM 7	1306
TM 8	1066
CM 3	174
CM 4	68
EM 2	142
EM 3	438
EM 4	972

FEATURE LABELS	POTENTIAL ACRES OF BORROW FROM LAKE BORGNE (2:1 BORROW TO FILL TO ACCOUNT FOR UNKNOWN P/L'S, CULTURAL FINDS,ETC)
CC1	637
CC 2	185
CC 3	396
CC 4 SITE 2	522
CC 4 SITE 3	238
CC 4 SITE 4	78
CC 5	825
CC 6	553

5.2.4 EM 1

Feature EM 1 is a marsh creation and nourishment feature located in the New Orleans East along the south shore of Lake Pontchartrain and bounded by Chef Menteur Highway, Highway 11, Lake Pontchartrain and Chef Pass (see plate C-02).

The project will consist of converting approximately 1,175 acres of open water to marsh habitat, along with the nourishment of approximately 2830 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the north/west lobe of Lake Borgne, and located immediately west of the mouth of Chef Pass. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Approximately 8.1 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature. Based off of surveys obtained in 2010, the average elevation within the restoration sites is approx -2.0' NAVD88. The material may be transported directly to the site via pipeline, or may be placed within barges that would then be transported to the south shore adjacent to the site. The barges would then be pumped out and the material placed within marsh creation and nourishment areas. For this report, direct placement via pipeline was used for costs analysis. Access to the marsh creation and nourishment site will be via the Chef Pass, leading to the south shore of Lake Pontchartrain. The dredge material will be placed to a maximum slurry elevation of +2.5' NAVD88, and dredge effluent will be returned to canal and bayou, immediately adjacent to and west and south of the marsh creation and nourishment site, via spill box weirs.

Approximately 44,800' of earthen retention dikes will be constructed from adjacent borrow to an elevation of approx +4.5' NAVD88 and 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

In addition, approximately 77,000' of interior earthen weirs will be constructed in order to assist in maximizing development of the marsh creation sites. The weirs will be constructed from adjacent borrow and will be constructed to an elevation of +1.5' to +2.0' NAVD88. The weirs will be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the weirs and the top of cut of the adjacent borrow pits.

In addition to the earthen dikes and weirs, it is estimated that three (3) closures, totaling approximately 3,820' in length, will be required in order to retain the dredge slurry. The closures would consist of vinyl sheet pile, sheets ranging from 30' to 40' in length, along with timber piles, ranging from 40' to 50' in length, spaced approximately 6' on center.

Surveys of the proposed restoration feature were taken in 2010 and are depicted in plan view on plate C-02. Based off of these surveys, the existing elevation within the marsh creation site is an average of approx -2.0' NAVD88 and the adjacent marsh is at approximate average elevation of +0.5 NAVD88'.

Ingress and egress to the site would be via Chef Pass, Lake Pontchartrain, Lake Borgne and the GIWW, as well as Federal, State and local highways.

5.2.5 EM 2

Feature EM 2 calls for marsh nourishment of Hog Island, located west of Hwy 90, and bounded by the Pearl River – East and West Mouth, Little Lake, and the Rigolets (see plate C-03).

The project will consist of nourishing approximately 800 acres of marsh. At the same time, approximately 295 acres of adjacent waters will be shallowed during this marsh nourishment feature which will be accomplished through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from Lake Borgne and the proposed borrow site is located immediately south of the mouth of the Rigolets. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. The material will be transported directly to the site via pipeline and placed within the marsh nourishment site. Access to the marsh nourishment site will be via the Rigolets, and both the East and West Mouth of the Pearl River. Approximately 1.3 million gross cubic yards of borrow will be required for this marsh nourishment feature. The dredge material will be placed to a maximum slurry elevation of approximately +2.0' NAVD88 in order for the initial fill placed over the existing marsh not to exceed 1.25' and to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work. Dredge effluent waters will be returned to adjacent waterways via spill box weirs that will be installed in the retention dike system.

Approximately 37,150' of earthen retention dikes will be constructed from adjacent borrow (either from within the marsh nourishment site or adjacent waterways) and 2.0' of freeboard will be maintained at all times during pumping operations. The earthen dikes will also be constructed to an approximate minimum 5.0' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the dikes and the top of cut of the adjacent borrow pits if borrow is obtained from within the site.

Surveys of the proposed restoration feature were taken in 2010 and are depicted in plan view on plate C-03. Based off of these surveys, the existing elevation of the marsh within the marsh nourishment site ranges from 0.0' to +2.0' NAVD88.

Ingress and egress to the site would be via access corridors depicted in the plan view, the GIWW, the Rigolets, West and East Mouth of Pearl River, Lake Borgne, as well as Federal, State and local highways.

5.2.6 EM 3

Feature EM 3 is a marsh creation and nourishment feature, located in the New Orleans East along the north shore of Lake Pontchartrain and west of Hwy 90 (see plates C-04 and 04A).

The project will consist of converting approximately 861 acres of open water to marsh habitat, along with the nourishment of approximately 180 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from Lake Borgne and the borrow site is located immediately south of the mouth of the Rigolets. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. The material will be transported directly to the site via pipeline and the material placed within marsh creation and nourishment areas. Access to the marsh creation and nourishment site will be via the Rigolets, leading to the north shore of Lake Pontchartrain, thence via a 300' access corridor leading from the lake shoreline to the marsh creation site. Approximately 4.1 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature. Based off of surveys obtained in 2010, the average elevation within the restoration sites is approx -1.75' NAVD88. The dredge material will be placed to a maximum slurry elevation of +2.5' NAVD88, and dredge effluent will be returned to Salt Bayou via spill box weirs.

Approximately 23,300' of earthen retention dikes will be constructed from adjacent borrow to an elevation of approx +4.5' NAVD88 and 2.0' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an approximate minimum 5.0' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

In addition, approximately 52,900' of interior earthen weirs will be constructed in order to assist in maximizing development of the marsh creation sites. The weirs will be constructed from adjacent borrow and will be constructed to an elevation of +1.5' to +2.0' NAVD88. The weirs will be constructed to an approximate minimum 5.0' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the weirs and the top of cut of the adjacent borrow pits.

It is noted that the project feature area also includes three (3) areas north of Hwy 433 and located between the 37, 59, 93 and 354 acre sites. These sites have been selected for enhancement under the "HSDRRS - Lake Pontchartrain and Vicinity Mitigation, Fritchie Restoration" project and are to be avoided and not impacted at any time.

Surveys of the proposed restoration feature were taken in 2010 and are depicted in plan view on plates C-04 and 04A. Based off of these surveys, the existing elevation within the marsh creation site is an average of approx -1.75' NAVD88 and the adjacent marsh is an approximate average elevation of +0.5 NAVD88'.

Ingress and egress to the site would be via access corridors depicted in the plan view, the GIWW, Lake Borgne and the Rigolets, as well as Federal, State and local highways.

5.2.7 EM 4

Feature EM 4 is a marsh creation and nourishment feature, located in the New Orleans East along the north shore of Lake Pontchartrain and immediately east of Hwy 90 (see plates C-05 and 05A).

The project will consist of converting approximately 2,625 acres of open water to marsh habitat, along with the nourishment of approximately 1,455 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from Lake Borgne and the proposed borrow site is located immediately south of the mouth of the Rigolets. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. The material will be transported directly to the site via pipeline and the material placed within marsh creation and nourishment areas. Access to the marsh creation and nourishment site will be via the Rigolets, leading to the north shore of Lake Pontchartrain, thence via a 300' access corridor leading from the lake shoreline to the marsh creation site. Approximately 9.2 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature. Based off of surveys obtained in 2010, the average elevation within the restoration sites is approx -1.5' NAVD88. The dredge material will be placed to a maximum slurry elevation of +2.5' NAVD88, and dredge effluent will be returned to adjacent waterways, including the Rigolets, via spill box weirs.

Approximately 70,300' of earthen retention dikes will be constructed from adjacent borrow to an elevation of approx +4.5' NAVD88 and 2.0' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an approximate minimum 5.0' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

In addition, approximately 49,400' of interior earthen weirs will be constructed in order to assist in maximizing development of the marsh creation sites. The weirs will be constructed from adjacent borrow and will be constructed to an elevation of +1.5' to +2.0' NAVD88. The weirs will be constructed to an approximate minimum 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the weirs and the top of cut of the adjacent borrow pits.

Surveys of the proposed restoration feature were taken in 2010 and are depicted in plan view on plates C-05 and 05A. Based off of these surveys, the existing elevation within the marsh creation site

is an average of approx -1.5' NAVD88 and the adjacent marsh is an approximate average elevation of +0.75 NAVD88'.

Ingress and egress to the site would be via access corridors depicted in the plan view, the GIWW, Lake Borgne and the Rigolets, as well as Federal, State and local highways.

5.2.8 BM 1

Feature BM 1 calls for marsh nourishment within the Biloxi Marshes immediately adjacent to the east shoreline of Lake Borgne (see plate C-09).

The project will consist of nourishing approximately 8,000 acres of marsh. At the same time, approximately 295 acres of adjacent waters will be shallowed during this marsh creation feature which will be accomplished through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Approximately 11 million gross cubic yards of borrow will be required for this marsh nourishment feature. The material will be borrowed from the south/east lobe of Lake Borgne, immediately west of the marsh nourishment site. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. The material will be transported directly to the site via pipeline and placed within the marsh nourishment site. Access to the marsh nourishment site will be via Lake Borgne and excavation for access to the site will not be required. The dredge material will be placed to a maximum slurry elevation of approximately +2.0' NAVD88 in order for the initial fill placed over the existing marsh not to exceed 1.25' and to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

A rear earthen weir, approximately 94,800' in length, will be constructed from adjacent borrow and essentially parallel the Lake Borgne shoreline. The weir will be constructed from adjacent borrow and will be constructed to an elevation of +1.5' to +2.0' NAVD88. The earthen weir will also be constructed to a minimum 5.0' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the weir and the top of cut of the adjacent borrow pit.

Approximately 47,600' of earthen retention dikes will also be constructed adjacent to the Lake Borgne shoreline from adjacent borrow to an elevation of approx +3.0' to +3.5' NAVD88 and 2.0' of freeboard will be maintained at all times during pumping operations. In addition, approximately 32,800' of earthen retention dikes will also be required in order to prevent impacts to Bayou St. Malo. These dikes will be constructed from adjacent borrow to an elevation of approx +3.0' to +3.5' NAVD88 and 2.0' of freeboard will be maintained at all times during pumping operations. All earthen dikes will be constructed to an approximate minimum 5.0' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and weirs and the top of cut of the adjacent borrow pits.

It is also noted that borrow for this feature will take place in the south/east lobe of Lake Borgne and within an area that was used as an anti-aircraft training center (AATC), located in Shell Beach, LA in the early to mid 1940's. As a result, it is possible that unexploded ordinances (UXOs) could be encountered when borrowing within the south/ east lobe of Lake Borgne. The cone defining the zone

within which these UXOs could potentially be located is depicted on the feature plate. Therefore, cutterhead dredges operating in this area will need to be equipped with approximately 2" x 2" intake screens and outfall/discharge baskets with screens small enough to catch any small munitions that might pass through the dredged prior to being deposited within the restoration area.

Surveys of the proposed restoration feature were taken in 2010 and are depicted in plan view on plate C-09. Based off of these surveys, the existing elevation within the marsh nourishment site is an average of approx +0.5' NAVD88, the average elevation at the location of the proposed Lake Borgne retention dike is approx 0.0' NAVD88, and the average elevations at the locations of the proposed Bayou St. Malo dike and rear earthen weir are approximately +0.5' NAVD88.

Ingress and egress to the site would be via access corridors depicted in the plan view, as well as the GIWW and Lake Borgne.

5.2.9 BR 1

Feature BR 1 calls for restoration of a portion of the Bayou La Loutre ridge. The area designated for ridge restoration is located immediately north of the MRGO, where Bayou La Loutre intersects the MRGO, and extends downstream along the south bank of Bayou La Loutre for a distance of approximately 17,500' (see plates C-12 and 12A).

The project will consist of restoring the ridge to an initial elevation of approximate +8.0' NAVD88 in order to achieve a desired final design elevation after consolidation of +6.0' NAVD88. The ridge would have a crown width of 25' and side slopes of 1V on 8H. While the base width of the ridge will vary with the topography, the average base width would be approximate 137', based off of an average existing ground elevation of +1.0' NAVD88 obtained from surveys taken in 2010. Surveys of the proposed restoration feature are depicted in plan view on plate C-12. A 50' access corridor along the backside would be made available for equipment necessary for hauling, moving and shaping of the material being placed at the site for restoration of the ridge.

The ridge would be constructed of silty sand which could come from the Mississippi River, the MRGO ODMDS site, or the Bonnet Carre spillway. For this report, borrow from the Mississippi River was used and borrow was figured to be obtained between river miles 83.0 and 85.0, along the right descending bank in order to minimize impacts to Mississippi River traffic. The excavated material would be loaded on barges and thence transported to the ridge restoration site via the IHNC, MRGO/GIWW, Chef Pass, Lake Borgne, Martello Channel and the MRGO downstream to Bayou La Loutre. This would be an approximate 54 mile transit (one way). This one-way transit distance is in line with the distance that would have to be transited if the material were borrowed from the MRGO ODMDS site and transported by barges through Breton Sound to Bayou La Loutre. Approximately 400, 000 cubic yards of silty sand would be required.

Access along Bayou La Loutre may require excavation. If excavation is required, excavation for floatation access would be allowed to elevation -6.0' NAVD88 by a 60' width and the permissible excavation is defined by the theoretical section depicted on the plate C-12. Material excavated for floatation would be placed within the footprint of the proposed ridge restoration work. Access to

Bayou La Loutre is available via the GIWW, Breton Sound, Lake Borgne, the MRGO, and other navigable waterways, as well as state and local highways.

5.2.10 CC 1

Feature CC 1 is a swamp restoration feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA. The project area is immediately adjacent to the 40 Arpent levee and Bayou Dupre/Violet Diversion channel (see plates C-13 and C-13A).

The project will consist of restoring approximately 1,020 acres of open water to an elevation conducive to swamp creation/restoration, along with the nourishment of approximately 935 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the north/west lobe of Lake Borgne and the proposed borrow site is located between Bayou Bienvenue and the Bayou Dupre Cut/Martello Channel. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Approximately 6 million gross cubic yards of borrow will be required for this swamp restoration and nourishment feature. Based off of surveys obtained in 2010, the average elevation within the restoration sites is approx -0.5' NAVD88. The material will be transported directly to the swamp restoration and nourishment site via pipeline. Access for the dredge pipeline from Lake Borgne will be via Dupre Cut/Martello Channel, the MRGO channel and Bayou Dupre. The dredge material will be placed to a maximum slurry elevation of +3.0' NAVD88 within the swamp restoration area, and dredge effluent waters will be returned to either adjacent marshes for nourishment, and/or Bayou Dupre. For nourishment of the 935 acres of adjacent wetlands, dredge material will be placed to a maximum slurry elevation of approximately +2.0' NAVD88 in order for the initial fill placed over the existing wetlands not to exceed 1.25' and to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

Approximately 35,700' of earthen retention dikes will be constructed from adjacent borrow and 2.0' of freeboard will be maintained at all times during pumping operations. This includes retention dikes that will be required to prevent dredged material from entering Bayou Chaperon which is considered a scenic stream and which is to not be impacted. The earthen dikes will be constructed to an elevation of +5.0' NAVD88, approximate 5.0' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. Based off of surveys obtained in 2010, the average elevation at the base of the retention dikes is approximately -1.0' NAVD88.

Based off of the 2010 survey data, it is estimated that three (3) closures, totaling approximately 1,345' in length, will be required in order to retain the dredge slurry. Two (2) earthen closures will be required along the west bank of Bayou Dupre and one (1) towards the northwest corner of the restoration feature and west of Bayou Chaperon. The earthen closures will be constructed from adjacent borrow and to an elevation of +5.0' NAVD88, approximate minimum 5.0' crown width, slopes no steeper than 1V on 4H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen closures and the top of cut of the adjacent borrow. Average elevation at these earthen closure sites is approximately -1.5' NAVD88.

In addition to the three (3) earthen closures, one (1) closure, consisting of vinyl sheet pile approx 30' in length, will be required at one (1) location along Bayou Dupre. The sheetpile closure be driven to an elevation of +4.0' NAVD88, will span approximately 200' and will also consist of timber piles, approximately 40' in length and spaced approximately 6' on center. Average elevation at the sheetpile closure location is approximately -1.5' NAVD88. This closure will be removed upon completion of the contract, or as soon as possible in order to assure that dredged material will not exit the restoration site.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, and Bayou Dupre, as well as Federal, State and local highways.

5.2.11 CC 2

Feature CC 2 is a swamp restoration feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA. The project area is immediately adjacent to Feature CC 1, the back dike canal adjacent to the MRGO south bank disposal area, and Bayou Dupre/Violet Diversion channel (see plates C-14 and 14A).

The project will consist of restoring approximately 250 acres of open water to an elevation conducive to swamp creation/restoration, along with the nourishment of approximately 250 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the north/west lobe of Lake Borgne and the proposed borrow site is located north of the Dupre Cut/Martello Channel. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Approximately 1.7 million gross cubic yards of borrow will be required for this swamp restoration and nourishment feature. Based off of surveys obtained in 2010, the average elevation within the restoration sites is approx -1.25' NAVD88. The material will be transported directly to the swamp restoration and nourishment site via pipeline. Access for the dredge pipeline from Lake Borgne will be via the Dupre Cut/Martello Channel, the MRGO channel, a 300' access corridor across the south bank disposal area, the back dike canal, and a 300 access corridor leading from the back dike canal to Feature CC 2. The dredge material will be placed to a maximum slurry elevation of +3.0' NAVD88 within the swamp restoration area, and dredge effluent waters will be returned to either adjacent marshes for nourishment, and/or Bayou Dupre. For nourishment of the adjacent 250 acres of wetlands, dredge material will be placed to a maximum slurry elevation of approximately +2.0' NAVD88 in order for the initial fill placed over the existing wetlands not to exceed 1.25' and to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

Approximately 11,500 of earthen retention dike will be constructed from adjacent borrow and 2.0' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an elevation of +5.0' NAVD88, approximate 5.0' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. Based off of surveys obtained in 2010, the average elevation at the base of the retention dike is approximately -1.5' NAVD88.

In order to assist in the development of the swamp restoration site, approximately 7,300' of interior earthen weirs will be constructed. The weirs will be constructed from adjacent borrow and will be constructed to an elevation of +1.5' to +2.0' NAVD88. The earthen weirs will also be constructed to a minimum 5.0' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the weir and the top of cut of the adjacent borrow pits. Based off of surveys obtained in 2010, the average elevation at the base of the weirs is approximately -1.25' NAVD88.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, the back dike canal, and Bayou Dupre, as well as Federal, State and local highways.

5.2.12 CC 3

Feature CC 3 is a swamp restoration feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA. The project area is immediately adjacent to the 40 Arpent levee and Paris Road (see plates C-15 and 15A).

The project will consist of restoring approximately 370 acres of open water to an elevation conducive to swamp creation/restoration, along with the nourishment of approximately 790 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the north/west lobe of Lake Borgne and the proposed borrow site is located between Bayou Bienvenue and the Bayou Dupre Cut/Martello Channel. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Approximately 3.7 million gross cubic yards of borrow will be required for this swamp restoration and nourishment feature. Based off of surveys obtained in 2010, the average elevation within the restoration sites is approximately -2.0' NAVD88. The material will be transported directly to the swamp restoration and nourishment sites via pipeline. Access for the dredge pipeline from Lake Borgne will be via a 300' access corridor across the MRGO north bank, the MRGO channel, and a 300' access corridor leading from the MRGO and crossing the south bank disposal area, the back dike canal and Feature CM1. The dredge material will be placed to a maximum slurry elevation of +3.0' NAVD88 within the swamp restoration areas, and dredge effluent waters will be returned to either adjacent marshes for nourishment. For nourishment of the adjacent 790 acres of wetlands, dredge material will be placed to a maximum slurry elevation of approximately +2.0' NAVD88 in order for the initial fill placed over the existing wetlands not to exceed 1.25' and to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

Approximately 20,400' of earthen retention dikes and 8,900' of earthen closures (6) will be constructed. Based off of surveys obtained in 2010, the average elevation at the base of the retention dikes is approximately 0.0' NAVD88 and approximately -2.0' NAVD88 at the six (6) closure locations. The earthen dikes and closures will also be constructed to an elevation of +5.0' NAVD88, approximate 5.0' crown width, slopes no steeper than 1V on 3H (for dikes) and 1V on 4H (for closures), and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. A 2.0' of freeboard will be maintained at all times during pumping operations.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, the back dike canal, and Bayou Dupre, as well as Federal, State and local highways.

5.2.13 CC 4 – Site 1

Project Description – Feature CC 4, Site 1, is a swamp restoration feature located south of the GIWW/MRGO (Reach 1) and within the Central Wetlands in Orleans Parish, LA. The project area is an open water area in the shape of a triangle, located between the IHNC and the Orleans / St Bernard Parish line, and immediately adjacent to the 40 Arpent levee and Bayou Bienvenue. (See plates C-16 and 16A)

The project will consist of restoring an area of open water, totaling approximately 400 acres in size, to an elevation conducive to swamp creation/restoration through dedicated dredging of material to be borrowed from the Mississippi River via hydraulic dredge, and transported via barges to an offloading area at approximate Mile 63.8 of the MRGO/GIWW (Reach 1) where the dredge material will then be pumped via pipeline to the restoration site. Access for the dredge pipeline from the GIWW/MRGO will be via a 300' access corridor extending across the MRGO/ GIWW south bank disposal area. The material will be borrowed from between Mississippi River Miles 84.5 AHP and 83.0 AHP along the right descending bank. Borrow will be allowed to an elevation of -70' NAVD88 and the top of cut on the landside will be no closer than 750' from the adjacent Mississippi River levee to assure stability of the levee is not jeopardized. Based off of surveys obtained in 2010, the average elevation within the restoration site is approximately -2.0' NAVD88. Approximately 2.6 million gross cubic yards of borrow will be required for this swamp restoration feature.

The dredge material will be placed to a maximum slurry elevation of +3.0' NAVD88, and dredge effluent waters will be returned to Bayou Bienvenue. At this time, as borings are currently not available, it is being assumed that the retention features will consist of earthen dikes and constructed from adjacent borrow, with a 2.0' of freeboard to be maintained at all times during pumping operations. However, it is possible that geotechnical investigations could warrant alternative types of retention features such as sheet pile. This assessment will be completed during the E&D phase of P&S preparation. Approximately 17,300' of earthen retention dikes would be required. Based off of surveys obtained in 2010, the average elevation at the base of the retention dikes is approximately 0.5' NAVD88. The earthen dikes will be constructed to an approximate elevation of +5.0' NAVD88, approximate 5.0' crown width, and slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, and Bayou Bienvenue, as well as Federal, State and local highways.

5.2.14 CC 4 – Sites 2, 3 and 4

Project Description – Feature CC 4, Sites 2, 3 and 4, is a swamp restoration feature located south of the GIWW/MRGO (Reach 1) and within the Central Wetlands in Orleans and St. Bernard Parishes, LA. The project area is located between the IHNC and Paris Road, and between feature CM 2 and the 40 Arpent levee (see plates C-17 and 17A).

The project will consist of restoring three (3) areas of open water, totaling approximately 1,065 acres in size, to an elevation conducive to swamp creation/restoration through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the north/west lobe of Lake Borgne and the proposed borrow sites are located southwest of Chef Pass. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Approximately 7.8 million gross cubic yards of borrow will be required for this swamp restoration feature. Based off of surveys obtained in 2010, the average elevation within the restoration sites is approximately -3.0' NAVD88 (Site 2) and approximately 2.0' NAVD88 (Sites 3 and 4). The material will be transported directly to the three (3) swamp restoration sites by pipeline via Bayou Bienvenue, and/or by barges via the GIWW/ MRGO and offloaded to the restoration sites. Access for the dredge pipeline from the GIWW/MRGO will be via three (3) 300' wide access corridors extending across the MRGO south bank disposal area, as well as Feature CM 2.

The dredge material will be placed to a maximum slurry elevation of +3.0' NAVD88', and dredge effluent waters will be returned to Bayou Bienvenue and/or Feature CM 2 which is adjacent to Sites 2, 3 and 4 of Feature CC 4. Approximately 32,200' of earthen retention dikes would be required. Based off of surveys obtained in 2010, the average elevation at the base of the retention dikes is approximately -3.0' NAVD88 for Site 2, and approximately -2.0' NAVD88 for both Sites 3 and 4. At this time, as borings are currently not available; it is being assumed that all dikes will be earthen and constructed from adjacent borrow, with a 2.0' of freeboard to be maintained at all times during pumping operations. However, it is possible that geotechnical investigations could warrant alternative types of retention features such as sheet pile. This assessment will be completed during the E&D phase of P&S preparation. The earthen dikes will be constructed to an approximate elevation of +5.0' NAVD88, 5.0' crown width, and slopes no steeper than 1V on 4H with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, and Bayou Bienvenue, as well as Federal, State and local highways.

5.2.15 CC 5

Project Description – Feature CC 5 is a swamp restoration feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA. The project area is immediately adjacent to and east of the Bayou Dupre/Violet Diversion channel and the 40 Arpent levee (see plate C-18).

The project will consist of restoring approximately 1,120 acres of open water to an elevation conducive to swamp creation/restoration, along with the nourishment of approximately 1550 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the north/west lobe of Lake Borgne and the proposed borrow site is located northeast of the Bayou Dupre Cut/Martello Channel. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Approximately 7.8 million gross cubic yards of borrow will be required for this swamp restoration and nourishment feature. Based off of surveys obtained in 2010,

the average elevation within the restoration site is approximately -0.25' NAVD88. The material will be transported directly to the swamp restoration and nourishment site via pipeline. Access for the dredge pipeline from Lake Borgne will be via Dupre Cut/Martello Channel, the MRGO channel and south bank disposal area, as well as Bayou Dupre and the Tennessee Gas pipeline canal that crosses through the northern half Feature CC 5.

The dredge material will be placed to a maximum slurry elevation of +3.0' NAVD88, and dredge effluent waters will be returned to either adjacent marshes for nourishment, Bayou Dupre, and/or the Tennessee Gas pipeline canal. For nourishment of the adjacent 1550 acres of wetlands, dredge material will be placed to a maximum slurry elevation of approximately +2.0' NAVD88 in order for the initial fill placed over the existing wetlands not to exceed 1.25' and to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work. Approximately 20,100' of earthen retention dikes will be constructed from adjacent borrow and 2.0' of freeboard will be maintained at all times during pumping operations. Based off of surveys obtained in 2010, the average elevation at the base of the retention dikes is approximately -0.25' NAVD88. The earthen dikes will be constructed to an approximate elevation of +5.0' NAVD88, an approximate 5.0' crown width, and slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, and Bayou Dupre, as well as Federal, State and local highways.

5.2.16 CC 6

Project Description – Feature CC 6 is a swamp restoration feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA. The project area is immediately adjacent to the back canal behind the MRGO south bank disposal area, and Bayou Dupre/Violet Diversion channel (see plate C-19).

The project will consist of the nourishment of approximately 2,568 acres of existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the north/west lobe of Lake Borgne and the proposed borrow site is located northeast of the Bayou Dupre Cut/Martello Channel. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Approximately 5.2 million gross cubic yards of borrow will be required for this swamp nourishment feature. Based off of surveys obtained in 2010, the average elevation within the restoration site is approximately 0.0' NAVD88. For nourishment of these existing wetlands, dredge material will be placed to a maximum slurry elevation of approximately +2.0' NAVD88 in order for the initial fill placed over the wetlands not to exceed 1.25' and to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work. The material will be transported directly to the swamp restoration and nourishment site via pipeline. Access for the dredge pipeline from Lake Borgne will be via Dupre Cut/Martello Channel, the MRGO channel and south bank disposal area, Bayou Dupre, the Tennessee Gas pipeline canal that crosses through the southern half of Feature CC 6, and the back dike canal.

Approximately 28,160' of earthen retention dikes will be constructed from adjacent borrow and 2.0' of freeboard will be maintained at all times during pumping operations. The earthen dikes will be constructed to an approximate elevation of +3.5' NAVD88, an approximate 5.0' crown width, and slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. In addition to the earthen dikes, it is estimated that five (5) earthen closures, totaling approximately 1,200' in length, will be required in order to retain the dredge slurry. The closures would be constructed to an approximate elevation of +3.5' NAVD88, an approximate 5.0' crown width, and slopes no steeper than 1V on 4H with a minimum 40' interior berm to be maintained between the toe of the closures and the top of cut of the adjacent borrow pits. The closures will be removed upon completion of the contract, or as soon as possible in order to assure that dredged material will not exit the restoration site. Based off of surveys obtained in 2010, the average elevation at the base of the retention dikes is approximately 0.5' NAVD88 and the average elevation at the five (5) closure locations is approximately -2.5' NAVD88.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, and Bayou Dupre, as well as Federal, State and local highways.

5.2.17 CM 1 and CM 5

Project Description – Features CM 1 and CM 5 are marsh creation and nourishment features located south of the GIWW/MRGO and within the Central Wetlands in St. Bernard Parish, LA. The project area for CM 1 is immediately adjacent to the back dike canal behind the MRGO south bank disposal area, Bayou Bienvenue and Paris Road (see plate C-20A). The project area for CM 5 is immediately adjacent to and north of Bayou Bienvenue, Paris Road, and Feature CM 2 (see plate C-20).

Feature CM 1 will consist of nourishing four (4) wetland areas, totaling approximately 1,240 acres in size. These four (4) areas consist of approximately 870 acres of existing marsh and approximately 370 acres of adjacent shallow water areas which will be nourished with dredged material. Feature CM 5 will consist of creating approximately 245 acres of marsh, along with the nourishment of an additional 70 acres of adjacent wetlands through dredged material. The dredge material that will be used to construct these marsh creation and nourishment features will be obtained from the GIWW/MRGO channel (Reach 1), between miles 66 and 60, as well as the Michoud Canal project which begins at approximate GIWW/MRGO mile 60 and extends east to the Michoud Canal slip. Borrow will be restricted to the currently authorized and NEPA cleared dimensions for these channels. It is currently estimated that Reach 1 of the GIWW/MRGO could provide approximately 2.6 million gross cubic yards of the estimated 2.5 million gross cubic yards of material that would be required to construct these features – approximately 1.5 million cubic yards for CM 1 and 1.0 million cubic yards for CM 5. Should additional material be required, it could come from the Michoud Canal project, or other sources such as Lake Borgne or the Mississippi River. The material would be obtained via hydraulic dredge and transported directly to the marsh creation and restoration sites via pipeline. Based off of surveys obtained in 2010, the elevation of the marsh within CM 1 ranged between 0.0 and +1.0' NAVD88 and the average elevation within CM 5 was approximately -1.0' NAVD88.

5.2.17.1 FEATURE CM 1

Disposal for Feature CM 1 will be unconfined with effluent allowed to run over adjacent wetlands for nourishment. Access for the dredge pipeline from the MRGO/ GIWW Reach 1 will be via a 300' wide access corridor that will straddle an existing aerial crossing corridor that runs through the GIWW/MRGO south bank disposal area at approx Mile 60.2, and then across Bayou Bienvenue to the restoration site. Access will also be available via the GIWW/MRGO, through the Bayou Bienvenue floodgate and down Bayou Bienvenue to the restoration site and the back dike canal.

The dredge material will be placed unconfined to a maximum slurry elevation of approximately +2.0' NAVD88 in order for the initial fill placed over the existing wetlands not to exceed 1.25' and to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work. Dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. Approximately 27,800' of perimeter earthen retention dikes, approximately 9,200' of earthen closures, and approximately 4,870' of vinyl sheetpile closures will be constructed in order to prevent material from entering Bayou Bienvenue and the back dike canal, as well as maximize retention of material at isolated open water areas. Upon completion of the project, the vinyl sheetpile closures will be removed and the earthen closures will be gapped to allow for interchange.

The earthen and closures will be constructed from adjacent borrow, with a 2.0' of freeboard to be maintained at all times during pumping operations. The earthen dikes and closures will be constructed to +4.0' NAVD88, an approximate 5.0' crown width, slopes no steeper than 1V on 3H for earthen dikes and no steeper than 1V on 4H for the earthen closures, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and closures and the top of cut of the adjacent borrow pits. Based off of surveys obtained in 2010, the average elevation at the base of the retention dikes was approximately 0.0' NAVD88 and the average elevation at the closure locations was approximately -1.0' NAVD88.

5.2.17.2 FEATURE CM 5

Disposal for Feature CM 5 will be confined with the dredge material transported via pipeline to the proposed restoration site and placed to a maximum slurry elevation of +2.5' NAVD88. Access for the dredge pipeline from the MRGO/ GIWW Reach 1 will be via two (2) access corridors that will cross the GIWW/MRGO south bank disposal area at approximate Miles 62.9 and 61.2, as well as Bayou Bienvenue. Dredge effluent waters will be returned to Bayou Bienvenue via spill box weirs. Approximately 6,000' of earthen retention dikes would be constructed and approximately 10,000' of existing dikes will be refurbished. A minimum 2.0' of freeboard will be maintained at all times during pumping operations. The earthen dikes will be constructed to +4.5' NAVD88, an approximate 5.0' crown width, and slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. Based off of surveys obtained in 2010, the average elevation at the base of the new retention dikes was approximately -2.0' NAVD88 and the average elevation at the locations of the dike to be refurbished was approximately +2.0' NAVD88.

Ingress and egress to the Features CM 1 and CM 5 would be via the GIWW/MRGO Reach 1, the designated access corridors crossing the GIWW/MRGO south bank disposal sites, Bayou Bienvenue, and the back dike canal, as well as Federal, State and local highways.

5.2.18 CM 2

Project Description – Feature CM 2 is a marsh creation and nourishment feature located south of the GIWW/MRGO (Reach 1) and within the Central Wetlands in St. Bernard Parish, LA. The project area is immediately adjacent to Bayou Bienvenue, Paris Road, and Feature CC 4 (see plates C-21 and 21A).

The project will consist of creating marsh over approximately 795 acres, along with the nourishment of an additional 190 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the north/west lobe of Lake Borgne and the proposed borrow site is located northeast of Bayou Bienvenue. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Approximately 4.72 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature. Based off of surveys obtained in 2010, the average elevation within the restoration site is approximately -2.0' NAVD88. The material will be transported to the marsh creation and nourishment site via pipeline. The material will be transported directly to the restoration site by pipeline via Bayou Bienvenue, and/or by barges via the GIWW/ MRGO and offloaded to the restoration sites. Access for the dredge pipeline from the GIWW/MRGO will be via two (2) access corridors extending across the MRGO south bank disposal area.

The dredge material will be placed to a maximum slurry elevation of +2.5' NAVD88 within the marsh creation site, and dredge effluent will be allowed to overflow adjacent marsh for nourishment. For nourishment of the 190 acres of adjacent wetlands, approximately 1.25' of dredge material will be placed over the existing wetlands to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

Approximately 32,450' of retention features would be constructed and effluent waters will be returned to either Bayou Bienvenue via spill box weirs and/or allowed to flow into adjacent Feature CC 4 site. Approximately 20,800' of earthen retention dikes would be required along the west, north and east sides of feature CM 2. In addition, approximately 3,750' of vinyl sheetpile closures will be constructed in order to prevent material from entering Bayou Bienvenue. The rear 7,900' of the restoration site will require a closure. The rear closure would be constructed from either adjacent earthen borrow or vinyl sheetpile, approximately 30'to 35' in length, with timber piles 40'to 45' in length and with timber piles spaced 6' to 8' apart for added support.

The earthen dikes and closures will be constructed from adjacent borrow, with a 2.0' of freeboard to be maintained at all times during pumping operations. The earthen dikes and closures will be constructed to +4.5' NAVD88, an approximate 5.0' crown width, slopes no steeper than 1V on 3H for earthen dikes and no steeper than 1V on 4H for the earthen closures, all with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and closures and the top of cut of the adjacent borrow pits. The sheetpile closures would be driven to an elevation of +4.5' NAVD88. Based off of surveys obtained in 2010, the average elevation at the base of the proposed retention

dikes was approximatley -0.5' NAVD88 and the average elevation at the closure locations was approximately -2.0' NAVD88.

As the determination was made to defer any required geotechnical investigations of the restoration areas during this phase of study, final determination of what type of rear closure will be used for this feature will be performed during the next phase of design. All vinyl sheetpile closures will be removed and the earthen closures will be gapped to allow for interchange. The closures will be removed upon completion of the contract, or as soon as possible in order to assure that dredged material will not exit the restoration site.

Ingress and egress to the site would be via the GIWW/MRGO, Bayou Bienvenue, the designated access corridors, as well as Federal, State and local highways.

5.2.19 CM 3

Project Description – Feature CM 3 is a marsh creation and nourishment feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA. The project area is immediately south of the back dike canal, located behind the MRGO south bank disposal area, and adjacent to and upstream of the Bayou Dupre/Violet Diversion channel. The feature is also adjacent to project Feature CC 2 (see plate C-22 and 22A).

The project will consist of creating approximately 300 acres of marsh, along with the nourishment of approximately 215 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the north lobe of Lake Borgne and the proposed borrow site is located northeast of Bayou Dupre Cut/ Martello Channel. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Approximately 1.6 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature. Based off of surveys obtained in 2010, the average elevation of the marsh creation site was approximately -2.0' NAVD88 and the average elevation of the adjacent marsh was approximately +0.5' NAVD88.

The material will be transported directly to the marsh creation and nourishment sites via pipeline. Disposal will be semi-confined with effluent allowed to run over adjacent wetlands. Access for the dredge pipeline from Lake Borgne will be via Bayou Dupre Cut/Martello channel, the MRGO channel, and via a 300' wide access corridor leading from the MRGO and crossing the south bank disposal area, the Bayou Dupre/ Violet Canal, and the adjacent back dike canal.

The dredge material will be placed semi-confined to a maximum slurry elevation of +2.5' NAVD88 for marsh creation and dredge effluent will be allowed to overflow adjacent marsh for nourishment. For nourishment of the 215 acres of adjacent wetlands, approximately 1.25' of dredge material will be placed over the existing wetlands to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

Approximately 26,800' of earthen retention dikes, along with approximately eight (8) earthen closures totaling approximately 4,230', will be constructed. In order to assist in the development of the marsh

creation and nourishment sites, approximately 9,400' of interior earthen weirs will also be constructed. The earthen dikes and closures will be constructed to +4.5' NAVD88, an approximate 5.0' crown width, slopes no steeper than 1V on 3H for earthen dikes and no steeper than 1V on 4H for the earthen closures, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and closures and the top of cut of the adjacent borrow pits. The earthen weirs will be constructed to an approximate elevation of +1.5' to +2.0' NAVD88. Upon completion of the project, the closures along Bayou Dupre/Violet Canal and the back dike canal will be removed. In addition, approximately 2,915' of vinyl sheetpile closures will be constructed in order to prevent material from entering Bayou Dupre and the Tennessee Gas pipeline canal. Approximately 2,285' of sheetpile closures will consist of 35' length sheetpile and approximately 630' will consist of 45' sheets, with timber piles 45' and 55' in length respectively, required and spaced 6'to 8' apart for added support. The sheetpile closures would be driven to a top elevation of +4.5' NAVD88.

Based off of surveys obtained in 2010, the average elevation at the base of the proposed retention dikes was approximately 0.0' NAVD88, -1.0' NAVD88 at the weir locations and the average elevation at the earthen closure locations were approximately -2.0' NAVD88. All vinyl sheetpile closures will be removed and the earthen closures will be gapped to allow for interchange. The sheetpile closures will be removed upon completion of the contract, or as soon as possible in order to assure that dredged material will not exit the restoration site.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, the back dike canal, and Bayou Dupre, as well as Federal, State and local highways.

5.2.20 CM 4

Project Description – Feature CM 4 is a marsh nourishment feature located south of the MRGO and within the Central Wetlands in St. Bernard Parish, LA. The project area is immediately adjacent to the back canal behind the MRGO south bank disposal area, the Bayou Dupre/Violet Diversion channel, and Feature CC 6. (See plate C-23 and 23A).

The project will consist of creating and nourishing a total of approximately 226 acres of marsh through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. Of this 226 acres, approximately 97.5 acres are open water at approximate elevation -2.0' NAVD88 that will be restored to marsh, and approximately 128.5 acres of adjacent wetlands at approximate elevation 0.0' NAVD88 will be nourished. Approximately 1.25' of dredge material will be placed over the existing wetlands to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

The material will be borrowed from the north lobe of Lake Borgne and the proposed borrow site is located northeast of Bayou Dupre Cut/ Martello Channel. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Approximately 600,000 gross cubic yards of borrow will be required for this marsh creation and nourishment feature.

The material will be transported directly to the marsh creation and nourishment sites via pipeline. Disposal will be unconfined with effluent allowed to run over adjacent wetlands. Access for the

dredge pipeline from Lake Borgne will be via Bayou Dupre Cut/Martello channel, the MRGO channel, the Bayou Dupre/ Violet Canal, and the adjacent back dike canal.

The dredge material will be placed unconfined to a maximum slurry elevation of +2.5' NAVD88 within the marsh creation areas. Dredge effluent will be allowed to run over adjacent marsh for marsh nourishment with approximately 1.25' of dredge material to be placed over the existing wetlands to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

Approximately 23,000' of earthen perimeter dikes will be required, along with approximately five (5) earthen closures totaling 2,470' that will be constructed in order to prevent material from entering adjacent natural and man-made waterways. Upon completion of the project, the closures will be breached to allow for interchange. Based off of surveys obtained in 2010, the average elevation at the base of the proposed retention dikes was approximately 0.0' NAVD88 and the average elevation at the earthen closure locations was approximately -1.0' NAVD88. All dikes and closures for this feature will be earthen and constructed from adjacent borrow, with a 2.0' of freeboard to be maintained at all times during pumping operations. The earthen dikes and closures will also be constructed to an elevation of +4.5' NAVD88, an approximate 5.0' crown width, slopes no steeper than 1V on 3H for the earthen dikes and no steeper than 1V on 4H for the earthen closures, all with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and closures and the top of cut of the adjacent borrow pits.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, the MRGO, Bayou Dupre, the back dike canal, as well as Federal, State and local highways.

5.2.21 HM 1

Feature HM 1 is a marsh creation and nourishment feature located in Hopedale, LA and bounded by Bayou La Loutre, Highway 624, Bayou Yscloskey, and the MRGO (see plate C-33).

The project will consist of converting approximately 757 acres of open water to marsh habitat, along with the nourishment of approximately 973 acres of adjacent wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the south/east lobe of Lake Borgne, immediately north of the marsh creation and nourishment site. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Based off of surveys obtained in 2010, the average elevation within the marsh creation site was approximately -2.0' NAVD88. Approximately 4.5 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature.

The material will be transported directly to the marsh creation and nourishment site via pipeline. Access for the dredge pipeline from Lake Borgne will be via Doulluts Canal, across the MRGO, and thence via a 200' wide access corridor across the former MRGO south bank disposal site to the marsh creation and nourishment site.

The dredge material will be placed to a maximum slurry elevation of +2.5' NAVD88 for marsh creation, and dredge effluent will be returned via spill box weirs to the adjacent back dike canal and

Portman Lagoon which both run north of and adjacent to the marsh creation and nourishment site. Dredge effluent will be allowed to run over the internal earthen weirs for nourishment of adjacent wetlands. The 973 acres outside the marsh creation area will be nourished with approximately 1.25' of dredge material placed over the existing wetlands to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

Approximately 54,500' of perimeter earthen retention dikes will be constructed from adjacent borrow and 2.0' of freeboard will be maintained at all times during pumping operations. The earthen dikes will be constructed to an approximate elevation of +4.5' NAVD88, a minimum 5.0' crown width, and with slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. In addition, an interior earthen weir, approximately 17,300' in length, will be constructed around the perimeter of the 757 acre marsh creation site in order to assist in maximizing the construction of these wetlands. The weir will be constructed from adjacent borrow and will be constructed to an elevation of +3.0' to 3.5'. The weirs will be constructed to an elevation of between +1.5' and +2.0' NAVD88, a minimum 5.0' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the weir and the top of cut of the adjacent borrow pits. Based off of surveys obtained in 2010, the average elevation at the base of the new retention dikes was approximately -0.5' NAVD88 and the average elevation at the locations of the weir approximately 0.0' NAVD88.

Ingress and egress to the site would be via the GIWW, Chef Pass, Lake Borgne, Doulluts Canal, and the MRGO, as well as Federal, State and local highways.

5.2.22 TM 1

Project Description – Feature TM 1 is a marsh creation and nourishment feature located south of the MRGO and within St. Bernard Parish, LA. The project area is located in the vicinity of Yscloskey, LA and south of LA 46 and between Bayou Terre Aux Boeufs and the Tennessee Gas twin pipeline canals (see plate C-34).

The project will consist of creating approximately 798 acres of marsh within two (2) proposed marsh creation sites, along with the nourishment of an additional 223 acres of existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the south/east lobe of Lake Borgne and immediately northeast of Bayou Yscloskey. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Based off of surveys obtained in 2010, the average elevation within the marsh creation site was approximately -2.0' NAVD88. Approximately 3.8 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature.

The material will be transported directly to the marsh creation and nourishment sites via pipeline. Access for dredge pipeline from Lake Borgne shall be via Bayou Yscloskey, thence crossing the MRGO channel and leading to a 200' wide access corridor across the MRGO south bank disposal site immediately adjacent to and upstream of the Tennessee Gas twin pipeline canal, and thence via a 450' wide access corridor (which includes the twin pipeline canal) leading to the marsh restoration site.

The dredge material will be placed semi-confined to a maximum slurry elevation of +2.5' NAVD88 within the marsh creation sites, and dredge effluent will be allowed to run over the rear earthen weirs for nourishment of adjacent wetlands. The 223 acres adjacent to the two (2) marsh creation sites and defining the northern boundary of feature TM 1 will be nourished with approximately 1.25' of dredge material placed over the existing wetlands to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

Approximately 18,000' of perimeter earthen retention dikes will be required, along with approximately three (3) vinyl sheetpile closures totaling approximately 2,930'. In order to assist in the development of the marsh creation and nourishment sites, approximately 17,300' of rear earthen weirs will be constructed at the marsh creation sites and approximately 21,500' of perimeter earthen weirs will be constructed at the 223 acre marsh nourishment site. The earthen dikes and weirs will be constructed to an approximate 5.0' crown width, and slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and weirs and the top of cut of the adjacent borrow pits. The earthen dikes will be constructed to an elevation of +4.5' NAVD88 and the weirs will be constructed to an approximate elevation of +1.5' to +2.0' NAVD88. Two (2) feet of freeboard will be maintained at all times along the earthen dikes during pumping operations. Approximately 2,630' of vinyl sheetpile closure would be required at the south end of the western marsh creation site. This closure would consist of vinyl sheet pile, approximately 35' in length, along with timber piles, approximately 45' in length and spaced 6' on center for added support. Another closure would be required along the east side of the eastern marsh creation site and would consist of vinyl sheet pile, approximately 40' in length, along with timber piles, approximately 50' in length and spaced 6' on center for added support. The sheetpile closures would be driven to a top elevation of +4.5' NAVD88. Based off of surveys obtained in 2010, the average elevation at the base of the earthen retention dikes was approximately -1.5' NAVD88, approximately -2.0' NAVD88 at the rear weir locations, approximately +0.5' NAVD88 at the location of the weirs for the marsh nourishment site, and average elevation of -1.0' and -5.0' NAVD88 at the western and eastern closure locations, respectively. Upon completion of the project, the closures will be removed.

It is also noted that borrow for this feature will take place in the south/east lobe of Lake Borgne and within an area that was used as an anti-aircraft training center (AATC), located in Shell Beach, LA in the early to mid 1940's. As a result, it is possible that unexploded ordinances (UXOs) could be encountered when borrowing within the south/ east lobe of Lake Borgne. The cone defining the zone within which these UXOs could potentially be located is depicted on the feature plate. Therefore, cutterhead dredges operating in this area will need to be equipped with approximate 2" x 2" intake screens and outfall/discharge baskets with screens small enough to catch any small munitions that might pass through the dredged prior to being deposited within the restoration area.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, the designated access corridor crossing the MRGO south bank disposal site, the Tennessee Gas pipeline canal, Bayou Terre Aux Boeufs, as well as Federal, State and local highways.

5.2.23 TM 2

Project Description – Feature TM 2 is a marsh creation and nourishment feature located south of the MRGO and within St. Bernard Parish, LA. The project area is located in the vicinity of Alluvial City, LA, south of Bayou La Loutre, and between Lake Ameda and the Tennessee Gas twin pipeline canals. (See plate C-34)

The project will consist of creating approximately 770 acres of marsh, along with the nourishment of an approximately 3,396 acres of existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the south/east lobe of Lake Borgne and immediately north of Bayou Yscloskey. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Based off of surveys obtained in 2010, the average elevation within the marsh creation site was approximately -3.0' NAVD88. Approximately 8.8 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature.

The material will be transported directly to the marsh creation and nourishment sites via pipeline. Access for dredge pipeline from Lake Borgne shall be via the Bayou Yscloskey, across the MRGO channel, and along Bayous Yscloskey and La Loutre south of the MRGO and leading to the marsh restoration site.

The dredge material will be placed semi-confined within the marsh creation site to a maximum slurry elevation of +2.5' NAVD88, and dredge effluent allowed running over the internal earthen weir for nourishment of adjacent wetlands. A total of approximately 3,396 acres be nourished with approximately 1.25' of dredge material placed over the existing wetlands, as well as within adjacent water bodies, to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work. Spill box weirs will be installed in the retentions dikes and the effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as the twin pipeline canal.

At this time, it is anticipated that all retention features for this project feature will be earthen. Approximately 163,200' of perimeter earthen retention dikes will be required, along with approximately 25,350' of internal earthen weirs that will be required for the 770 acre marsh creation site. Two (2) feet of freeboard will be maintained at all times along the perimeter dikes during pumping operations. The earthen dikes and weirs will be constructed to an approximate 5.0' crown width, and slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and weirs and the top of cut of the adjacent borrow pits. The earthen dikes will be constructed to an elevation of +4.5' NAVD88 and the weirs will be constructed to an approximate elevation of +1.5' to +2.0' NAVD88. Based off of surveys obtained in 2010, the average elevation at the base of the earthen retention dikes was approximately 0.25' NAVD88, and approximately 0.0' NAVD88 at the rear weir location.

It is also noted that borrow for this feature will take place in the south/east lobe of Lake Borgne and within an area that was used as an anti-aircraft training center (AATC), located in Shell Beach, LA in the early to mid 40's. As a result, it is possible that unexploded ordinances (UXOs) could be encountered when borrowing within the south/ east lobe of Lake Borgne. The cone defining the zone within which these UXOs could potentially be located is depicted on the feature plate. Therefore,

cutterhead dredges operating in this area will need to be equipped with approximate 2" x 2" intake screens and outfall/discharge baskets with screens small enough to catch any small munitions that might pass through the dredged prior to being deposited within the restoration area.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, Bayous Yscloskey and Bayou La Loutre, as well as Federal, State and local highways.

5.2.24 TM 7

Feature TM 7 is a marsh creation and nourishment feature located south of the MRGO and within St. Bernard Parish, LA. The project area is located in the vicinity of Delacroix Island and bounded by Feature TM 1 on the north, Feature TM 8 on the south, Bayou Terre Aux Boeufs on the west, and the Tennessee Gas twin pipeline canals on the east. (See plates C-36 and 36A).

The project will consist of creating and nourishment of approximately 2,255 acres of wetlands within seven (7) proposed marsh creation sites, along with the nourishment of approximately 2,144 acres of adjacent existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the south/east lobe of Lake Borgne and immediately northeast of Bayou Yscloskey. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Based off of surveys obtained in 2010, the average elevation within the marsh creation site was approximately -2.5' NAVD88. A total of approximately 12.4 million gross cubic yards of borrow will be required for this marsh creation and marsh nourishment feature.

Access for dredge pipeline from Lake Borgne shall be via either Fort Bayou and/or Bayou Yscloskey, thence crossing the MRGO channel and leading to a 200' wide access corridor across the MRGO south bank disposal site immediately adjacent to and upstream of the Tennessee Gas twin pipeline canal, and thence for approximately 3 miles via a 450' wide access corridor (which includes the twin pipeline canal) leading to the marsh restoration sites.

The dredge material will be placed semi-confined within the marsh creation sites to a maximum slurry elevation of +2.5' NAVD88 and the dredge effluent discharged towards adjacent wetlands at select locations where gaps and/or spill box weirs will be installed in the retention dike system. Two (2) feet of freeboard will be maintained at all times during pumping operations. In addition, approximately 2,214 acres of adjacent wetlands will be nourished with approximately 1.25' of dredge material placed over these existing wetlands, as well as within existing water bodies, to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

Approximately 105,000' of perimeter earthen retention dikes and closures will be required, along with approximately five (5) vinyl sheetpile closures totaling approximately 10,275'. The earthen dikes and closures will be constructed to an elevation of +4.5' NAVD88, an approximate 5.0' crown width, and slopes no steeper than 1V on 3H for the dikes and 1V on 4H for the closures, all with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. The sheetpile closures would consist of vinyl sheet pile, approximately 35' in length, along with timber piles, approximately 45' in length and spaced 6' on center for added support. Based off of surveys obtained in 2010, the average elevation at the base of the earthen

retention dikes was approximately +0.25' NAVD88 and approximately -3.0' NAVD88 at the closure locations. Upon completion of the project, the closures will be removed.

It is also noted that borrow for this feature will take place in the south/east lobe of Lake Borgne and within an area that was used as an anti-aircraft training center (AATC), located in Shell Beach, LA in the early to mid 1940's. As a result, it is possible that unexploded ordinances (UXOs) could be encountered when borrowing within the south/ east lobe of Lake Borgne. The cone defining the zone within which these UXOs could potentially be located is depicted on the feature plate. Therefore, cutterhead dredges operating in this area will need to be equipped with approximate 2" x 2" intake screens and outfall/discharge baskets with screens small enough to catch any small munitions that might pass through the dredged prior to being deposited within the restoration area.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, the designated access corridor crossing the MRGO south bank disposal site, the Tennessee Gas pipeline canal, Bayou Terre Aux Boeufs, as well as Federal, State and local highways.

5.2.25 TM 8

Project Description – Feature TM 8 is a marsh creation feature located south of the MRGO and within St. Bernard Parish, LA. The project area is located in the vicinity of Delacroix Island and northeast of Bayou Terre Aux Boeufs, and west of the Tennessee Gas twin pipeline canals. (See plates C-37 and 37A).

The project will consist of creating approximately 1,511 acres of marsh within five (5) proposed marsh creation sites through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the south/east lobe of Lake Borgne and immediately north of Bayou Yscloskey. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Based off of surveys obtained in 2010, the average elevation within the marsh creation sites was approximately -3.0' NAVD88. Approximately 9.7 million gross cubic yards of borrow will be required for this marsh creation feature.

Access for dredge pipeline from Lake Borgne shall be via either Fort Bayou and/or Bayou Yscloskey, thence crossing the MRGO channel and leading to a 200' wide access corridor across the MRGO south bank disposal site immediately adjacent to and upstream of the Tennessee Gas twin pipeline canal, and thence for approximately 3 miles via a 450' wide access corridor (which includes the twin pipeline canal) leading to the marsh restoration sites.

The dredge material will be placed semi-confined to a maximum slurry elevation of +2.5' NAVD88 and dredge effluent waters will be allowed to run over earthen weirs and upon adjacent marsh for marsh nourishment, as well as adjacent water bodies. Approximately 63,900' of perimeter earthen retention dikes will be required, along with approximately five (5) earthen closures totaling approximately 6,970'. In order to assist in the development of the marsh creation and nourishment sites, approximately 14,700' of earthen weirs will be constructed at the marsh creation sites. The earthen dikes and weirs will be constructed to an approximate 5.0' crown width, and slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of

the earthen dikes and weirs and the top of cut of the adjacent borrow pits. The earthen closures will be constructed to an approximate 5.0' crown width, and slopes no steeper than 1V on 4H with a minimum 40' interior berm to be maintained between the inside toe of the earthen closures and the top of cut of the adjacent borrow pits. The earthen dikes and closures will be constructed to an elevation of +4.5' NAVD88 and the weirs will be constructed to an approximate elevation of +1.5' to +2.0' NAVD88. Two (2) feet of freeboard will be maintained at all times along the earthen dikes during pumping operations. Based off of surveys obtained in 2010, the average elevation at the base of the earthen retention dikes was approximately +0.5' NAVD88, approximately 0.0' NAVD88 at the weir locations, and approximately -1.75' NAVD88 at the closure locations. Upon completion of the project, the earthen closures will either be degraded or gapped to allow for interchange.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, the designated access corridor crossing the MRGO south bank disposal site, the Tennessee Gas pipeline canal, Bayou Terre Aux Boeufs, as well as Federal, State and local highways.

5.2.26 LM 1

Project Description – Feature LM 1 is a marsh creation and nourishment feature located just inside the IHNC surge barrier, at the confluence of the MRGO and the GIWW, and within Orleans and St. Bernard Parishes, LA. (See plate C-38)

The project will consist of creating approximately 3,253 acres of marsh, along with the nourishment of approximately 1,064 acres of adjacent existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the north/west lobe of Lake Borgne and immediately southwest of Chef Pass. Borrow within the lake will be limited to a maximum of 17' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Based off of surveys obtained in 2010, the average elevation within the marsh creation sites was approximately -2.25' NAVD88. Approximately 14.3 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature. The material would be obtained via hydraulic dredge and transported directly to the marsh creation and nourishment sites via pipeline.

Disposal within the marsh creation sites will be semi-confined with effluent allowed to run over adjacent wetlands for nourishment. Access for the dredge pipeline from Lake Borgne will be via the access corridor depicted on plate C-38, Bayou Bienvenue and through the northern Bayou Bienvenue floodgate which is currently under construction.

The dredge material will be placed semi-confined within the marsh creation sites to a maximum slurry elevation of +2.5' NAVD88, and dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. Approximately 103,700' of perimeter earthen retention dikes will be required, along with approximately nine (9) vinyl sheetpile closures totaling approximately 10,050' in length. In order to assist in the development of the marsh creation sites, approximately 93,700' of interior earthen weirs will also be constructed. The earthen dikes and weirs will be constructed to an approximate 5.0' crown width, and slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and weirs and the top of cut of the adjacent borrow pits. The earthen dikes will be constructed to an elevation

of +4.5' NAVD88 and the weirs will be constructed to an approximate elevation of +1.5' to +2.0' NAVD88. Two (2) feet of freeboard will be maintained at all times along the earthen dikes during pumping operations. The closures will consist of vinyl sheet pile, approximately 40' in length, along with timber piles, approximately 50' in length and spaced 6' on center for added support. The sheetpile closures would be driven to a top elevation of +4.5' NAVD88. Based off of surveys obtained in 2010, the average elevation at the base of the earthen retention dikes was approximately +0.5' NAVD88, approximately -1.0' NAVD88 at the weir locations, and approximately -5.5' NAVD88 at the closure locations. Upon completion of the project, the closures will be removed.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, and Bayou Bienvenue, as well as Federal, State and local highways.

5.2.27 LM 2

Project Description – Feature LM 2 is a marsh creation and nourishment feature located north of the MRGO and within St. Bernard Parish, LA. The project area is located between the MRGO and Proctor Point and adjacent to both the north and south lobes of Lake Borgne (see plate C-39).

The project will consist of creating approximately 225 acres of marsh immediately the north/west lobe of Lake Borgne, south of Proctor Point, and behind proposed Feature LS 1, along with the nourishment of an approximately 2,523 acres of existing wetlands through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the north/west lobe of Lake Borgne, southwest of Proctor Point and adjacent to the proposed restoration feature. Borrow within the lake will be limited to a maximum of 6.5' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Based off of surveys obtained in 2010, the average elevation within the marsh creation site was approximately -2.0' NAVD88. Approximately 4.45 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature.

The material would be obtained via hydraulic dredge and transported directly to the marsh creation and nourishment sites via pipeline. Disposal within the marsh creation site located south of Proctor Point will be semi-confined with an earthen weir constructed on the backside of the marsh creation site. Dredge effluent will allowed to flow over the weir run over adjacent wetlands for nourishment. Material placed within the marsh nourishment sites will be unconfined with effluent waters allowed to run over adjacent wetlands.

Access for the dredge pipeline from Lake Borgne will be via the access corridors depicted on plate C-39. Excavation for flotation access will not be required. Based upon preliminary lake bottom classification surveys, an area of hard bottom surface, which is conducive to sturgeon habitat, falls within the northern portion of Lake Borgne and between the proposed borrow site and Lake Borgne shoreline. As excavation for flotation access will not be performed, marsh buggy access will simply be allowed within the area(s) where the proposed access corridor(s) cross the hard bottom substrate area(s) in order to access the marsh creation sites.

The dredge material will be placed semi-confined within the marsh creation site to a maximum slurry elevation of +2.5' NAVD88. In order to assist in the development of the marsh creation site, a rear

earthen weir, approximately 11,500' in length, will be constructed around the marsh creation site and dredge effluent waters will be allowed to run over the weir and upon adjacent marsh, as well as adjacent water bodies, for marsh nourishment. The earthen weir will be constructed to an approximate 5.0' crown width, and slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of the earthen weirs and the top of cut of the adjacent borrow pit. The interior earthen weirs will be constructed to an approximate elevation of between +1.5' and +2.0' NAVD88. In order to prevent material from entering the north and south lobes of earthen Lake Borgne, approximately 49,200' of perimeter retention dikes will be constructed along the Lake Borgne shoreline. The earthen dikes will be constructed to an approximate 5.0' crown width, and slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of the dikes and the top of cut of the adjacent borrow pit. The dikes will be constructed to an approximate elevation of between +4.5' NAVD88. In addition to the dikes and weir, sheetpile closures may be required within three (3) bayous on the northwest shoreline of the south/east lobe of Lake Borgne. The closures, approximately 600' in total length, will consist of vinyl sheet pile, varying from 20' to 40' in length, along with timber piles, varying from 30' to 50' in length and spaced 6' on center for added support. The sheetpile closures would be driven to a minimum top elevation of +2.5' NAVD88. Upon completion of the project, the closures will be removed. Based off of surveys obtained in 2010, the average elevation at the base of the earthen retention dikes and weir was approximately +0.5' NAVD88, and approximately -6.0' NAVD88 at the closure locations. Access to the closure locations will be via Lake Borgne and it is possible that some floatation dredging may be required to access these three (3) sites. It is estimated that three (3) access channels might be required, each approximately 800' in length and 70' in width. The material from these access channels will be side cast adjacent to the channels and the access channels backfilled with any remaining stockpile materials upon completion of the work.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, and Lake Borgne, as well as Federal, State and local highways.

5.2.28 LM 3

Project Description – Feature LM 3 is a marsh creation and nourishment feature located along the south shore of the south/east lobe of Lake Borgne, and bounded by the MRGO, Lena Lagoon and Bayou St. Malo, and located St. Bernard Parishes, LA (see plate C-40).

The project will consist of creating approximately 911 acres of marsh, along with the nourishment of approximately 950 acres of adjacent existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the south/east lobe of Lake Borgne and adjacent to the proposed restoration feature. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Based off of surveys obtained in 2010, the average elevation within the marsh creation sites was approximately -2.0' NAVD88. Approximately 6.4 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature.

The dredge material will be placed to a maximum slurry elevation of +2.5' NAVD88 within the areas targeted for marsh creation and approximately 1.25' of dredge material will be placed over existing

wetlands within the areas designated for marsh nourishment in order to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

Access for the dredge pipeline from Lake Borgne will be via the access corridors depicted on plate C-40. Excavation for flotation access will not be required. Based upon preliminary lake bottom classification surveys, an area of hard bottom surface, which is conducive to sturgeon habitat, falls within the portion of Lake Borgne between the proposed borrow site and Lake Borgne shoreline. As excavation for flotation access will not be performed, marsh buggy access will simply be allowed within the areas where the proposed access corridors cross the hard bottom substrate areas in order to access the marsh creation and nourishment sites.

Approximately 49,000' of perimeter earthen retention dikes will be required, along with approximately 40,300' of earthen weirs that will be constructed within the marsh creation sites. The earthen dikes and weirs will be constructed to an approximate 5.0' crown width, and slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and weirs and the top of cut of the adjacent borrow pits. The earthen dikes will be constructed to an elevation of +4.5' NAVD88 and the weirs will be constructed to an approximate elevation of +1.5' to +2.0' NAVD88. Two (2) feet of freeboard will be maintained at all times along the earthen dikes during pumping operations. Based off of surveys obtained in 2010, the average elevation at the base of the earthen retention dikes and weirs was approximately +0.5' NAVD88.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, and Lake Borgne, as well as Federal, State and local highways.

5.2.29 LM 4

Project Description – Feature LM 4 is a marsh creation and nourishment feature located just inside the IHNC surge barrier, at the confluence of the MRGO and the GIWW, and within Orleans and St. Bernard Parishes, LA (see plates C-41 and 41A).

The project will consist of creating approximately 226 acres of marsh, along with the nourishment of approximately 55 acres of adjacent existing wetlands, through dedicated dredging of material to be borrowed from Lake Borgne via hydraulic dredge. The material will be borrowed from the north/west lobe of Lake Borgne and east of the mouth of Bayou Bienvenue. Borrow within the lake will be limited to a maximum of 12' below the lake bottom and at no time will borrow be allowed beyond this maximum depth. Based off of surveys obtained in 2010, the average elevation within the marsh creation sites was approximately -1.5' NAVD88. Approximately 1.2 million gross cubic yards of borrow will be required for this marsh creation and nourishment feature.

The material would be obtained via hydraulic dredge and transported directly to the marsh creation and nourishment sites via pipeline and/or barges. Disposal within the marsh creation sites will be semi-confined with effluent allowed to run over earthen weirs and upon adjacent wetlands for nourishment.

Access for the dredge pipeline from Lake Borgne will be via Bayou Bienvenue. Excavation for flotation access will not be required. Based upon preliminary lake bottom classification surveys, an area of hard bottom surface, which is conducive to sturgeon habitat, falls within the portion of Lake Borgne between the proposed borrow site and the mouth of Bayou Bienvenue. As excavation for flotation access will not be performed, marsh buggy access will simply be allowed within the areas where the proposed access corridors cross the hard bottom substrate areas in order to access the marsh creation and nourishment sites.

The dredge material will be placed semi-confined within the marsh creation sites to a maximum slurry elevation of +2.5' NAVD88, and dredge effluent waters will be allowed to run over adjacent marsh for marsh nourishment, as well as adjacent water bodies. Approximately 1.25' of dredge material will be placed over existing wetlands within the areas designated for marsh nourishment in order to allow for the fill to consolidate to approximately 0.75' to 1.0' following completion of the work.

Approximately 24,000' of perimeter earthen retention dikes will be required and 2.0' of freeboard shall be maintained at all times during pumping operations. In order to assist in the development of the marsh creation sites, approximately 3,200' of earthen weirs will also be constructed around the marsh creation sites. The earthen retention dikes and weirs will be constructed to an approximate 5.0' crown width, and slopes no steeper than 1V on 3H with a minimum 40' interior berm to be maintained between the inside toe of the retention dikes and earthen weirs and the top of cut of the adjacent borrow pits. The earthen dikes will be constructed to an approximate elevation of +4.5' NAVD88 and the earthen weirs will be constructed to an elevation of between +1.5' and +2.0' NAVD88. In addition to the dikes and weirs, a sheetpile closure, totaling approximately 800' in length, will also be required along the north side of the western marsh creation site. The closure will consist of vinyl sheet pile, approximately 35' to 40' lengths, with timber piles 45' to 50' in length and spaced 6' on center for added support. The sheetpile closures would be driven to +4.5' NAVD88. Upon completion of the project, the closure will be removed. Based off of surveys obtained in 2010, the average elevation at the base of the earthen retention dikes and weir was approximately +0.5' NAVD88, and approximately -3.0' NAVD88 at the closure location.

Ingress and egress to the site would be via the GIWW/MRGO, Chef Pass, Lake Borgne, and Bayou Bienvenue, as well as Federal, State and local highways.

5.2.30 Planting

All marsh and swamp creation features have a planting plan associated with them. Details of this plan can be found in Appendix M to the EIS.

5.3 SHORELINE PROTECTION

5.3.1 Lake Shoreline Protection

Several different feature alternatives are proposed in the restoration of the project area, including shoreline protection to stabilize existing bank lines to promote plant growth, limit shoreline erosion, reduce bankline recession and interior marsh loss, and provide general stability to the existing topography.

Preliminary alternative analysis and screening to develop a tentatively selected plan maintained five (5) shoreline protection features in the final array of alternatives, and one (1) oyster reef demonstration feature. These shoreline protection features are described in the following pages. Specifically, two (2) features are located in Lake Pontchartrain (ES1 & ES2), three (3) features are located in Lake Borgne (ES3, LS1, & BS1), and the final oyster reef demonstration feature was located in Breton Sound; north of the inshore terminus of the MRGO north jetty.

The Lake Pontchartrain features assist in protecting existing infrastructure, and the existing land bridge between the Lakes Pontchartrain and Catherine. The Lake Borgne features will minimize shoreline erosion and provide protection to existing marsh habitat. Historic shoreline erosion rates cited in this report were obtained from the "Shoreline Change Rates of Lake Borgne", contributors: Zganjar, Westphal, McCarty, Bridges, and Penland. The Breton Sound features will be constructed as breakwater features, protecting the interior land features from wind driven waves out of Breton Sound. All completed structures will provide viable habitat and protection for various aquatic species.

Preliminary hydraulic analysis was performed to provide minimal foreshore criteria such as stone size, dike crown width and height. These designs were advanced with completion of minimal site specific hydrographic/topographic surveys and analysis of geotechnical considerations. Dike alignment was determined, based on water depths and bankline profile at the proposed placement site. Due to ongoing bankline recession and nearshore erosion, final design will require comprehensive surveys at each specific site to be taken during the PED phase. All Lake Borgne and Lake Pontchartrain shoreline protection features will be constructed using the following stone proposed stone gradation:

Stone (Weight in Pounds)	Percent Finer by Weight
1500-600	100
650-300	50
330-100	15

Stone meeting the requirements of this construction effort has been produced from multiple (previously approved) sources and used extensively for shoreline protection efforts throughout the District. A list of approved stone sources is updated periodically and includes quarries providing limestone, sandstone, gneiss, granite, dolomite, and basalt. Because of the proximity of the project site to the Mississippi River, we find most of our stone supplies (limestone and sandstone) come from Missouri, Kentucky, Arkansas, and Illinois; all having direct barge loading and shipping via the Mississippi River.

In general, all stone shall be a hard, durable material free from cracks, seams and other defects. Neither the width nor thickness of any piece shall be less than one third of its length. The faces of individual pieces of stone shall be roughly angular, not rounded in shape. Stone that weighs less than 155 pounds per cubic foot or has more than 2 percent absorption will not be accepted.

Differing alternative designs were contemplated for the shoreline protection features. Rubble mound structures, in addition to providing shoreline protection: (1) afford habitat for various species, (2)

afford continued access between the lake and the marsh for many species, and (3) afford recreational fishing opportunities, (4) afford continued protection even after some settlement or failures occur and (5) provide run-up considerations to dampen wave energy. In addition, these project areas are prone to seasonal hurricanes and tropical storms. Whereas the rubble mounds will simply be submerged during these potentially high-tidal storm events, the vertical wall and floating breakwater solutions are subject to significant forces and potential failure/maintenance during these events. Although relatively poor soil conditions result in concerns for stone dike settlement and increased construction quantities, alternative vertical wall (concrete panels, steel/vinyl sheetpile, timber pile walls) were eliminated from consideration for various reasons. Vertical wall construction on these long stretches of shoreline protection would greatly minimize water interaction and access for wildlife between the lake and the marsh. The proposed rock structures allow continued water interchange and the side slopes accommodate access by wildlife. In addition the vertical wall construction would result in 100% wave refraction in this shallow water region, likely resulting in scour at the wall toe along the structure. Vertical construction alternatives such as concrete and sheetpile walls were eliminated for multiple reasons with two main concerns being: (1) for the fairly long lengths of proposed shoreline protection, these walls would deter "critter" access from the lake to the marsh, which is not a desirable feature in environmental mitigation. (2) Vertical walls result in basically 100% wave diffraction, which could result in undesired scour on the unprotected side in these proposed shallow water depths. Floating structures such as the concrete or tire devices, in addition to "appearance" on these environmental mitigation efforts, will (1) limit access to the bankline for recreational/fishing vessels, (2) be prone to vandalism and anchor fatigue, (3) result in specific maintenance requirements inherited by the local sponsor, which may not be as forgiving as stone structures. Displaced or detached units would likely require immediate maintenance response. Successful stone foreshore dike projects have been successfully completed in the project area. These existing project designs will be referenced and modeled/altered as necessary to achieve success. An alternative design will be considered during the PED phase for the worst areas of settlement to incorporate a lightweight core section into the dike design to minimize settlement and construction quantities.

Multiple rock placement efforts to provide shoreline protection in the project area have been completed and/or currently under construction. Anticipated rock quantity contingencies present in the report are based on actual placement efforts realized in these previous contracts.

- CWPPRA, PO-32 Contract called for foreshore construction of approximately 3.5 miles of Lake Borgne shoreline south of proposed feature BS-1. Work was completed in 2008. Geotechnical analysis recommended using an anticipated settlement rate of 75% in estimating contract quantities. The actual settlement rate based on final contract quantities was approximately 25%. A major under run was realized in the contract quantity. Based upon recent site visits, this reach of foreshore rock protection remains fairly stable.

- Lake Borgne Shoreline Protection, Bayou Bienvenue Reach contract calls for foreshore construction of approximately 2.6 miles of Lake Borgne shoreline. Geotechnical analysis recommended using an anticipated settlement rate of 60% in estimating contract quantities. The actual settlement rate based on ongoing construction (approximately 50% complete) is currently running at approximately 45%.

- Lake Borgne Shoreline Protection, Bayou Dupre Reach contract calls for foreshore construction of approximately 3.3 miles of Lake Borgne shoreline. (The proposed feature LS-1 falls between this Bayou Dupre Reach and the previously mentioned Bayou Bienvenue Reach on the south shore of Lake Borgne.) Geotechnical analysis recommended using an anticipated settlement rate of 40% in estimating contract quantities. The actual settlement rate based on ongoing construction (approximately 45 to 50% complete) is currently running at approximately 45% to 55%. However, the contractor was directed to target a slightly higher target elevation to accommodate this increased percentage, thereby purposely slightly increasing realized tonnage per foot.

- The CWPPRA Bayou Chevee Shoreline Protection contract constructed in 1996 called for foreshore protection construction covering slightly less than 2 miles of Lake Pontchartrain shoreline, immediately south of proposed feature ES-1. Contract quantities were based on an anticipated settlement rate of approximately 40%. Actual settlement realized came in slightly lower. This reach of foreshore rock protection appears fairly stable today, approximately 15 years after construction.

Actual settlement rates for the aforementioned contracts, all on Lake Borgne and Lake Pontchartrain ranged from approximately 25% to 55%. As such, estimated settlement rates of 40% to 50% were used in quantifying Lake Shoreline features of this report.

Preliminary survey data has been obtained for previously proposed Breton Sound shoreline protection reaches. Preliminary geotechnical analysis indicates that rock structures in these water depths would require significant stability berms in addition to additional unanticipated rock quantities to reach desired height of protection. Due to these greater than anticipated water depths at the project sites and associated significant feature construction cost increases, offshore stone protection on the outer reaches of existing Biloxi Marsh were not carried forward. Feature BS2 will now be designated as an oyster reef demonstration area as a result of significant public comment that artificial oyster reefs should be a component of the plan, as surveys indicate this area would be suitable.

Descriptions of the remaining lake shoreline protection features, and general information on a proposed oyster reef element are as follows.

5.3.1.1 BS1

Element BS1 is located along the northeast shoreline of Lake Borgne (plate C-10). The project can be described as a nearshore stone dike, constructed along the existing water's edge for the purpose of shoreline protection. In conjunction with several other completed and proposed shoreline protection efforts, this reach of proposed work will complete shoreline protection of the entire south

lobe of Lake Borgne. This rock feature will tie into a reach of shoreline protection proposed under the State DNR CIAP efforts, beginning at Pointe Aux Marchettes and extending north east for approximately 10 miles. This project will halt shoreline erosion; protecting an estimated 50,637 feet of shoreline. The foreshore dike alignment intersections several natural bayous and canals which open up into Lake Borgne, and allow tidal interaction. These natural openings will be accommodated with 11 anticipated gaps in the foreshore dike to allow continued fish and wildlife access into the interior marshes.

Foreshore rock protection is proposed to stop wind driven wave erosion, and enlargement of natural openings into the marsh platform. Continued erosion along this reach will result in further fragmentation of the shoreline, increased tidal influence into the marsh, and accelerated recession of the shoreline. This area is currently eroding at approximately 3 to 5 feet per year due to storm and wind driven wave erosion.

The rock protection will be configured as a linear near-shore dike section. 10 cross section surveys were taken in March 2011 at approximate one (1) mile intervals along the proposed rock dike construction alignment. A stability analysis was performed based on existing borings in the vicinity and cross section data that was taken. Results of this analysis indicated that a 36 foot wide stability berm sloped from elevation 0.0 to elevation -1.0 was required to meet a 1.3 safety factor. This stability berm requirement significantly increased the anticipated cost of this construction feature, and will be revisited if more comprehensive surveys and analysis are conducted during a PED phase of design. This future evaluation may result in the incorporation of a light-weight core section embedded in the dike template to reduce structure weight and ultimate berm requirements. A lightweight core section has been previously used in previous Lake Borgne shoreline foreshore protection on the CWPPRA PO-32 contract along the south east rim of the lake, completed in 2008. A theoretical dike template of the currently proposed design is provided in the Geotechnical write-up of the Engineering appendix. The proposed dike centerline will be located at the approximate -2.0 to -3.0 foot contour. Although it was desirable to potentially construct slightly further offshore to allow for backfilling of the structure with flotation excavation material, deeper water depths further offshore discouraged this course of action. Each of the ten survey cross sections taken was assigned to a specific reach of shoreline based on shoreline topography. Stone quantities for the dike proper and the required stability berm were computed and an additional 40% of the dike proper quantity was added for anticipated settlement. Settlement was not added to the berm section. The dike will be constructed to an elevation of +4.0 NAVD88 with a 4-foot crown width. The dike will be constructed of a graded 1500# top size stone, underlain with a geotextile fabric to minimize settlement. The geotextile fabric quantity was computed, adding an additional 5 foot extension on either toe. The geotextile was measured in square yards. Overlapped fabric was not computed for quantification. An average width of 83' of geotextile was required. It is currently estimated that 890,000 tons of stone and 470,000 square yards of separator geotextile fabric will be required to complete this construction effort.

Flotation dredging is anticipated for access to the site for construction equipment and material barges. Flotation excavation along the dike alignment will be limited to an 80-foot bottom width channel not to exceed elevation -7.0 NAVD88. This limited flotation depth has been used successfully for similar work in Lake Borgne and Lake Pontchartrain with no serious implications to project cost. Flotation dredging was restricted to 10 feet beyond the toe of the stability berm. Barge

access to the site is available via the GIWW through the Rigolets and across Lake Borgne. The survey sections indicated that access corridors from the lake to the worksite were likely not required as the lake nearshore depths approach the -7.0' target in the vicinity of the outer limit of the flotation channel. As such, adequate deep water in the vicinity of the project will support movement of materials and equipment. Material excavated from the flotation channel would be stockpiled lakeside of the flotation channel to be backfilled if necessary upon completion of construction. The intent of this backfill requirement is to remove any shallow obstructions to recreational navigation. It is anticipated that the majority of stockpiled material will be washed away by wave action during the construction duration and any subsequent backfilling requirements will be minimal. The construction duration for total completion of this feature was estimated for two (2) separate contracts at approximately 845 days per contract.

5.3.1.2 LS1

Element LS1 is located in southern Lake Borgne, to be constructed along the perimeter of Proctor Point between the eastern and western lobes of Lake Borgne (plate C-42). The project can be described as a nearshore stone dike, constructed along the existing water's edge for the purpose of shoreline protection. This rock feature is bounded by the ongoing $75 million supplemental Bayou Dupre rock project to the west, and the proposed $75 million supplemental West of Shell Beach shoreline protection project to the east; extending along the lake shoreline for approximately 8.7 miles. This project will halt shoreline erosion, protect an estimated 45,000 feet of shoreline, and assist in retention of dredged material for future proposed marsh creation/nourishment efforts on Proctor Point (Element LM2). The foreshore dike alignment intersections several natural bayous and canals which open up into Lake Borgne, and allow tidal interaction. These natural openings will be accommodated with six (6) anticipated gaps in the foreshore dike to allow continued vessel traffic and allow fish and wildlife access into the interior marshes.

Foreshore rock protection is proposed for construction to stop wind driven wave erosion. The bankline of Lake Borgne in this area is eroding at approximately 4 feet per year conservatively) due to storm and wind driven wave erosion. Critical breaches in the shoreline are impacting interior wetland habitat including shallow water ponds and vegetated marshes. The interior marshes continue to fragment due to subsidence and tidal flows. The rock protection will be configured as a linear near shore dike section. 10 cross section surveys were taken in 2011 at approximate one (1) mile intervals along the proposed rock dike construction alignment. A stability analysis was performed based on existing borings in the vicinity and cross section data that was taken. Results of this analysis indicated that a significant 55-foot wide stability berm sloped from elevation 1.0 to elevation 0.0 was required to meet a 1.3 safety factor. In addition, a 25-foot landside berm was recommended at elevation +1.5. These are the most significant stability berm requirements of all the proposed stone features, significantly increasing the anticipated cost of this construction feature, and potentially resulting in construction complications due to the limited reach of anticipated stone placement equipment. As discussed in the BS-1 write-up above, future evaluation of this feature will also include the incorporation of a light-weight core section embedded in the dike template to reduce structure weight and ultimate berm requirements. The current theoretical dike template is provided in the Geotechnical write-up of the Engineering appendix. Promisingly, the ongoing foreshore dike construction within the Bayou Dupre reach immediately west of Proctor Point is currently being successfully constructed without berm requirements, and it is anticipated that further analysis during the PED phase will minimize the current berm recommendations for this feature. As such, the

lakeside dike template was modified to incorporate a 35' berm for quantity computations. In general this will result in a lower safety factor, but minimizes required stone quantities and constructability concerns. Additional borings would likely be taken during PED to more closely analyze required berm widths. However, as no life or infrastructure is impacted by the lower safety factor, current considerations could be given to proceeding with a lesser berm as was done on other reaches of Lake Borgne shoreline protection construction. In general, the proposed dike will be located at the approximate -2.0 to -3' foot contour, with the lakeside toe at the approximate -3.0 to -4.0 NAVD88 contour. Two survey lines taken on the east side of Proctor Point indicate deeper waters along that reach of bankline. The design may be converted to a bank paving section if comprehensive surveys taken during the next PED phase reveal consistent deeper waters. Each cross section taken was assigned to a specific section of shoreline based on shoreline topography. Stone quantities for the dike proper and the required stability berm were computed and an additional 40% of the dike proper quantity was added for anticipated settlement. Settlement was not added to the berm section. The dike will be constructed to an elevation of +4.0 NAVD88 with a 4-foot crown width. The dike will be constructed of a graded 1500# top size stone, underlain with a geotextile fabric to minimize settlement. The geotextile fabric quantity was computed, adding an additional 5 foot extension on either toe. The geotextile was measured in square yards. Overlapped fabric was not computed for quantification. An average width of 90' of geotextile was required. It is currently estimated that 930,000 tons of stone and 450,000 square yards of separator geotextile fabric will be required to complete this construction effort.

Flotation dredging along the dike alignment is anticipated for access to the site for construction equipment and material barges. Flotation excavation along the dike alignment will be limited to an 80-foot bottom width channel not to exceed elevation -7.0 NAVD88. Flotation dredging quantities were based from the hydrographic survey cross sections taken within this feature reach. In general, the flotation channel would begin approximately 70' off the dike centerline. In general, material excavated from the flotation channel would be stockpiled lakeside of the flotation channel to be backfilled if necessary upon completion of construction. The intent of this backfill requirement is to remove any shallow obstructions to recreational navigation upon completion of construction. It is anticipated that the majority of stockpiled material will be washed away by wave action during the construction duration and any subsequent backfilling requirements will be minimal. Backfill requirements will be estimated at approximately 25% of the original flotation excavation quantity.

Barge access to the site is available via the GIWW through Chef Pass. Any required access channel from the lake to the flotation channel alignment would be minimal. Access corridors, if used, would be spaced approximately 1 mile apart, with a bottom width not to exceed 100'. The construction duration for total completion of this feature was estimated for two (2) separate contracts at approximately 871 days per contract.

5.3.1.3 ES3

Element ES3 is located in the northwest quadrant of Lake Borgne (plate C-8). The project is fronting the GIWW and ultimately Lake Catherine. The project can be described as a nearshore stone dike, constructed along the existing water's edge for the purpose of reducing shoreline erosion and protection of adjacent marsh. In conjunction with several other completed and proposed shoreline protection efforts, this reach of proposed work will complete protection of the entire Lake Borgne shoreline south of the Rigolets. This rock feature will tie into a reach of shoreline protection proposed

under the State DNR CIAP efforts (Orleans Land bridge Shoreline Protection Project, PO-36), beginning at Alligator Point and extending north approximately 14 miles to the Rigolets. This project will halt shoreline erosion, protect an estimated 70,020 feet of shoreline. The foreshore dike alignment intersections several natural bayous and canals which open up into Lake Borgne. These natural openings will be accommodated with eight (8) gaps in the foreshore dike to allow continued vessel traffic and well as fish and wildlife access into the interior marshes.

Foreshore rock protection is proposed for construction to stop wind driven wave erosion, and enlargement of natural openings into the marsh platform. This reach of Lake Borgne shoreline fronts a critical land bridge between Lake Borgne and Lake Catherine, and affords a barrier between Lake Borgne and the GIWW. The bankline of Lake Borgne fronts numerous openings into the marsh, which allow tidal interaction. Continued erosion along this reach will result in further fragmentation of the shoreline, increased tidal influence into the marsh, and accelerated recession of the shoreline. This area is currently eroding at approximately 6-9 feet per year due to storm and wind driven wave erosion.

The rock protection will be configured as a linear near shore dike section. 14 cross section surveys were taken in March 2011 at approximate one (1) mile intervals along the proposed rock dike construction alignment. A stability analysis was performed based on existing borings in the vicinity and cross section data that was taken. Results of this analysis indicated that a 14 foot wide stability berm at -0.5 was required to meet a 1.3 safety factor. This stability berm will also provide toe protection against wave wash for the entire project reach. A theoretical dike template is provided in the Geotechnical write-up of the Engineering appendix. The proposed dike will be located at the approximate -2.0 foot contour. The dike will be constructed to an elevation of +4.0 NAVD88 with a 5-foot crown width. Each cross section taken was assigned to a specific section of shoreline based on shoreline topography. Stone quantities for the dike proper and the required stability berm were computed and an additional 50% of the dike proper quantity was added for anticipated settlement. Settlement was not added to the berm section. The dike will be constructed of a graded 1500# top size stone, underlain with a geotextile fabric to minimize settlement. The geotextile fabric quantity was computed, adding an additional 4 foot extension on either toe. The geotextile was measured in square yards. Overlapped fabric was not computed for quantification. An average width of 55' of geotextile was required. It is currently estimated that 655,000 tons of stone and 425,000 square yards of separator geotextile fabric will be required to complete this construction effort.

Flotation dredging is anticipated for access to the site for construction equipment and material barges. Flotation excavation along the dike alignment will be limited to an 80-foot bottom width channel not to exceed elevation -7.0 NAVD88. Flotation dredging was restricted to 20 feet beyond the toe of the stability berm. Required flotation excavation is estimated at approximately 600,000 cubic yards of earthen material, to be stockpiled lakeside of the flotation channel for backfilling upon completion of construction. As stated in previous write-ups, the intent of this backfill requirement is to remove any shallow obstructions to recreational navigation upon completion of construction. It is anticipated that the majority of stockpiled material will be washed away by wave action during the construction duration, minimizing any subsequent backfilling. Backfill requirements will be estimated at approximately 25% of the original flotation excavation quantity.

Barge access to the site is available via the GIWW through the Rigolets and across Lake Borgne. The survey sections indicated that access corridors from the lake to the worksite would be required to provide adequate water depths to support movement of materials and equipment, especially in the deep cove in the southern half of the project. The corridors will be spaced approximately 1 mile apart, with a bottom width not to exceed 100'. The construction duration for total completion of this feature was estimated for two (2) separate contracts at approximately 778 days per contract.

5.3.1.4 ES1

Element ES1 is located in eastern Lake Pontchartrain (plate C-6). The actual work limits are bounded by a rail road bridge and existing shoreline protection above the I-10 to the north, and extends south to the existing CWPPRA Bayou Chevee shoreline protection project to the south. The project will be constructed as a nearshore stone dike, constructed along the existing water's edge for the purpose of reducing shoreline erosion and protection of existing infrastructure and adjacent marsh. This project will halt shoreline erosion, protect an estimated 20,530 feet of shoreline. The foreshore dike alignment intersects several natural openings and canals which open up into the Lake Pontchartrain Middle Ground. These natural openings will be accommodated with approximately five (5) gaps in the foreshore dike to allow continued fish and wildlife access into the interior marshes, as well as boat access into the Irish Bayou Community. Project alignment will also be gapped at the crossing for the I-10 and I-11 corridor, where existing shoreline protection exists.

Six (6) cross sections were taken in March 2011 at approximate one-half to one (1) mile intervals along the proposed rock dike construction alignment. These surveys indicated a general bankline recession of approximately 4-feet per year based on comparison with the 2005 photography. Each survey line was plotted in cross section format and the stone template superimposed. Each cross section was assigned a specific section of shoreline based on shoreline topography. Stone quantities for the dike were computed and an additional 40% of the dike quantity was added for anticipated settlement.

The rock foreshore dike will be constructed to a crown elevation of +4.0' with a 5' crown and 1V on 2H side slopes. A 3-foot wide stability bench at elevation +1 is required on both sides of the dike centerline. A theoretical dike template is provided in the Geotechnical write-up of the Engineering appendix. The dike will be constructed of a graded 1500# top size stone, underlain with a geotextile fabric to minimize settlement. Based on the resulting dike footprint, the geotextile fabric quantity was computed, adding an additional 5-foot extension on either toe. The geotextile was measured in square yards. Overlapped fabric was not computed for quantification. An average width of 43-feet of geotextile was required. It is currently estimated that 210,000 tons of stone and 100,000 square yards of separator fabric will be required to complete this construction effort.

Barge access to the site is available via the GIWW through the Rigolets or via IHNC and across Lake Pontchartrain. Flotation dredging is anticipated for access to the site for construction equipment and material barges. Flotation excavation along the dike alignment will be limited to an 80-foot bottom width channel not to exceed elevation -7.0 NAVD88. Due to bankline profiles realized from the survey effort, disposal of flotation excavation materials landside of the flotation channel does not

appear feasible. All flotation excavation will be stockpiled on the lake side to be backfilled upon completion of construction. Flotation excavation will be restricted to 50-feet beyond the dike centerline. South of the I-10, two gaps in the foreshore dike alignment are proposed; the first a navigation gap at the entrance to the Irish Bayou area, and the second a water access gap to the open water areas west of the existing shoreline. Access corridors will be allowed to accommodate barge movement during construction. The corridors, if used, will be spaced approximately one (1) mile apart, with a bottom width not to exceed 100'. Material from the access corridors will be side cast and backfilled upon completion of construction. The construction duration for total completion of this feature is approximately 788 days.

5.3.1.5 ES2

Element ES2 is located in eastern Lake Pontchartrain, in an area sometimes defined as "Middle Ground" (see plate C-7). The work limits are bounded by Chef Pass and the Rigolets. The site is broken out into three separate reaches, separated by existing camps and similar structures.

This reach of Lake Pontchartrain shoreline fronts a critical land bridge between Lake Pontchartrain and Lake Catherine, and affords a barrier between Lake Pontchartrain and the GIWW. The project will be constructed as a nearshore stone dike, constructed along the existing water's edge for the purpose of reducing shoreline erosion and protection of existing infrastructure and adjacent marsh. This project will halt shoreline erosion; protecting an estimated 30,765 non-continuous feet of shoreline. The foreshore dike alignment intersects several natural openings and canals which open up into the Lake Pontchartrain Middle Ground. These natural openings will be accommodated with seven (7) gaps in the foreshore dike to allow continued fish and wildlife access into the interior marshes.

Five (5) cross sections were taken in March 2011 at approximate one (1) mile intervals along the proposed rock dike construction alignment. Each survey line was plotted in cross section format and the stone template superimposed. Each cross section was assigned a specific section of shoreline based on shoreline topography. Stone quantities for the dike were computed and an additional 50% of the dike quantity was added for anticipated settlement.

The rock foreshore dike will be constructed to a crown elevation of +4.0' with a 5' crown and 1V on 2H side slopes. A 3-foot wide stability bench at elevation +1 is required on both sides of the dike centerline. A theoretical dike template is provided in the Geotechnical write-up of the Engineering appendix. The dike will be constructed of a graded 1500# top size stone, underlain with a geotextile fabric to minimize settlement. Based on the resulting dike footprint, the geotextile fabric quantity was computed, adding an additional 5-foot extension on either toe. The geotextile was measured in square yards. Overlapped fabric was not computed for quantification. An average width of 43-feet of geotextile was required. It is currently estimated that 310,000 tons of stone and 150,000 square yards of separator fabric will be required to complete this construction effort.

Flotation dredging is anticipated for access to the site for construction equipment and material barges. Flotation excavation along the dike alignment will be limited to an 80-foot bottom width channel not to exceed elevation -7.0 NAVD88. Barge access to the site is available via the GIWW through the Rigolets. The project alignment offers a fairly broken shoreline. In general, all flotation

excavation will be stockpiled on the lake side to be backfilled upon completion of construction. This is to assure no underwater obstructions remain fronting the shoreline upon demobilization of the construction equipment. In isolated pockets where possible, the required flotation excavation will be cast landward of the dike alignment in an effort to beneficially use this material to restore the shoreline embankment. Flotation excavation will be restricted to 50-feet beyond the dike centerline. Access corridors will be allowed to accommodate barge movement during construction. The corridors, if used, will be spaced approximately one (1) mile apart, with a bottom width not to exceed 100'. Material from the access corridors will be side cast and backfilled upon completion of construction. The construction duration for total completion of this feature is approximately 401 days.

5.3.1.6 BS2

As stated previously, Breton Sound Shoreline Protection features were eliminated from further consideration due to greater than anticipated water depths at the project sites and associated significant feature construction cost increases. In lieu of total elimination, it was decided to replace the proposed stone foreshore feature at BS2 with various bio-engineered oyster reef units. In addition to simple placement of limestone pads to enhance and maintain oyster growth, several technical solutions to oyster reef construction exist that can be implemented into this Element design, including but not limited to concrete rings, metal frames, geotextile filled bags, etc. The Element BS2 footprint encompassed approximately seven (7) miles of shoreline, north of the MRGO and adjacent to the outer marsh fringe of Eloi Bay immediately south of Bayou La Loutre (plate C-11). It is envisioned that oyster reef units can be established with appropriate spacing and bedding as required to result in functioning units. For instance, doubling the width of the proposed features and halving the length provides a more compact (potentially more stable) final product for approximately the same construction effort and cost. Currently, approximately seven (7) miles of oyster habitat construction is assumed for this planning effort. These dimensions and final planning of feature layouts can be further coordinated with the local oyster industry and State planning representatives.

In an effort to regenerate oyster growth, a primary requirement is the creation of a hard surface onto which oyster larvae can attach to. Steel, rock, oyster shell, and wood are all potential materials; with the key to this demonstration project being to provide a stable platform, able to resist anticipated site conditions. Although this demonstration effort is proposing the use of pre-fabricated products and standard stone paving, the use of concrete rubble such as construction waste products should be considered for large scale production. Both the concrete and potential steel rebar would be adequate for this application.

For this demonstration project Element B2, located in Breton Sound bounded by Bayou La Loutre and Eloi Bay, was divided into three (3) fairly equal length test reaches. Each reach will be constructed as described below in an attempt to promote oyster growth. It should be understood that the ultimate design section(s) can be scaled to meet available funding and needs. Costs should be fairly proportional in enlarging the section, for instance doubling the width of the feature should approximately double the costs provided. All three (3) reaches are currently constructed to a width of 15' to 20' along the shoreline. In Reaches 1 and 2, a 6-inch crushed stone blanket was included to place atop a filter fabric base. In each scenario, the filter fabric width was set at 17 feet and the 6

inch crushed stone blanket width was set at 15 feet. This crushed stone will provide stability to the structure, assist in anchoring the filter fabric, add additional height to the structure, and provide additional oyster habitat. The quantity of fabric and crushed stone is exactly the same for both alternatives; the cost differential will rest solely in the commercial product cost. The proposed configuration not only provides oyster habitat, but should also provided some wave break potential for shoreline protection. No flotation excavation is anticipated for construction of these elements. The structures will all be built at approximately the -3.0 to -4.0 contour. It is desired to get the top of the structures to approximately the low water elevation. This will provide visual observability during low water and, as previously stated should provide some shoreline protection feature to these elements.

Reach 1, approximately 11,200 feet in length will be constructed using Triangular Steel Structures (Reefblks). These structures are prefabricated double framed steel rebar units which hold mesh bags that are filled with oyster shell and seed oysters. The structures emulate and create new artificial oyster reef, and potentially provide some immediate shoreline relief. Based on water depths at the project site, it is anticipated that these structures will be constructed within 50' of the existing marsh shoreline. The welded triangular frame measures 5' on each side and stands 3' high. On this frame hang nine mesh weave baskets filled with oyster shells. The units are deployed in a saw-tooth pattern to maximize bankline coverage. The weight of the 5' x 3' metal unit is 155 pounds. The complete unit with oyster bags weighs 530 pounds. No flotation dredging is anticipated to construct this test reach. The resulting structure could theoretically be placed on geotextile separator fabric alone in lieu of the crushed stone pad to minimize costs and to keep the soft earth foundation material out of the oyster reef structure. The crushed stone pads do however provide additional hard surface for oyster habitat. Each unit is anchored with a 3' screw anchor and cable.

Reach 2, approximately 11,200 feet in length will be constructed using 5' diameter concrete rings (OysterBreak). Two rows of concrete rings would be placed approximately 1 foot apart, and interlocked by a second layer single ring. This configuration (based on the 20" height of the rings) provides slightly over 3' in height, which mimics the Reach 1 metal frames. The configuration could be revised to place three (3) rows of rings in a single layer, covering approximately 17' per linear foot of bankline; providing a greater base footprint but less height. Concrete rings fabricated with oyster shell show significantly more success than concrete alone. Assuming the low center of gravity of these rings, no anchor system is proposed for this test reach.

Reach 3, approximately 13,200 feet in length will be the most simplistic of the construction efforts, involving placement of a crushed stone, oyster shell, or combination pad paralleling the shoreline. In an effort to compare the three alternatives, the pad will be constructed to a height of three feet and base width of approximately 15 feet. If constructed of oyster shell alone, it is recommended that the shell be contained in mesh bags to minimize losses and structure migration. This reach will also be placed on a geotextile separator fabric. The anticipated construction duration for total completion of this feature is approximately 318 days.

5.3.2 MRGO Bankline Restoration

One of the most direct impacts resulting from the existence of the MRGO channel is continued bankline erosion resulting from boat and wind waves and natural tidal action. Several different

feature alternatives are proposed to directly alleviate and mitigate bankline loss, including shoreline protection to stabilize existing bank lines, bankline reestablishment via placement of structural walls, and marsh creation behind the newly aligned shoreline configurations. Due to the construction of closure structures on both the north and south limits of the MRGO channel, access to MRGO ecosystem construction sites will be from the GIWW via Chef Pass or the Rigolets and then across Lake Borgne to either the Dupre Cut or Doullet's Canal.

5.3.2.1 MRGO Shoreline Restoration

The tentatively selected plan currently includes three (3) distinct reaches of north bank reestablishment between approximate miles 58.5 to 56.0, miles 48.2 to 44.4, and miles 39.9 to 37.5. These alternatives will narrow the open water top width of the MRGO by reestablishing a new north shore bank line via wall construction. These three reaches combine for a proposed 548 acres of marsh creation behind a combination vinyl sheet pile/timber pile wall. The wall will be constructed along approximately a -6.0 NAVD88 contour, and will serve not only as future shoreline protection, but also as a retention device for dredged material placement. In light of the retention requirements for marsh creation, the ultimate retention structure must be built to a minimum +4.0 NAVD88 elevation to allow for marsh platform overbuild and subsequent dewatering and settlement to a suitable target marsh elevation. Dredged material will be obtained by cutterhead dredging of the proposed borrow sites within Lake Borgne, and will be transported directly to the marsh creation and nourishment site via pipeline. Several alternatives were investigated for construction of these potential retention structures.

Rock Dike Retention. A standard rock foreshore dike was considered. Poor soil conditions prohibited the use of rock dike containment, which would required a theoretical 10-foot height along the proposed alignment. Anticipated continued settlement and failure concerns, in addition to the extensive quantities of rock required, eliminating this potential alternative.

Concrete Wall Retention. Concrete wall construction has been successfully completed for shoreline wave wash protection within the New Orleans District. The proposed wall called for 80-foot long x 18" grooved concrete piles at 20-foot spacing to provide structural strength. Installation of 6" thick x 20' wide x 6' tall concrete panels would complete the structure; being slid into the grooves between the piles for retention of dredged material. Two panels would be installed per section, resulting in complete coverage from +4.0 to -8.0 NAVD88. A crushed stone scour protection blanket was proposed on the channel side of the wall to prevent undermining. Preliminary geotechnical analysis indicated potential stability concerns upon placement of the marsh creation backfill, eliminating this alternative from consideration.

Vinyl Sheet pile/Timber Pile Retention. The tentatively selected plan calls for a combination timber pile/vinyl sheet pile wall section. The tentative design requires 70-foot class B treated timber piles driven at 4-foot spacing along the proposed wall alignment. Each pile will be battered within the marsh creation sites at a 30 degree angle with an additional similar pile. The timber piles will support a vinyl sheet pile wall, consisting of SG 950 vinyl sheet pile driven from +4.0 NAVD88 to -38.0 NAVD88. The wall will be completed with a double row of 4" x 6" timber wales, a 2" wide timber cap and associated hardware. Minimal strength geotextile separator fabric will drape the interior of the vinyl wall prior to marsh creation to maximize material retention. Due to the channel bed elevation

along the alignment and the recent closure construction on both ends of the MRGO channel, crushed stone toe protection was eliminated from the feature design. The depth of water along the wall alignment, deep embedment length of the proposed piles, and elimination of deep draft navigation wave action alleviated the concerns of toe scour along the proposed walls.

5.3.2.1.1 MRGO-7

Element MRGO-7 will be constructed along the north bank of the MRGO channel between approximate channel miles 58.5 to 56.0 (non-continuous), located immediately east of the IHNC Surge Barrier (plate C-29). It will consist of 9,170 linear feet of vinyl sheet pile wall, to be backfilled with earthen material to create approximately 110 acres of new marsh. Based on historic available surveys it is anticipated that the existing elevation within the marsh creation site is an average elevation of -4.5'. It was assumed that the adjacent marsh is an approximate average elevation of +1.5'. This will be the ultimate marsh target elevation for the proposed marsh creation. Borrow for the marsh fill is anticipated to come from approximately two (2) miles offshore in Lake Borgne, with pipeline access via Bayou Bienvenue. Borrow within the lake will be limited to a maximum of 10'-12' below the lake bottom. Including anticipated foundation settlement and contingencies, approximately 1,650,000 cubic yards of borrow material will be required to construct the proposed marsh platform. The proposed borrow site was sized at 192 acres to accommodate this need. Prior to hydraulic dredging and material placement, approximately 6,050 linear feet of backside retention dikes will be constructed along the existing marsh platform. In addition, approximately 3,750 linear feet of earthen closures will be required across open waters areas. These earthen retention features will be constructed to elevation +4.0 NAVD88 with a crown width of 5-feet, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. Interior borrow ditches will be allowed for construction of the earthen retention features, which will be backfilled during the marsh creation operation. The dredge material will be placed to an anticipated slurry elevation of +2.5 to +3.0, allowing for 1.0' to 1.5' of freeboard. Strategically placed overflow weirs will be located to allow dredge slurry to overflow and nourish additional existing marsh. No flotation excavation is anticipated to access and construct this feature. Stone bank protection features, approximately 150-feet in length, will be constructed at each point where the timber/vinyl walls tie-into the natural bankline. A total of approximately 4,000 tons of stone will be required for these features. The construction duration for total completion of this feature is approximately 230 days.

5.3.2.1.2 MRGO-8w

Element MRGO-8w will be constructed along the north bank of the MRGO channel between approximate channel miles 48.2 to 44.4 (non-continuous) (plate C-30). It will consist of 17,785 linear feet of vinyl sheet pile wall (plate S-9), to be backfilled with earthen material to create approximately 236 acres of new marsh. Based on historic available surveys it is anticipated that the existing elevation within the marsh creation site is an average elevation of -5.0'. It was assumed that the adjacent marsh is an approximate average elevation of +1.5'. This will be the ultimate marsh target elevation for the proposed marsh creation. Borrow for the marsh fill is anticipated to come from within two (2) miles offshore in Lake Borgne, with pipeline access via an existing access canal West of Shell Beach to the MRGO channel. Borrow within the lake will be limited to a maximum of 10'-12' below the lake bottom. Including anticipated foundation settlement and contingencies, approximately 3,500,000 cubic yards of borrow material will be required to construct the proposed marsh platform.

The proposed borrow sites were sized at 400 acres to accommodate this need. Two separate polygons were identified to provide adequate borrow and avoid depicted environmental "hard bottom" locations. Prior to hydraulic dredging and material placement, approximately 23,800 linear feet of backside retention dikes will be constructed along the existing marsh platform. In addition, approximately 2,800 linear feet of earthen closures will be required across open waters areas. These earthen retention features will be constructed to elevation +4.0 NAVD88 with a crown width of 5-feet, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. Interior borrow ditches will be allowed for construction of the earthen retention features, which will be backfilled during the marsh creation operation. The dredge material will be placed to a maximum slurry elevation of +2.5 to +3.0, allowing for 1.0' to 1.5' of freeboard. Strategically placed overflow weirs will be located to allow dredge slurry to overflow and nourish additional existing marsh. No flotation excavation is anticipated to access and construct this feature. Stone bank protection features, approximately 150-feet in length, will be constructed at each point where the timber/vinyl walls tie-into the natural bankline. A total of approximately 4,000 tons of stone will be required for these features. The vinyl wall construction under consideration for this element is divided into two distinct non-continuous reaches. Between these two (2) reaches the element proposal calls for approximately 2,140 linear feet of foreshore dike construction. The dike will be constructed to elevation +4.0 NAVD88, with a 4 foot crown and 1v on 2h side slopes. The dike centerline will target construction along the -2.0' contour, resulting in a quantity including anticipated settlement and contingencies of approximately 20,000 tons. The dike will require geotextile fabric underlay to minimize settlement, extending 4 feet beyond each toe-of-dike. The anticipated fabric quantity including a 10% contingency is approximately 9,700 square yards. The construction duration for total completion of Feature MRGO-8w is approximately 306 days.

5.3.2.1.3 MRGO-5

Element MRGO-5 will be constructed along the north bank of the MRGO channel between approximate channel miles 39.9 to 37.5 (plate C-27). It will consist of 13,685 linear feet of vinyl sheet pile wall, to be backfilled with earthen material to create approximately 236 acres of new marsh. Based on historic available surveys it is anticipated that the existing elevation within the marsh creation site is an average elevation of -4.0'. It was assumed that the adjacent marsh is an approximate average elevation of +1.5'. Borrow for the marsh fill is anticipated to come from approximately two (2) miles offshore in Lake Borgne, with pipeline access via Doullut's Canal to the MRGO channel. Borrow within the lake will be limited to a maximum of 10' to 12' below the lake bottom. Including anticipated foundation settlement and contingencies, approximately 3,000,000 cubic yards of borrow material will be required to construct the proposed marsh platform. The proposed borrow site was sized at 336 acres to accommodate this need. Prior to hydraulic dredging and material placement, approximately 14,950 linear feet of backside retention dikes will be constructed along the existing marsh platform. In addition, approximately 2,050 linear feet of earthen closures will be required across open waters areas. These earthen retention features will be constructed to elevation +4.0 NAVD88 with a crown width of 5-feet, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. Interior borrow ditches will be allowed for construction of the earthen retention features, which will be backfilled during the marsh creation operation. The dredge material will be placed to an anticipated slurry elevation of +2.5 to +3.0, allowing for 1.0' to 1.5' of freeboard. Strategically placed overflow weirs will be located to allow dredge slurry to overflow

and nourish additional existing marsh. Minimal flotation excavation may be required in the western half of the project reach to assure adequate access to the project site. All material excavated for flotation access will be cast to the north of the wall alignment and used in the marsh creation effort. Stone bank protection features, approximately 150-feet in length, will be constructed at each point where the timber/vinyl walls tie-into the natural bankline. A total of approximately 2,000 tons of stone will be required for these features. The construction duration for total completion of this feature is approximately 555 days.

5.3.2.2 MRGO Shoreline Protection

In addition to the bankline restoration features above, additional reaches of the north bank of the MRGO are included in this restoration plan to be protected along their existing alignment with newly constructed stone foreshore dikes. These dikes are proposed landward of the -4.0 NAVD88 contour to minimize stone quantities and afford protection against continued bankline recession and erosion. With the de-authorization of the MRGO channel, vessel driven waves resulting from deep draft navigation are no longer a concern. Preliminary hydraulic analysis was performed to provide minimal foreshore criteria such as stone size, dike crown width and height. To protect against the smaller tidal and wind-driven waves, a standard near-shore trapezoidal stone dike with a 4-foot crown to elevation +3.0 NAVD88 is sufficient for bankline protection. The dike side slopes will be specified as 1v on 3h channel side, and 1v on 2h marsh side to better accommodate wave run-up on the channel side. Prior to the discontinuation of deep draft navigation and the stone closure of the MRGO, all foreshore work on the navigation channel was constructed using 2200# top size stone gradation to protect against vessel driven waves. All MRGO shoreline protection features inshore of the existing stone channel closure in the proximity of Bayou la Loutre at channel mile will now be constructed using the following stone proposed stone gradation:

Stone (Weight in Pounds)	Percent Finer by Weight
650-260	100
280-130	50
130-40	15

Three (3) reaches of new foreshore dike protection are proposed as follows:

5.3.2.2.1 MRGO-1

Element MRGO-1 will be constructed along the north bank of the MRGO channel between approximate channel miles 56.6 and 57.4 (plate C-23B). This stone protection feature is embedded within the limits of the non-continuous shoreline restoration Element MRGO-7 discussed above. It will consist of approximately 3,848 linear feet of rock foreshore dike, constructed immediately nearshore of the existing marsh platform within these limits. This dike structure will be constructed with a 4-foot crown width to elevation +3.0 NAVD88. Dike side slopes will be 1v on 3h channel side, and 1v on 2h marsh side. The trapezoidal stone dike section will be underlain with a geotextile separator fabric. The requirement for flotation excavation to access the site with rock and equipment barges is anticipated. Allowances for flotation dredging will be limited to an access channel located 50-feet off the centerline of the proposed structure, not to exceed 80' in width or elevation -7.0

NAVD88. Material excavated for flotation will be stockpiled channelward of the rock structure and backfilled upon completion of the construction effort. It appears based on survey analysis that water depths for a majority of the work reach are already adequate for equipment and material barges. It will be assumed that only half of the dike alignment will require minimal flotation dredging. Estimated flotation excavation quantity is 12,000 cubic yards. Preliminary analysis indicates that approximately 45,000 tons of stone and 20,000 square yards of geotextile fabric will be required to complete construction of this element. The construction duration for total completion of this feature is approximately 85 days.

5.3.2.2.2 MRGO-8r

Element MRGO-8r will be constructed along the north bank of the MRGO channel between approximate channel miles 50.9 and 48.2 (plate C-31). This stone protection feature is immediately west of and ties into the limits of the shoreline restoration Element MRGO-8 discussed above. The western limit of work ties into existing foreshore protection. This feature will consist of approximately 14,825 linear feet of rock foreshore dike, less three (3) 200-foot gaps left within the alignment for navigation and water interchange, constructed immediately nearshore of the existing marsh platform within these limits. The water interchange gaps will be left at existing openings and/or natural bayous, and will allow fish and wildlife habitat passage into the interior marshes. This dike structure will be constructed with a 4-foot crown width to elevation +3.0 NAVD88. Dike side slopes will be 1v on 3h channel side, and 1v on 2h marsh side. The trapezoidal stone dike section will be underlain with a geotextile separator fabric. Flotation excavation to access the site with rock and equipment barges is anticipated. Allowances for flotation dredging will be limited to an access channel located 50-feet off the centerline of the proposed structure, not to exceed 80' in width or elevation -7.0 NAVD88. Material excavated for flotation will be cast behind the dike alignment where adequate open water exists, or stockpiled channelward of the rock structure and backfilled upon completion of the construction effort. Estimated flotation excavation quantity is 90,000 cubic yards. Preliminary analysis indicates that approximately 165,000 tons of stone and 75,000 square yards of geotextile fabric will be required to complete construction of this element. The construction duration for total completion of this feature is approximately 423 days.

5.3.2.2.3 MRGO-6

Element MRGO-6 will be constructed along the north bank of the MRGO channel between approximate channel miles 35.7 and 34.2, non-continuous (plate C-28). This stone protection feature is immediately east of the existing stone channel closure of the MRGO, and ties into an existing foreshore dike which ends immediately downstream of that structure. Element MRGO-6 will consist of approximately 8,132 linear feet of rock foreshore dike, constructed immediately nearshore of the existing marsh platform within these limits. This proposed foreshore extension is broken into two (2) reaches separated by natural water access channels. The lengths of these two reaches are approximately 3,820 feet and 4,312 feet respectively. This dike structure will be constructed with a 4-foot crown width to elevation +4.0 NAVD88. This is slightly higher than the proposed shoreline protection inside the channel closure to account for more significant weather induced waves. Dike side slopes will be 1v on 3h channel side, and 1v on 2h marsh side. The trapezoidal stone dike section will be underlain with a geotextile separator fabric. Minimal requirements for flotation excavation to access the site with rock and equipment barges is anticipated. Allowances for flotation

dredging will be limited to an access channel located 50-feet off the centerline of the proposed structure, not to exceed 80' in width or elevation -7.0 NAVD88. Material excavated for flotation, where necessary, will be stockpiled channelward of the rock structure and backfilled upon completion of the construction effort. Preliminary analysis indicates that approximately 113,000 tons of stone and 45,000 square yards of geotextile fabric will be required to complete construction of this element. Because of the project location outside of the MRGO stone channel closure, access to the site for equipment and construction materials will likely be from the Mississippi River via the Baptiste Collette/MRGO Alternate Route. The construction duration for total completion of this feature is approximately 382 days. This element will be constructed using a top size of 2200# stone since it's outside the protection of the MRGO closure. Standard requirements for this gradation of stone are as follows:

Stone (Weight in Pounds)	Percent Finer by Weight
2200-900	100
930-440	50
460-130	15

5.3.2.3 MRGO Shoreline Repairs

Several existing stone foreshore features exist along the north shore of the MRGO channel, all constructed to minimize damage to existing marsh and to retain existing shoreline materials from sluffing into the MRGO channel. Although the majority of these existing features were repaired after Hurricane Katrina, it is prudent to consider the long term maintenance requirements of all existing and proposed ecosystem features and those features that provide protection thereto. Protection to existing MRGO north bank shoreline protection features are not warranted at the time of this document preparation, but repairs to these elements will be done as needed. Repairs to these structures will consist of capping the existing structure with additional stone, and/or repairing isolated failures, areas of settlement, and breaches. The dike structures will be restored to an elevation of +3.0 NAVD88 with a 4-foot crown width. Specific features meeting this description are tabulated in the chart below:

Feature Name	Description	Location
MRGO-2	North Shore Foreshore	MRGO Miles 44.4 to 39.9 (Non-Continuous).

Eight distinct reaches of existing rock foreshore exist within these miles, separated by existing canals or back water bodies. Respective reaches of rock navigating from west to east are approximately 2350', 1378', 726', 1178', 2188', 4890', 4982' and 3938' in length, for a total feature length of 21,630 linear feet. No fabric underlay is required for this maintenance effort. Based on site surveys, majority of these reaches will require minimal flotation dredging to access for equipment and material barges. Maintenance cycles would be targeted on a 10-year cycle, beginning in Target year 10.

MRGO-3	North Shore Foreshore	MRGO Miles 56.0 to 51.0(Non-Continuous)

Similar to the MRGO-2 reach, this project feature is segmented into nine distinct reaches of rock foreshore due to the fragmented existing bankline, existing canals or back water bodies, etc. The combined total feature length is approximately 26,650 linear feet. No fabric underlay is required for this maintenance effort. Based on site surveys, no flotation dredging is required for equipment and material barges access. Maintenance cycles would be targeted on a 10-year cycle, beginning in Target year 10.

MRGO-4	North Shore Foreshore	MRGO Miles 35.6 to 37.2 (Non-Continuous) and MRGO Miles 33.9 to 32.9

These existing rock elements were constructed as retention features for marsh creation and nourishment during backfilling of existing pipeline canals. The reach of non-continuous dike between miles 35.6 and 37.2 spans the MRGO stone closure and will require separate access from either side of the closure to complete construction. These reaches of foreshore dike are currently in fairly stable condition. Stone repairs inside the MRGO closure structure will cover 4,550 linear feet of existing foreshore. No flotation dredging is anticipated for this reach of repairs. Access will be through Lake Borgne. The reach(es) of repairs outside the MRGO stone closure structure will require access via the MRGO channel; most likely using the Baptiste Collette/MRGO Alternate Route from the Mississippi River. Repairs of the reach of foreshore dike between miles 33.9 and 32.9 will span 5,058 linear feet of existing foreshore dike and will likely require moderate flotation excavation to access the project footprint by equipment and materials barges. A slightly larger stone gradation will be used outside the closure structure than inside due to potential higher wave/storm energy. Maintenance cycles would be targeted on a 10-year cycle, beginning in Target year 10.

5.4 DIVERSION CHANNEL EXCAVATION AND DISPOSAL

5.4.1 Project Description

Feature D 1 is for the construction of a freshwater diversion near Violet, LA located in St Bernard Parish (see plate C-42). The proposed diversion would be constructed off the Mississippi River, approximate river mile 85.8L AHP. The diversion channel will be approximately 22,500' in length and tie into the MRGO at approximate Mile 55.6.

The diversion channel will be constructed to a 375' bottom width, with side slopes between 1V on 3H and 1V and 4H (to be verified upon receipt of geotech field data and tests prior to submission of final feasibility) and with a invert for the channel ranging from approximate elevation -8.5' NAVD88 (2004.65) on the river side to approximate elevation -11.5' NAVD88 (2004.65) on the MRGO side. In addition, a minimum 40' berm would be maintained between the inner toe of the guide levees and the top of cut of the diversion channel, with the exception of the Central Wetlands reach where a minimum 60' berm would be required. Excluding excavation required for the structural components associated with this diversion, approximately 4,090,000 gross CYS (net grade plus 1' of allowable overdepth) will be excavated for construction of the diversion channel.

The diversion channel will consist of excavation within 3 specific reaches. The first reach will extend between Highway 46 (E. St. Bernard Highway) and the 40 Arpent Levee. Approximately 1,240,000 gross CYS will be excavated from within this reach. Approximately 607,000 cys will be used for construction of guide levees along both banks of the diversion channel. At this time, based upon the limited geotechnical and survey data currently available, the guide levees would be constructed to a maximum 6' height above the natural ground line with 1V on 6H side slopes and an approximate crown width of 175'. Disposal of this material would be uncompacted.

As the material within the Central Wetlands area (located between the 40 Arpent Levee and the back dike canal immediately south of and adjacent to the MRGO south bank disposal area) is not considered suitable for guide levee construction, the remaining 633,000 gross CYS to be excavated from within the reach between Highway 46 and the 40 Arpent Levee will be hauled to the Central Wetlands to cap the core of the guide levees to be constructed within that reach of the proposed diversion. Prior to placement of this material, a 3' thick sand fill base approximately 90' wide would be placed along the guide levee alignments, along with an additional 3' high sand core with a 12' crown. Approximately 200,000 CYS of sand would be required. In addition, a 950 lbs/ft geotextile will also be placed over the 3' sand fill base prior to construction of the 3' sand core and excavated fill cap and berm. See Figure 77 below.

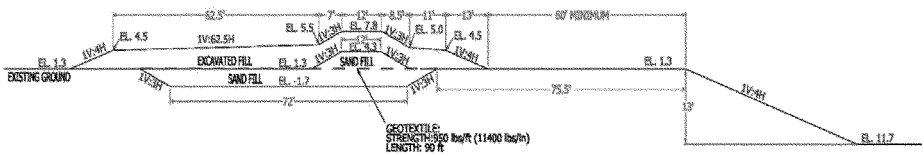


Figure 77 Guide Levee Design for Central Wetlands

In addition to the guide levees, 2-300' wide earthen weirs will also be constructed along each bank of the diversion channel and within existing shallow open waters within the Central Wetlands. The weirs will have a crest elevation of +1.0'.

The diversion channel between the 40 Arpent Levee and the back dike canal immediately south of and adjacent to the MRGO south bank disposal area will be excavated via hydraulic dredge and it is anticipated that approximately 2,100,000 gross CYS will be removed during this process. Access for the dredge is anticipated to be via the GIWW, Bayou Bienvenue via the Bienvenue floodgate and the back dike canal immediately adjacent to and behind the former MRGO south bank disposal areas. As surveys are not presently available at this time, it is estimated that flotation access dredging within the canal will be required. The material that is excavated for flotation access will be side cast to the maximum extent practicable for either marsh creation or nourishment southeast of the canal, or for re-construction of the former bank line.

The hydraulic dredged material will be placed within portions of Features CM 1 and CC1 for both marsh nourishment and swamp restoration/nourishment. Approximately 290 acres of existing marsh

and shallow open waters would be nourished within Feature CM 1. For Feature CC 1, it is estimated that approximately 212 acres of swamp would be restored and another 182 acres nourished. Perimeter retention dikes would be constructed around Features CM 1 and CC 1 would in order to contain the dredge slurry. The slurry would be placed to a maximum elevation of +4 within CM 1 and a maximum slurry elevation of +4.5' within CC 1. Approximately 43,550' of earthen retention dikes (16,700' for Feature CC 1 and 26,850' for Feature CM 1) will be constructed from adjacent borrow, and 2' of freeboard will be maintained at all times during pumping operations. The earthen dikes shall also be constructed to an approximate 5' crown width, slopes no steeper than 1V on 3H, and with a minimum 40' interior berm to be maintained between the inside toe of the earthen dikes and the top of cut of the adjacent borrow pits. In addition, as Feature CC 1 is immediately west of Bayou Chaperon, which is considered a "scenic stream", measures will be taken to assure this waterway is not impacted.

Material excavated from within the former MRGO south bank disposal area will be placed uncompacted along the banks of the diversion channel in order to create a continuous guide levee. Based upon the limited geotechnical and survey data currently available, these guide levees would be constructed to a maximum 8' height above the natural ground line with 1V on 10H side slopes and an approximate crown width of 325'. Approximately 740,000 gross CYS will be excavated from within this reach.

As topographic surveys were not available for this phase of the study, an available LIDAR survey was used in order to estimate the existing ground line elevations and estimated quantities to be dredged from within the various reaches. For determining disposal capacities within the swamp and marsh restoration/creation/nourishment sites, it was assumed that the existing elevation within the swamp restoration site (Feature CC 1) is an approximate average elevation of -1.0' and that the adjacent marsh is an approximate average elevation of +1.5'. For the marsh nourishment Feature CM 1, it was assumed that the existing marsh ranged in elevation from +0.5' and +1.0', and that approximately 1.5' of fill would be placed throughout this project feature for nourishment.

Ingress and egress to the site would be via the Mississippi River, the GIWW, the MRGO, and Bayou Bienvenue, the back dike canal, as well as Federal, State and local highways.

5.4.2 Back Dike Canal

The hydraulic design called for a weir to elevation +1 at the intersection of the guide levees and the back dike canal. Because of the requirement to maintain navigation in this canal these weirs were removed from the plan. This feature will be reanalyzed and if induced flooding issues are a concern navigable features such as navigable gates will be added at this location.

5.4.3 Detailed Design

More detailed design of the diversion channel and levees will be done as part of a separate study and report for the diversion.

6.0 RECREATION FEATURES

6.1 GENERAL

Two recreation features are included as part of the proposed plan. These features are in the Bienvenue Triangle and at Shell Beach. A brief description of these features is shown below. Further details of these plans can be found in Appendix W of the EIS.

6.2 BIENVENUE TRIANGLE RECREATION FEATURE

The site of the proposed recreation feature is located in Orleans Parish's Bienvenue Triangle. Located at the terminus of Caffin Avenue, the site currently offers a viewing platform overlooking the marsh. The platform is used by the neighborhood, tourist and by schools both recreationally and as an educational tool. Martin Luther King Elementary School located on Caffin Avenue and North Claiborne Avenue currently uses the platform for teaching students about environmental principles, processes and a general education concerning marshland, habitat, and wildlife.

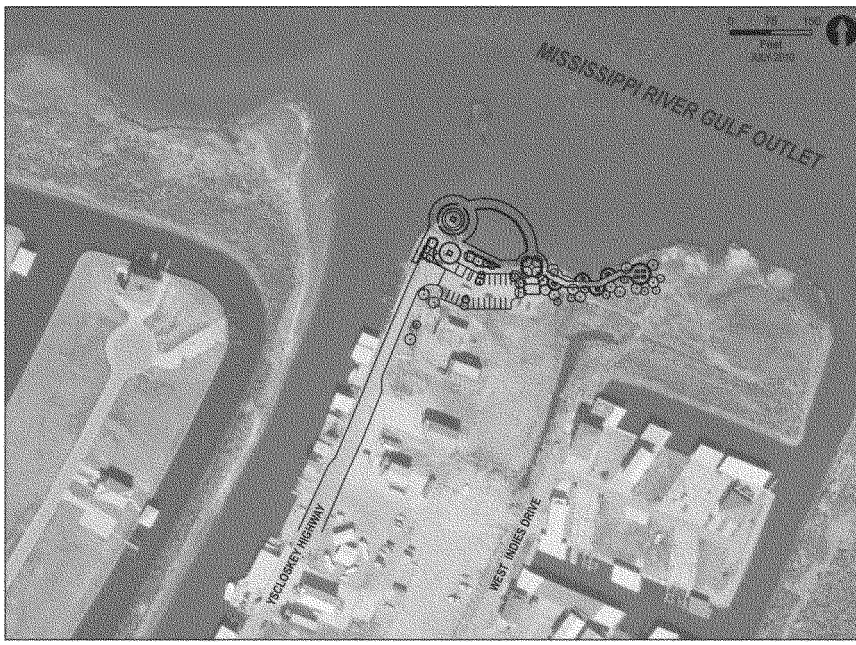
The recommended plan for the Bienvenue Triangle consists of a 100 lf (linear feet) of platform, 995 lf of boardwalk into the swamp, 4 picnic shelters, interpretive signage, bathrooms, parking, solar lighting and vegetative plantings. Figure 78 showns the recommended plan for the Bienvenue Triangle. Details of the plan are shown on plates RF-1 to RF-3.

Figure 78 Bienvenue Triangle Recreation Feature

6.3 SHELL BEACH RECREATION FEATURE

Currently, the shoreline of Shell Beach, located in St. Bernard Parish at the end of Yscloskey Road where it meets the MRGO, is often used by fisherman. Fishermen are confronted with a rocky, jagged shoreline and snakes in the area. The shoreline is used extensively on the weekends by many in the area. Additionally, a memorial is located at this location which lists the names of those who lost their lives as a result of Hurricane Katrina. The recreational plan will attempt to incorporate the memorial in a way that is both respectful and functional.

The recommended plan for Shell Beach consists of a 343 lf of boardwalk into the MRGO, 805 lf of shoreline boardwalk to 5 picnic shelters (2 handicap accessible), interpretive signage, bathrooms, parking, solar lighting and vegetative plantings. Figure 79 shows the recommended plan for Shell Beach. Details of the plan are shown on plates RF-4 to RF-8.



SHELL BEACH RECREATIONAL FEATURE: OPTION B

Figure 79 Shell Beach Recreation Features

7.0 STRUCTURES

7.1 SCOPE

The analysis and design concepts for the structural concepts are presented in the following text. A general layout of the diversion is presented on plate C-42.

7.2 REFERENCES

The structural components shall be designed according to the applicable portions of the US Army Corps of Engineers (USACE) publications and other applicable reference material.

7.2.1 USACE Publications

(1) EM 1110-2-2105, Design of Hydraulic Steel Structures (Mar 93), Including Change 1, (May 94)

(2) EM 1110-2-2104, Strength Design for Reinforced Concrete Hydraulic Structures, June 92 (Including Change 1, Aug 03)

(3) EM 1110-2-2102, Waterstops and Other Joint Materials (Sep 95).

(4) EM 1110-2-2400, Structural Design and Evaluation of Outlet Works (June 03)

(5) EM 1110-2-2502, Retaining and Flood Walls (Sep89).

(6) EM 1110-2-2701, Vertical Lift Crest Gates (Nov 97).

(7) EM 1110-2-2902, Conduits, Culverts, and Pipes (Oct 97), Including Change 1, (Mar 98).

(8) EM 1110-2-2906, Design of Pile Foundations (Jan. 91)

(9) EM 385-1-1, Safety Manual (Sep 2008)

(10) EM 1110-2-2503, Design of Sheet Pile Cellular Structures Cofferdams & Retaining Structures, Sept. 89

(11) Hurricane and Storm Damage Risk Reduction System (HSDRRS) Design Criteria 2010, where applicable.

7.2.2 Technical Publications

(1) American Association of State Highway and Transportation Officials (AASHTO)

(2) American Concrete Institute, Building Code Requirements for Structural Concrete (ACI 318)

(3) American Institute of Steel Construction (AISC), Manual of Steel Construction Allowable Stress Design, (9th Edition)

(4) American Welding Society, Structural Welding Code, (AWS-D 1.1)

(5) Louisiana Department of Transportation and Development (LDOTD), Louisiana Standard Specifications for Roads and Bridges

(6) Portland Cement Association, Concrete Culverts and Conduits.

(7) AREMA

7.2.3 Computer Programs

(1) CWALSHT" WES Program No. X0031.

(2) Pile Group Analysis (CPGA)," WES Program No. XOO8O.

(3) Pile Group Graphics Display (CPGG) ,WES Program N0. XOO81.

(4) "C-Frame," WES Program N0. X0030.

(5) Structural Analysis and Design Software, "STAAD

(6) Ensoft, "Group 7.0"

7.3 DESIGN CRITERIA

7.3.1 General

Design criteria shall be according to the referenced EM's and technical publications.

7.3.2 Material Weights

Item	Unit Weight (PCF)

Water	62.4 to 64.0 (Site dependent)
Reinforced Concrete	150.0
Steel	490.0
Rip rap	132.0
Semi-Compacted Granular Fill	120.0
Fully-Compacted Granular Fill, Wet	122.0
Fully-Compacted Granular Fill Effective	58.0
90% -Compacted Clay Fill, Wet	110.0
Non-plastic Embankment	120.0
Asphaltic Concrete	100.0

7.3.3 Design Stresses

7.3.3.1 Concrete

Reinforced concrete hydraulic structures shall follow USACE criteria (EM 1110-2-2104). EM 1110-2-2104 procedures are referenced to the load factors and strength reduction factors found in ACI 318. In general, the specified compressive strength (f 'c) shall be 4000 psi.

A Single Live Load Factor of 1.7, for dead and lives, loads shall be used in addition to a Hydraulic Factor.

A Hydraulic Factor of 1.3 shall be applied to both shear and moment. The hydraulic factor is used to improve crack control in hydraulic reinforced concrete structures by increasing reinforcement requirements, thus reducing steel stresses.

Strength reduction factor for bending shall be 0.90 and the strength reduction factor for shear shall be 0.85.

7.3.3.2 Reinforcement

The design strength of reinforcement shall be based on the use of ASTM A 615, Grade 60, steel having yield strength of 60,000 psi.

Maximum Flexural Reinforcement

0.25 pb (Recommended)
0.375 pb (Permitted w/o special studies)

Minimum Flexural Reinforcement - per ACI Code

Temperature Reinforcement - 0.0028Ag (1/2 in each face)

7.3.3.3 Structural Steel

The basic stresses for structural steel shall be in accordance with the 9th Edition of the AISC, Manual of Steel Construction Allowable Stress Design, as modified by EM 1110-2-2105, Design of Hydraulic Steel Structures.

Minimum thickness for corrosion control shall be 5/16".

Allowable stress = 5/6 of AISC allowable stress.

Allowable stresses for the design of welds shall be according to the latest AWS Welding Code as modified by EM 1110-2-2101.

7.3.3.4 Sheet Piling

Design Stresses

Fb = 0.5 fy
Fv = 0.33 fy
Fa = 5/6 AISC allowable

Thickness = 0.375 in. minimum, only hot-rolled steel sheet piling sections are allowed.

7.3.3.5 Service Piling

The allowable compressive strength used for southern pine treated timber piling will be 825 psi (parallel to grain).

Prestressed concrete piling will be 14" square piles with a specified compressive strength (f'c) of 6000 psi.

H-Piles - The basic stresses for structural steel shall be in accordance with the 9th Edition of the AISC, Manual of Steel Construction Allowable Stress Design, as modified by EM 1110-2-2906, Design of Pile Foundations.

7.3.3.6 Allowable Overstress

The allowable overstresses used in the design of the structural components shall be as shown in the following table:

Loading Condition	Allowable Overstress
Normal Operating	0 %
Construction	16-2/3 %
Maintenance Dewatering	33-1/3 %
Project Flood	0 %
Temporary Loadings (Wind and Impact)	33-1/3 %

7.4 GENERAL DESCRIPTION OF PROJECT FEATURES

7.4.1 Gated Diversion Structure at the Mississippi

See plates S-1 and S-2 for details of the structure.

7.4.1.1 Inflow monoliths (U-1 and U-2)

The inflow portion of the structure is comprised of two 30'-0" long reinforced concrete, U-frame monoliths. The base of each monolith flares, from a maximum width of 86'-6" at the channel, downward until they meet the gated portion of the structure. The tops of the base slabs remain constant at El. -11.8. Both monoliths will be designed independently and founded upon steel piles. Steel sheet pile, provided for erosion protection, will follow the outside perimeter of each monolith.

7.4.1.2 Service gate monolith (C-1)

The service gate monolith can be considered as comprised of two sections. The upper 16'-6" by 71'-0" tower extends from the top of the base slab, at El. -11.8 to El. 25.0. This section houses the four vertical lift service gates and accompanying machinery. The lower 56'-6" length of the monolith is a typical 67-0" wide box culvert section. The top of the base slab remains constant at El. -11.8 for the full length of the monolith. The monolith will be founded upon steel piles and will support a portion of the main line levee. Steel sheet piling extending to El. -35.0 is provided along the front sides of the monolith for seepage cut-off. A walkway will extend from the top of the levee (El. 20) to the top of the tower (El. 25), providing access to the gate machinery.

7.4.1.3 Box Culvert Monoliths

The main body of the structure is composed of 15 box culvert type monoliths designated (C-3) thru (C-17). Each monolith is 27' wide by 15' long, containing 4 individual 13-0" by 13-0" chambers. The top of the base slab is continuous at El. -11.8, with the top roof continuous at El. +4.2. Each monolith will be pile founded and designed independently. Expansion joints will be provided between monoliths to prevent load transfer. The pile foundations vary as required for the applied loads.

7.4.1.4 Monolith (C-2 and C-3)

These monoliths will support most of the main line levee on steel piles. A seepage cutoff wall spans its entire width.

7.4.1.5 Monoliths (C-4 and C-5)

These monoliths support the Railroad (one track) on steel piles.

7.4.1.6 Monoliths (C-6 thru C-13, C-16 and C-16)

These are typical monoliths supporting 2 ft. of backfill.

7.4.1.7 Monoliths (C-14 and C-15)

These monoliths support the LA Hwy 18 on steel piles.

7.4.1.8 Downstream bulkhead monolith (C-18)

The downstream bulkhead monolith is comprised of two sections. The first 17'-0" is in part a typical 67'-0"' wide box culvert and contains provisions for placing the downstream bulkheads. The lower 48'-0" of the monolith is a reinforced concrete U-frame. The top of the base slab is at El. -11.8. The base of the U-frame portion of the monolith flares from a width of 62'-6" to 76-6". The monolith will be founded upon steel piles.

7.4.1.9 Outflow monoliths (U-3 and U-4)

The outflow portion of the structure is comprised of two reinforced concrete U-frame monoliths. The bases of the monoliths flare from a width of 76'-6" at monolith C-9, to 90'-0" at the channel. The walls of both monoliths remain constant at El. 12. The tops of the base slabs remain constant at El. -11.8. Both monoliths are pile founded on steel piles. Steel sheet piling provided for erosion protection follows the outside perimeter of both monoliths.

7.4.1.10 Service gates

Flow through the structure will be regulated by four vertical flush-bottom sluice gates, one at the entrance of each chamber. Each gate will be constructed from cast- iron with bronze seats or stainless steel.

7.4.1.11 Emergency bulkheads

Two (2) emergency bulkheads will be constructed from structural steel for maintenance dewatering and emergency closures. The bulkheads shall be placed by land based equipment into the slots provided in monolith (C-18). The bulkheads will be stored on a rack at the outflow channel end of the structure.

7.4.2 Highway Crossing at West Judge Perez

The work consists of excavating a 1,500-foot segment of the Violet Diversion Structure Outfall Channel and constructing a simple span concrete bridge at the existing West Judge Perez roadbed (605 feet long with 10 spans) (see plates S-3 and S-4). The work includes constructing and removing a detour road and preloading a portion of the new approach ramps. The bridge

construction includes testing and installing precast, prestressed, concrete piles; channel excavation and riprap placement; fabricating and installing Type III precast, prestressed concrete girders; constructing cast-in-place abutments, T-walls, bridge deck, and barrier walls. Roadwork includes placing an embankment and asphalt and concrete approach slabs; installing roadway appurtenances; and drainage work.

7.4.3 Gated Structure at the 40 Arpent Canal

See plates S-5 and S-6 for details of the structure.

7.4.3.1 Inflow monolith (U-1)

The inflow portion of the structure is comprised of one 30'-0" long reinforced concrete, U-frame monoliths. The base of the monolith flares, from a maximum width of 118 '-0" at the channel, downward until they meet the gated portion of the structure. The tops of the base slabs remain constant at El. -12.8. The monolith will be founded on steel piles. Steel sheet pile provided for erosion protection, follows the outside perimeter of each monolith.

7.4.3.2 Service gate monolith (C-1)

The service gate monolith can be considered as comprised of two sections. The upper 16'6" by 71' tower extends from the top of the base slab, at El. 0.2, to El. 12.0. This section houses the seven vertical lift service gates and accompanying machinery. The lower 61' length of the monolith is a typical 58-6" wide box culvert section. The top of the base slab remains constant at El. -12.8for the full length of the monolith. The monolith will be founded upon steel piles and supports a portion of the main line levee. Steel sheet piling extending to El. -35.0 is provided along the front sides of the monolith for seepage cut-off. A walkway will extend from the top of the levee (El. 10) to the top of the tower (El. 12), providing access to the gate machinery.

7.4.3.3 Downstream bulkhead monolith (C-2)

The downstream bulkhead monolith is comprised of two sections. The first 17'-0" is in part a typical 108'-0" wide box culvert and contains provisions for placing the downstream bulkheads. The lower 48'-0" of the monolith is a reinforced concrete U-frame. The top of the base slab is at El. -12.8. The base of the U-frame portion of the monolith flares from a width of 108'-0" to 117'-6". The monolith will be founded upon steel piles.

7.4.3.4 Service gates

Flow through the structure will be regulated by seven (7) vertical flush-bottom sluice gates, one at the entrance of each chamber. Each gate will be constructed from cast- iron with bronze seats or stainless steel.

7.4.3.5 Emergency bulkheads

Two (2) emergency bulkheads will be constructed from structural steel for maintenance dewatering and emergency closures. The bulkheads shall be placed by land based equipment into the slots

provided in monolith (C-2). The bulkheads will be stored on a rack at the outflow channel end of the structure.

The location of the structure at the 40 Arpent levee will be placed in such a manner that the 40 Arpent canal will be blocked off. The impacts of this structure on the local drainage are being studied and the appropriate actions will be taken to ensure this project does not impact the local drainage system.

7.4.4 Gated Structure at the MRGO Outlet

See plates S-7 and S-8 for details of the structure.

7.4.4.1 Inflow monoliths (U-1 and U-2)

The inflow portion of the structure is comprised of two 30'-0" long reinforced concrete, U-frame monoliths. The base of each monolith flares, from a maximum width of 150 '-6" at the channel, downward until they meet the gated portion of the structure. The tops of the base slabs remain constant at El. -14.4. Both monoliths will be designed independently and founded upon steel piles. Steel sheet pile, provided for erosion protection, will follow the outside perimeter of each monolith.

7.4.4.2 Service gate monolith (C-1)

The service gate monolith, can be considered as comprised of two sections. The upper 16'-6" by 71' tower extends from the top of the base slab, at El. 1.6, to El. 32.0. This section houses the eight vertical lift service gates and accompanying machinery. The lower 53'-6" length of the monolith is a typical 131'-0" wide box culvert section. The top of the base slab remains constant at El. -14.4 for the full length of the monolith. The monolith will be founded upon steel piles and supports a portion of the main line levee. Steel sheet piling extending to El. -35.0 is provided along the front sides of the monolith for seepage cut-off. A walkway will extend from the top of the floodwall (El. 30) to the top of the tower (El. 32), providing access to the gate machinery.

7.4.4.3 Monoliths (C-2 and C-3)

These are typical monoliths supporting 2 ft. of backfill.

7.4.4.4 Downstream bulkhead monolith (C-4)

The downstream bulkhead monolith is comprised of two sections. The first 17'-0" is in part a typical 131'-0" wide box culvert and contains provisions for placing the downstream bulkheads. The lower 48'-0" of the monolith is a reinforced concrete U-frame. The top of the base slab is at El. -14.4. The base of the U-frame portion of the monolith flares from a width of 131'-0" to 140'-6". The monolith will be founded upon steel piles.

7.4.4.5 Outflow monoliths (U-3 and U-4)

The outflow portion of the structure is comprised of two reinforced concrete U-frame monoliths . The bases of the monoliths flare from a width of 140'-6" at monolith C-4, to 154'-0" at the channel. The

tops of the base slabs remain constant at El. -14.4. The monolith will be pile founded on steel piles. Steel sheet piling provided for erosion protection follows the outside perimeter of both monoliths.

7.4.4.6 Service gates

Flow through the structure will be regulated by eight (8) vertical flush-bottom sluice gates, one at the entrance of each chamber. Each gate will be constructed from cast- iron with bronze seats or stainless steel.

7.4.4.7 Emergency bulkheads

Two emergency bulkheads will be constructed from structural steel for maintenance dewatering and emergency closures. The bulkheads shall be placed by land based equipment into the slots provided in monolith (C-4). The bulkheads will be stored on a rack at the outflow channel end of the structure.

7.5 LOADING CONDITIONS

7.5.1 Diversion Structure

7.5.1.1 General

A wide range of possible loading conditions will be considered for both the planned operation and construction of the structure. In addition to dead and live loads, the effects of superimposed temporary loadings such as wind, debris, and boat impact will be considered.

7.5.1.2 Construction

Lateral earth pressures will be developed considering the type of backfill, and where appropriate, will be considered as loading on various structural elements during the entire construction period. These cases will be designated as follows:

Construction with no backfill
Construction with fully compacted backfill
Construction with total backfill (TW=O. 0)

7.5.1.3 Hydraulic

The structure will be investigated for a range of possible hydraulic and operational modes. These cases will be designated as follows:

Maint. Dewatering, 2 culverts (HW=8.0, TW=4.0)
Maint. Dewatering, 2 culverts (HW=8.0, 'TW=0.0)
Normal operating (HW=12.5, TW=5.0)
Maximum Operating (HW=18.0, TW=0.0)
Flood Stage (HW=22.0, TW=0.0)

Hurricane (HW=0. 6, TW=7.5)

7.5.1.4 Uplift

Uplift pressure is comprised of position pressure and seepage pressure. Position pressure is based on the hydrostatic head due to the difference in water elevation and the base of the structure. Seepage pressure is a function of the equipotential flow line caused by the difference in water elevation between headwater and tailwater. To insure a conservative design, two uplift conditions, designated 1 and 2, will be used in the design for all monolith foundations. Uplift condition 1 will be derived assuming the sheet pile cut-off under the sluice gate monolith as effective. Uplift condition 2 will be derived by assuming the sheet pile cut-off as ineffective.

7.5.1.5 Superimposed

In addition to the primary loads on the structure, the application of the following additional loadings will be considered:

(1) **Soil drag loads (D).** Drag load due to differential settlement of the surrounding backfill with respect to the structure will be incorporated into the design.

(2) **Silt Loads (S).** Structural components will be designed for silt deposits up to 12 feet in height, where applicable.

(3) **Debris loads (DI).** A uniform load of 1.5 kips per foot water line will applied to the applicable structural.

(4) **Boat impact (BI).** A uniform load of 5.0 kips per foot in the direction of flow will be applied 1 foot above the waterline.

(5) **Wind loads (WI).** A wind load of 50 psf will be considered in the design of applicable structural components.

(6) **Highway loads (H)** • A Louisiana Department of Transportation and Development HST-18 truck loading will be considered in the design of its applicable structural component

(7) **Train loads (T).** Cooper E-80 train loads will be applied to the applicable structural components of the permanent work. A Cooper E-65 load will be used in the design of the temporary detour.

8.0 RELOCATIONS

8.1 SUMMARY

8.1.1 Scope and Purpose

All the relocation information provided below pertains to relocations for the proposed diversion. This information will be updated as part of the separate study on the diversion. There are no relocations identified for the shoreline protection or marsh/swamp creation/nourishment features. Relocation data was collected and tabulated by U.S. Army Corps of Engineers, New Orleans District, Engineering Division, Relocations Team, to a feasibility study level. Relocations Team made contact with owners to obtain preliminary information on existing facilities. Relocations Team then made assumptions based on project design and facility locations to determine project relocation requirements and for developing the cost estimates presented in this report. A preliminary compensable interest report will be compiled during the Preconstruction Engineering and Design phase.

The MRGO Ecosystem Restoration Feasibility Study, study includes diverting freshwater from the Mississippi River and introducing it to the western Mississippi Sound for the purpose of salinity control, with some of the water influencing the Central Wetlands area. A multi celled gated box culvert control structure will be placed through the Mississippi River levee. An outlet structure will be constructed through the existing HSDRRS system at the MRGO. The two structures will be connected by a channel with guide levees on each side. The diversion canal will stretch from the Mississippi River to the MRGO; crossing both Judge Perez Drive and St. Bernard Highway. It is anticipated that a temporary detour roadway will be required at Judge Perez Drive and a temporary detour (shoe-fly) for the railroad between St. Bernard Highway and the Mississippi River. A bridge will be constructed at Judge Perez Drive and the detour road will be removed upon completion of construction. This report has been prepared by the U.S. Army Corps of Engineers, New Orleans District, Engineering Division, Relocations Team.

8.1.2 Estimated Relocation Cost

The total preliminary estimated costs for relocation of pipelines, power and communication lines for the proposed project is $14,116,437 (Note: the total cost doesn't include the cost of the railroad or road relocation.) This figure includes 12% for owner's engineering and design, 10% for owner's contract administration, and 35% for contingencies. The relocation plan and cost will be revised during the separate study on the Violet Diversion.

8.1.3 Authority for Accomplishing Relocations

The MRGO Ecosystem Restoration Study was authorized by the Water Resources Development Act of 2007 Section 7013. Cost-sharing is subject to the rules for ecosystem restoration projects established in Section 210 of WRDA 1996, with the exception of the Violet Freshwater Diversion, which would be divided between the States of Louisiana and Mississippi as stipulated in WRDA 2007, Section 3083. Accordingly, the non-Federal share will be 35 percent of the implementation

costs. Non-Federal sponsors are responsible for 100 percent of lands, easements, rights-of-way, utility or public facility relocations, and dredged or excavated material disposal areas (LERRD), and operation, maintenance, repair, rehabilitation, and replacement (OMRR&R). The value of LERRD is credited to the 35 percent share.

8.2 DESCRIPTION OF AFFECTED FACILITIES, PROPOSED RELOCATION, AND COSTS

Described below are the facilities affected by the project. All relocations will be performed concurrent with construction.

8.2.1 Roads

All roadways and bridges requiring replacement or installation to accommodate the project are accounted for in structural design (Section 6). There will be a two (2) lane temporary detour roadway and a permanent bridge installation at Judge Perez Drive. The bridge installation and temporary detour roads are considered relocation items.

8.2.2 Railroads

Existing Alabama Great Southern Railroad (Norfolk) between St. Bernard Highway and the Mississippi River shall have a temporary shoe-fly during construction. The design will be accounted for under structural design (Section 6) however; the temporary shoe-fly is considered a relocation item.

8.2.3 Facilities

(1) American Midstream (Enbridge) Pipeline (From MRGO to Judge Perez Drive).

Item 1 consists of an 8"gas pipeline. The line would be directionally drilled 35' beneath the channel (approximately 1000 linear feet) with a lateral shift of 5'-10'. A hot tap will be required and the owner will be responsible for removing the existing pipe. This work will be performed by American Midstream (Enbridge) Pipeline. The estimated cost for this relocation is as follows:

Cut, cap and remove existing line (approximately 1000 linear feet). Install new pipeline, directionally drilling 35' beneath channel (approximately 1000 linear feet). Install hot tap at both ends of existing pipe and connect new pipeline. New line shall be installed with an approximate 5'-10' lateral shift. = $1,826,523

Item 2 consists of a 16"gas pipeline. The line would be directionally drilled 35' beneath the channel (approximately 1000 linear feet) with a lateral shift of 5'-10'. A hot tap will be required and the owner will be responsible for removing the existing pipe. This work will be performed by American Midstream (Enbridge). The estimated cost for this relocation is as follows:

Cut, cap and remove existing line (approximately 1000 linear feet). Install new pipeline, directionally drilling 35' beneath channel (approximately 1000 linear feet).Install hot tap at both ends of existing pipe and connect new pipeline. New line shall be installed with an approximate 5'-10' lateral shift. = $2,300,859

(2) Gulf South Pipeline (From MRGO to Judge Perez Drive)

Item 1 consists of a 16" gas pipeline. Both lines would be directionally drilled 35' beneath the channel (approximately 1000 linear feet) with a lateral shift of 5'- 10'. A hot tap will be required and the owner will be responsible for removing the existing pipe. This work will be performed by Gulf South Pipeline. The estimated cost for this relocation is as follows:

Cut, cap and remove existing line (approximately 1000 linear feet). Install new pipeline, directionally drilling 35' beneath channel (approximately 1000 linear feet). Install hot tap at both ends of existing pipe and connect new pipeline. New line shall be installed with an approximate 5'-10' lateral shift. = $2,300,859

Item 2 consists of a 20" gas pipeline. Both lines would be directionally drilled 35' beneath the channel (approximately 1000 linear feet) with a lateral shift of 5'- 10'. A hot tap will be required and the owner will be responsible for removing the existing pipe. This work will be performed by Gulf South Pipeline. The estimated cost for this relocation is as follows:

Cut, cap and remove existing line (approximately 1000 linear feet). Install new pipeline, directionally drilling 35' beneath channel (approximately 1000 linear feet). Install hot tap at both ends of existing pipe and connect new pipeline. New line shall be installed with an approximate 5'-10' lateral shift. = $2,646,729

(3) St. Bernard Parish (water main) - (At Judge Perez Drive)

Item 1 consists of a water main (approximately 10"). The assumed current alignment of the water main is parallel to Judge Perez Drive. Owner will perform a temporary bypass following the route of the temporary detour road (approximately 800 linear feet). The permanent relocation will be attached to the newly installed bridge after construction complete (approx. 700 linear feet). The relocation of St. Bernard Parish's water main will be performed by St. Bernard Parish. The estimated cost for this relocation is as follows:

Cut, cap and remove existing pipeline (approximately 700 linear feet). Owner will route the new pipeline (approx. 800 linear feet) along alignment of the temporary detour road. Upon bridge construction completion, the temporary line will be cut, capped and removed. The permanent line will be attached to the newly constructed bridge (approx. 700 linear feet) = $345,870

(4) Entergy Louisiana, LLC (Entergy) – (At Judge Perez Drive)

Item 1 encompasses 2 existing power poles and approximately 700 linear feet of 13.8kV power cable. The owner will temporarily install 4 new poles and approx. 800 linear feet of 13.8kV cable along the temporary detour road alignment. The permanent relocation will be along the original alignment after construction completion. The construction of the new support system will be performed by Entergy Louisiana, LLC. The estimated cost for this relocation is as follows:

Temporarily install 4 new poles and approx. 800 linear feet of 13.8kV cable following temporary detour road alignment. After installing new poles and cable, owner will remove 2 existing poles and 700 linear feet of 13.8kV along existing alignment. For the permanent relocation the owner will install 2 new poles and 700 linear feet of 13.8kV cable along the original alignment. After the new poles are installed the owner will remove the 4 poles and associated cable along the detour route and re-establish service. = $184,464

(5) AT&T Communications (Telephone) – (At Judge Perez Drive)

Item 1 assumes aerial lines that share poles with Entergy. Therefore the temporary and permanent relocation shall follow that of Entergy Louisiana, LLC. The relocation will be performed by AT&T. The estimated cost for this relocation is as follows:

Temporarily route approx. 800 linear feet of cable on newly installed Entergy poles following temporary detour road alignment. After installation of new poles owner will remove 700 linear feet of cable along existing alignment. For the permanent relocation the owner will install 700 linear feet of cable along the original alignment on 2 newly installed Entergy poles. After the new poles are installed the owner will remove the cable along the detour route associated with the 4 poles (along detour route) and re-establish service. = $156,465

(6) Cox Communications (Cable) – (At Judge Perez Drive)

Item 1 assumes aerial lines that share poles with Entergy. Therefore the temporary and permanent relocation shall follow that of Entergy Louisiana, LLC. The relocation will be performed by Cox Communications. The estimated cost for this relocation is as follows:

Temporarily route approx. 800 linear feet of cable on newly installed Entergy poles following temporary detour road alignment. After installation of new poles owner will remove 700 linear feet of cable along existing alignment. For the permanent relocation the owner will install 700 linear feet of cable along the original alignment on 2 newly installed Entergy poles. After the new poles are installed the owner will remove the cable along the detour route associated with the 4 poles (along detour route) and re-establish service. = $107,055

(7) St. Bernard Parish (sewer main) – (At Judge Perez Drive)

Item 1 consists of a sewer main (approximately 10"). The assumed current alignment of the sewer main is parallel to Judge Perez Drive. Owner will perform a temporary bypass following the route of the temporary detour road (approximately 800 linear feet). The permanent relocation will be attached to the newly installed bridge after construction complete (approx. 700 linear feet). The relocation of St. Bernard Parish's sewer main will be performed by St. Bernard Parish. The estimated cost for this relocation is as follows:

Cut, cap and remove existing pipeline (approximately 700 linear feet). Owner will route the new pipeline (approx. 800 linear feet) along alignment of the temporary detour road. Upon bridge construction completion, the temporary line will be cut, capped and removed. The permanent line will be attached to the newly constructed bridge (approx. 700 linear feet) = $345,870

(8) Atmos Gas 6" Natural Gas Pipeline – (At Judge Perez Drive)

Item 1 consists of a 6" natural gas line. The assumed current alignment of the line is parallel to Judge Perez Drive. Owner will perform a temporary bypass following the route of the temporary detour road (approximately 800 linear feet). The permanent relocation will be a directional drill (with a lateral shift of 5'- 10' from original alignment) 35' beneath the channel (approx. 1000 linear feet). A hot tap will be required and the owner will be responsible for removing the existing pipe. The relocation of Atmos's natural gas pipeline will be performed by Atmos Gas. The estimated cost for this relocation is as follows:

Cut, cap and remove existing line (approximately 800 linear feet). Install new pipeline, directionally drilling 35' beneath channel (approximately 1000 linear feet). Install hot tap at both

ends of existing pipe and connect new pipeline. New line shall be installed with an approximate 5'-10' lateral shift from original alignment. = $1,831,464

(9) St. Bernard Parish (water main) – (At St. Bernard Highway)

Item 1 consists of a water main (approximately 10"). The assumed current alignment of the water main is parallel to St. Bernard Highway. Owner will perform a temporary bypass with an offset of 50' from the current alignment. The bypass will run for a distance of 500'. After completion of the bypass the owner will remove approx. 400 linear feet of existing pipeline. The owner will permanently relocate the pipeline (approx. 400 linear feet) along its original alignment upon completion of construction. The relocation of St. Bernard Parish's water main will be performed by St. Bernard Parish. The estimated cost for this relocation is as follows:

Cut, cap and remove existing pipeline (approximately 400 linear feet). Owner will install a temporary bypass (approximately 500') offset 50' from the current alignment. Upon completion of construction the owner will permanentlyrelocate along the original alignment (approximately 400 linear feet. = $251,991

(10) Entergy Louisiana, LLC. (Entergy) – (At St. Bernard Highway)

Item 1 encompasses 2 existing power poles and approximately 700 linear feet of 13.8kV power cable. The owner will temporarily install 4 new poles and approx.800 linear feet of 13.8kV cable offset 75' from the existing alignment; removing the existing (2) poles and associated cable (approx. 700 linear feet). The permanent relocation will be along the original alignment after construction completion. The construction of the new support system will be performed by Entergy Louisiana, LLC. The estimated cost for this relocation is as follows:

Temporarily install 4 new poles and approx. 800 linear feet of 13.8kV cable offset 75' from the existing alignment. After installing new poles and cable, owner will remove 2 existing poles and 700 linear feet of 13.8kV along existing alignment. For the permanent relocation the owner will install 2 new poles and 700 linear feet of 13.8kV cable along the original alignment. After the new poles are installed the owner will remove the 4 poles and associated cable along the detour route and re-establish service. = $184,464

(11) AT&T Communications (Telephone) – (At St. Bernard Highway)

Item 1 assumes aerial lines that share poles with Entergy. Therefore the temporary and permanent relocation shall follow that of Entergy Louisiana, LLC. The relocation will be performed by AT&T. The estimated cost for this relocation is as follows:

Temporarily route approx. 800 linear feet of cable on newly installed Entergy poles offset 75' from the existing alignment. After installation of new poles owner will remove 700 linear feet of cable along existing alignment. For the permanent relocation the owner will install 700 linear feet of cable along the original alignment on 2 newly installed Entergy poles. After the new poles are installed the owner will remove the cable along the temporary alignment and re-establish service. = $156,465

(12) Cox Communications (Cable) – (At St. Bernard Highway)

Item 1 assumes aerial lines that share poles with Entergy. Therefore the temporary and permanent relocation shall follow that of Entergy Louisiana, LLC. The relocation will be performed by Cox Communications. The estimated cost for this relocation is as follows:

Temporarily route approx. 800 linear feet of cable on newly installed Entergy poles offset 75' from the existing alignment. After installation of new poles owner will remove 700 linear feet of cable along existing alignment. For the permanent relocation the owner will install 700 linear feet of cable along the original alignment on 2 newly installed Entergy poles. After the new poles are installed the owner will remove the cable along the temporary alignment and re-establish service. = $107,055

(13) St. Bernard Parish (sewer main) – (At St. Bernard Highway)

Item 1 consists of a sewer main (approximately 10"). The assumed current alignment of the water main is parallel to St. Bernard Highway. Owner will perform a temporary bypass with an offset of 50' from the current alignment. The bypass will run for a distance of 500'. After completion of the bypass the owner will remove approx. 400 linear feet of existing pipeline. The owner will permanently relocate the pipeline (approx. 400 linear feet) along its original alignment upon completion of construction. The relocation of St. Bernard Parish's sewer main will be performed by St. Bernard Parish. The estimated cost for this relocation is as follows:

Cut, cap and remove existing pipeline (approximately 400 linear feet). Owner will install a temporary bypass (approximately 500') offset 50' from the current alignment. Upon completion of construction the owner will permanently relocate along the original alignment (approximately 400 linear feet. = $251,991

(14) Atmos Gas 10" Natural Gas Pipeline – (At St. Bernard Highway)

Item 1 consists of a sewer main (approximately 10"). The assumed current alignment of the water main is parallel to St. Bernard Highway. Owner will perform a temporary bypass with an offset of 50' from the current alignment. The bypass will run for a distance of 500'. After completion of the bypass the owner will remove approx. 400 linear feet of existing pipeline. The owner will permanently relocate the pipeline (approx. 400 linear feet) along its original alignment upon completion of construction. The relocation of Atmos Gas's sewer main will be performed by Atmos Gas. The estimated cost for this relocation is as follows:

Cut, cap and remove existing pipeline (approximately 400 linear feet). Owner will install a temporary bypass (approximately 500') offset 50' from the current alignment. Upon completion of construction the owner will permanently relocate along the original alignment (approximately 400 linear feet. = $741,150

(15) AT&T Communications (Fiber Optics) – (At the Railroad)

Item 1 encompasses an assumed 2" pipeline with a 6-cable, fiber optic bundle. The owner will permanently jack the cables (encased in the 2" pipeline) beneath the Railroad after the installation of the culverts (approximately 400 linear feet of pipe). The relocation of AT&T's fiber optic lines will be performed by AT&T. The estimated cost for this relocation is as follows:

Cut, cap and remove existing pipeline (approximately 400 linear feet). Owner will install a temporary bypass (approximately 500') offset 50' from the current alignment. Upon completion of construction the owner will permanently relocate along the original alignment (approximately 400 linear feet. = $192,699

(16) Entergy Louisiana, LLC. (Entergy) – (At the Railroad)

Item 1 encompasses 2 existing power poles and approximately 700 linear feet of 13.8kV power cable. The owner will temporarily install 4 new poles and approx. 800 linear feet of 13.8kV cable offset 75' from the existing alignment; removing the existing (2) poles and associated cable (approx. 700 linear feet). The permanent relocation will be along the original alignment after construction completion. The construction of the new support system will be performed by Entergy Louisiana, LLC. The estimated cost for this relocation is as follows:

Temporarily install 4 new poles and approx. 800 linear feet of 13.8kV cable offset 75' from the existing alignment. After installing new poles and cable, owner will remove 2 existing poles and 700 linear feet of 13.8kV along existing alignment. For the permanent relocation the owner will install 2 new poles and 700 linear feet of 13.8kV cable along the original alignment. After the new poles are installed the owner will remove the 4 poles and associated cable along the detour route and re-establish service. = $184,464

9.0 OPERATION, MAINTENANCE, REPAIR, REPLACEMENT AND REHABILITATION (OMRR&R)

9.1 SHORELINE PROTECTION

For the rock shoreline protection features a maintenance event is assumed to be needed in year 5 based on the fact that a majority of the settlement occurs fairly quickly after construction. Additional maintenance events would occur at 10 year intervals after the first maintenance event. For existing features MRGO 2, MRGO 3 and MRGO 4 since the initial construction is a maintenance event, the initial lift at year 5 would not be needed. These would be maintained at 10 year intervals after the initial event. Table 54 below shows the estimated cost and year for these maintenance events.

Table 54 Shoreline Protection Maintenance Events

Feature	Maintenance Event 1		Maintenance Events 2-5	
	Year	Estimated Cost	Years	Estimated Cost Per Event
LS1	FY21	$2,475,000	FY31, FY41, FY51, FY61	$2,475,000
BS1	FY22	$2,612,500	FY32, FY43, FY53, FY63	$2,612,500
ES1	FY23	$937,500	FY33, FY43, FY53, FY63	$937,500
ES2	FY23	$1,293,750	FY33, FY43, FY53, FY63	$1,293,750
ES3	FY24	$2,187,500	FY34, FY44, FY54, FY64	$2,187,500
MRGO1	FY19	$281,250	FY29, FY39, FY49, FY59	$281,250
MRGO6	FY20	$500,000	FY30, FY40, FY50, FY60	$500,000
MRGO8	FY23	$812,500	FY33, FY43, FY53, FY63	$812,500
MRGO2	N/A	N/A	FY33, FY43, FY53, FY63	$1,225,000
MRGO3	N/A	N/A	FY33, FY43, FY53, FY63	$1,506,250
MRGO4	N/A	N/A	FY33, FY43, FY53, FY63	$206,250

9.2 MARSH AND SWAMP CREATION AND NOURISHMENT

For the marsh and swamp creation and nourishment features acres needed to be restored during a maintenance event were determined based on the calendar year of predicted marsh collapse used in the WVA . Further details of this determination are described the Main Report. The maintenance event would occur as shown in Table 55. Marsh and swamp restoration maintenance quantities were based off of the following assumptions:

- areas requiring maintenance will have subsided to an elevation of approximately -1.0' NAVD88;
- allowable borrow depth at the time maintenance is performed would be 12' maximum below the lake bottom for Lake Borgne borrow and MRGO Reach 1/ GIWW and/or Michoud Canal would again be used for O&M of Features CM 1 and CM 5; and
- all required retention features would consist of earthen materials obtained from adjacent borrow.

Table 55 OMRR&R Marsh and Swamp Creation and Restoration

Contract	Features	Acres	Estimated Cost
1	CM1, CM2, CM5, CC1, CC3	670	$51,240,000
2	CM3, CM4, CC2, CC5, CC6	794	$46,240,000
3	LM1, EM1	1,050	$44,140,000
4	LM2, LM4, MRGO7, EM2, EM3, EM4	946	$53,840,000
5	BM1, MRGO5, MRGO8, LM3	1,375	$47,920,000
6	HM1, TM1, TM2	882	$51,200,000
7	TM7, TM8	764	$54,040,000

The contracts listed in Table 55 were scoped out as such in an attempt to balance out the amount of borrow required per contract, to minimize mobilization costs, and to assure that each contract requiring borrow from Lake Borgne would be restricted to one lobe.

9.3 INVASIVE SPECIES CONTROL

Invasive species control measures would be required throughout the life of the project. It was estimated that the cost would be ten percent of the initial planting cost or $10,757,000.

10.0 COST ESTIMATES

10.1 ALTERNATIVE COST ESTIMATES

The cost estimates for the measures combined to make the alternatives were prepared in an expedited manner based on readily available New Orleans District data and quantities provided by the PDT. The estimated costs were based upon an analysis of each line item evaluating quantity, production rate, and time, together with the appropriate equipment, labor, and material costs or the costs were based on in- house knowledge and experience by NOD cost engineers who estimated similar projects. Cost Estimates were developed using historical data, CEDEP, and Mii estimating software. All features were estimated based on standard construction methods all of which are common to the New Orleans District and South Louisiana. The estimates assumed access was available to proposed areas unless otherwise stated. Each element cost was developed independently and assumed equipment availability is not an issue. A 25% - 30% contingency was added to the measure estimates along with 4% E&D and 6% S&A. Table 56 shows the preliminary measure estimates.

Table 56 Preliminary Measure Estimates

Measure	Estimated Cost
ES1	$14,683,913
ES2	$18,571,669
ES3	$58,351,563
EM5	$36,589,438
EM1	$46,198,629
EV1	$6,400,031
EM3	$25,540,625
EM4	$147,391,754
EM2	$12,564,063
LM4	$23,947,344
LM1	$114,479,063
LM2	$45,485,688
LS1	$38,338,438
LM3	$38,070,313
Old 024	$247,779,354
MRGO7	$27,127,513
MRGO2	$6,590,625
MRGO1	$6,325,000

Table 56 Preliminary Measure Estimates	
Measure	Estimated Cost
MRGO3	$3,400,050
MRGO5	$34,279,575
MRGO8	$52,991,950
MRGO6	$6,121,800
MRGO4	$2,023,500
CC4	$279,000,000
CM2	$28,010,000
CM5	$26,160,000
CM1	$55,330,000
CC3	$97,240,000
CC2	$63,600,000
CC1	$120,210,000
CC5	$136,640,000
CC6/CM4	$171,600,000
Old 030sp	$2,535,075
Old 010sp	$27,056,219
Old 011sp	$10,791,431
BS1	$51,122,500
Old 014sp	$36,700,950
BM1	$113,745,504
Old 042	$124,850,000
Old 020	$92,890,000
Old 98asp	$42,050,580
Old 98bsp	$94,188,380
Old 111sp	$36,817,138
Old 017sp	$23,998,397
Old 107sp	$23,703,108
BM2	$38,040,000
BS3	$83,963,523
BS2	$40,373,548
JS1	$30,210,180
Old 110	$96,733,313

Table 56 Preliminary Measure Estimates	
Measure	Estimated Cost
BR1	$16,760,000
Old 133b	$12,500,000
TM4	$40,028,317
TM6	$100,449,254
TM5	$81,671,910
TM3	$26,234,611
TM2	$93,534,375
TM1	$43,901,348
TM7	$190,090,000
TM8	$98,523,567
HM1	$36,171,252
Old 004	$146,676,754
Old 013	$375,209,660
Old 022	$195,558,004
Old 023	$199,156,723
Old 78	$260,536,348
Old 191	$30,530,000
Old 240	$52,652,029

10.2 DETAILED COST ESTIMATES

The cost estimate for the TSP is $3,371,652 (fully funded). Details on how this cost was prepared are shown below. Tables 57, 58 and 59 show the baseline project cost, October 2011 cost and fully funded project cost from the Total Project Cost Sheet (TPCS), The TPCS is included in Annex 10.

Table 57 Baseline Project Cost Estimate	
FEATURE	COST ($1,000)
01 Lands and Damages	99,060
06 Fish & Wildlife Facilities	133,990
06 Fish & Wildlife Facilities Adaptive Management	142,115
14 Recreation Facilities	4,362
17 Marsh Creation	2,181,565
30 PED	96,687

Table 57 Baseline Project Cost Estimate	
30 PED Adaptive Mgmt & Monitoring (AM&M)	34,709
31 Construction Management	132,594
31 Construction Management AM&M	9,570
Total Project Cost	2,834,652

Table 58 October 2012 Project Cost Estimate	
FEATURE	COST ($1,000)
01 Lands and Damages	99,060
06 Fish & Wildlife Facilities	136,477
06 Fish & Wildlife Facilities Adaptive Management	144,752
14 Recreation Facilities	4,443
17 Marsh Creation	2,222,056
30 PED	98,030
30 PED Adaptive Mgmt & Monitoring (AM&M)	35,191
31 Construction Management	134,435
31 Construction Management AM&M	9,703
Total Project Cost	2,884,147

Table 59 Fully Funded Project Cost Estimate	
FEATURE	COST ($1,000)
01 Lands and Damages	99,060
06 Fish & Wildlife Facilities	164,088
06 Fish & Wildlife Facilities Adaptive Management	194,610
14 Recreation Facilities	4,766
17 Marsh Creation	2,541,801
30 PED	122,208
30 PED Adaptive Mgmt & Monitoring (AM&M)	52,279
31 Construction Management	176,102
31 Construction Management AM&M	16,739
Total Project Cost	3,371,652

10.2.1 Contingencies

Contingencies are based on a Cost Risk Analysis. Results of this analysis are discussed in the Risk Analysis Section below.

10.2.2 Escalation

Escalation is based upon the US Army Corps of Engineers Engineering Manual (EM) 1110-2-1304 Civil Works Construction Cost Index System (CWCCIS) revised 30 Sep 2011.

10.2.3 MCACES

The cost estimate for the recommended plan was prepared utilizing Mii. The summary portion of the Mii estimate is included in annex 10. The estimated costs were based upon an analysis of each line item evaluating quantity, production rate, and time, together with the appropriate equipment, labor, and material costs.

10.2.4 Risk Analysis

A cost risk analysis was performed for this project in accordance with ER 1110-2-1302 paragraph 7.3.2 and ER 1110-2-1302, appendix B, paragraph 4. The result of the cost risk analysis is shown in the Project Cost and Schedule Risk Analysis Report included in annex 10.

11.0 DESIGN AND CONSTRUCTION SCHEDULE

11.1 CONSTRUCTION SEQUENCE

A construction sequence was developed as shown below. The sequence was based on the construction durations, land loss rates and the limitations of alternating dredging cycles in the lobes of Lake Borgne. Each of the features would be done under a separate contract. This sequence was used to develop the design and construction schedule.

Year 1 LS1A, MRGO1, MRGO6, LM1, LM4, LM2, Beinevnue Recreation Feature
Year 2 BS1A, BS2, CC4 Site 1, BR1, CM1/CM5
Year 3 ES1, LS1B
Year 4 ES2, ES3A, BS1B
Year 5 Shell Beach Recreation Feature, TM1, TM2, HM1, MRGO5, MRGO8
Year 6 ES3B, EM1, MRGO7
Year 7 BM1, LM3
Year 8 CM3, CM4, CM2, CC2, CC3
Year 9 EM2, EM3, EM4
Year 10 MRGO2, MRGO3, MRGO4
Year 11 CC1, CC4 Site 2/3/4, CC5, CC6
Year 12 TM7, TM8

11.2 DESIGN AND CONSTRUCTION SCHEDULE

11.2.1 General

The design and construction schedule used to develop the Mii, Cost and Schedule Risk Analysis and TPCS is shown in figure 80. This schedule includes construction of the features and associated plantings. A more detailed construction schedule can be found in annex 11.

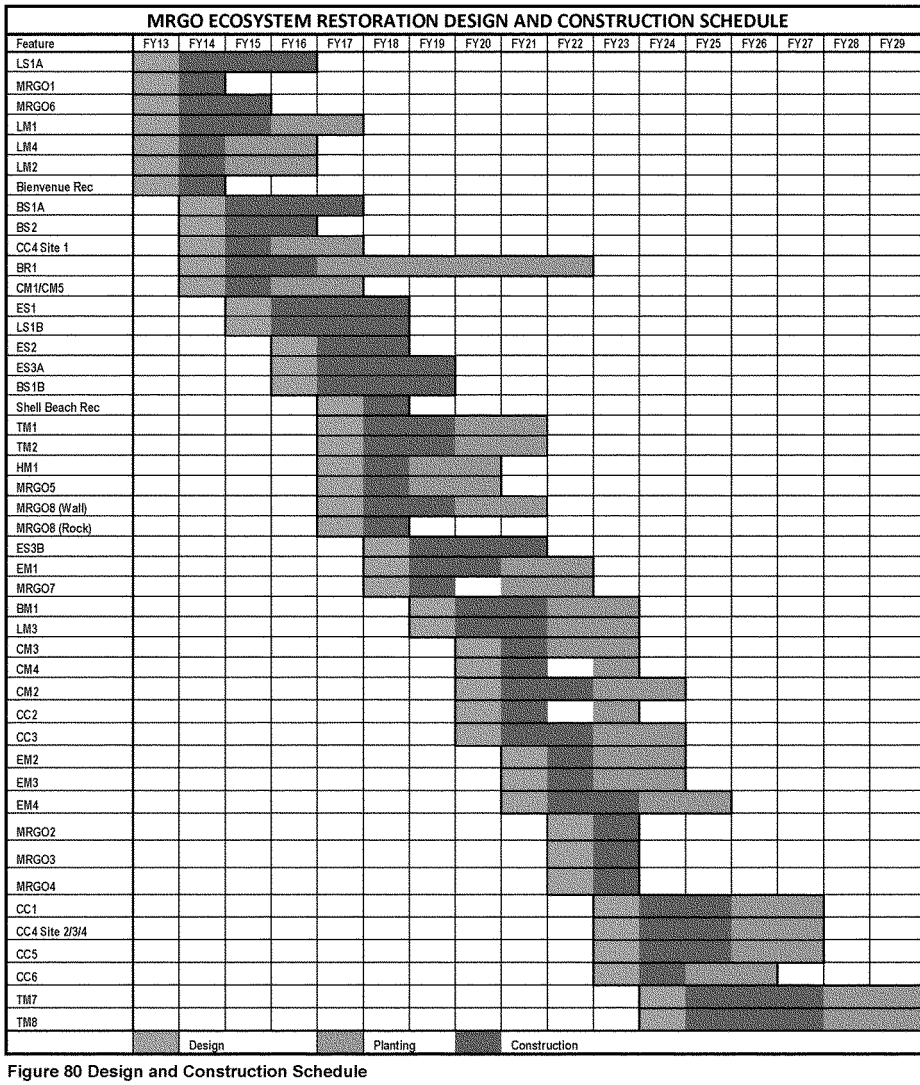


Figure 80 Design and Construction Schedule

11.2.2 Revised Implementation

The timing and availability of financial resources for implementation is a major uncertainty that must be considered given current Federal budgetary constraints. If the plan is not implemented in the near future, conditions will continue to degrade. The impact of the uncertainties associated with the future condition of the study area could increase restoration costs, decrease restoration benefits, or both. The uncertainties associated with implementation are increased because a non-Federal sponsor has not been identified.

Construction sequencing assumed optimal funding appropriations and an aggressive schedule to complete implementation as soon as realistically possible. Given the considerable need for the plan, Federal interest, significance of resources, and the conditional authorization for implementation, an aggressive implementation sequence was considered appropriate. The implementation of the HSDDRS demonstrates National interest in study area resources and the magnitude of what can be achieved when stakeholders are united in purpose. However, current budgetary conditions and the lack of a non-Federal sponsor make it very likely that reality will differ from these optimal assumptions. Risk and uncertainties related to implementation have been assessed in the Cost Risk Analysis. However, due to uncertainties associated with the timing and availability of funding for the plan, only features that are sustainable without the implementation of any other feature are recommended for construction at this time. Further details of this recommendation including the proposed tiered implementation plan can be found in the Main Report.

ANNEX 1

MODELING REPORT

MISSISSIPPI RIVER – GULF OUTLET (MRGO)
ECOSYSTEM RESTORATION STUDY
LOUISIANA AND MISSISSIPPI

HYDRAULICS AND HYDROLOGY

Preliminary Hydrodynamic and Hydraulic Modeling for a Proposed Freshwater Diversion in the Vicinity of Violet, Louisiana

DRAFT MODELING REPORT

Submitted: October 9, 2009
Updated: March 15, 2010

New Orleans District

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LIST OF ACRONYMS

BOC: Basis of Comparison
cfs: cubic feet per second
CWA: Central Wetlands Area
EPA: Environmental Protection Agency
FWOP: Future Without Project
FWP: Future With Project
GIWW: Gulf Intracoastal Waterway
IHNC: Inner Harbor Navigation Canal
LACPR: Louisiana Coastal Protection and Restoration
LADEQ: Louisiana Department of Environmental Quality
LADNR: Louisiana Department of Natural Resources
LDWF: Louisiana Department of Wildlife and Fisheries
LSU: Louisiana State University
MRGO: Mississippi River-Gulf Outlet Canal
NOAA: National Oceanographic and Atmospheric Administration
NRC: National Research Council
UNO: University of New Orleans
USACE: United States Army Corps of Engineers
USGS: United States Geological Survey
WRDA: Water Resources Development Act
WWTP: Waste Water Treatment Plant

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1 EXECUTIVE SUMMARY

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2 INTRODUCTION

Section 7013 of the Water Resources Development Act (WRDA) of 2007 authorizes development of the Mississippi River Gulf Outlet (MRGO) Ecosystem Restoration Plan, which will be developed by the U.S. Army Corps of Engineers (USACE) as a supplement to the MRGO Deep-Draft Deauthorization Report to Congress. The USACE is currently conducting a Feasibility Study to aid in the development of this Plan, the goal of which is to restore estuarine habitat areas affected by the MRGO navigation channel.

Section 3083 of the 2007 WRDA authorizes the diversion of freshwater at or near Violet, Louisiana, for the purposes of reducing salinity in the western Mississippi Sound, enhancing oyster production, and promoting the sustainability of coastal wetlands. According to this section, the project must be designed to meet, or maximize the ability to meet, the salinity levels identified in the 1984 feasibility study of the USACE entitled "Mississippi and Louisiana Estuarine Areas: Freshwater Diversion to Lake Pontchartrain Basin and Mississippi Sound". An ad-hoc group consisting of representatives from a variety of federal and state agencies recommended that the desired salinity regime be met 40% to 50% of the time (USACE, 1982). Experience of the Louisiana Department of Wildlife and Fisheries (LDWF) marine biologists indicates that if good seed oyster production is obtained 1 out of 2 or 3 years, the oystermen will have plenty of oysters. Therefore, the diversion should be designed to allow sufficient freshwater flow to establish the proposed salinity regime 4 or 5 years in 10 or at a minimum of approximately 40% of the time.

The hydraulics and hydrology studies outlined here provide a planning level examination of the potential impacts of diversions of Mississippi River water near Violet Canal on the estuarine areas of Biloxi Marsh. An assessment of these same diversions on the Central Wetlands Area (CWA) between the River and the MRGO/Lake Borgne regions is also conducted to determine beneficial levels of flow in the CWA to meet restoration objectives.

2.1 BACKGROUND

The study area consists of approximately 3.8 million acres of land and open water within the Lake Pontchartrain basin and Lake Borgne ("MRGO Ecosystem …") (Figure 1). In Mississippi, the study area includes the Western Mississippi Sound, its bordering wetlands, and Cat Island. These areas include portions of the Pearl River and the Coastal Streams hydrologic basins.

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There was once major freshwater, sediment, and nutrient input into the basin as a result of seasonal flooding of the Mississippi River. The construction of levees has confined the river between its banks and has eliminated this seasonal flooding, resulting in the elimination of sediments to these areas. The loss of freshwater has also caused saltier waters to encroach on these areas.

Manmade channels and canals that stretch from the Gulf of Mexico inland to freshwater areas allow saltwater to penetrate much farther inland, particularly during droughts and storms, which has had severe effects on freshwater wetlands (Wang 1987). Extreme salinity changes can stress fresh and intermediate marshes to the point where vegetation dies and the wetlands convert into open water (Flynn et al. 1995). By altering salinity gradients and patterns of water and sediment flow through marshes, channel and canal dredging has altered the processes essential to a healthy coastal ecosystem. Since 1932, more than 66,000 acres of marsh, or over 22 percent, has converted to open water in the Pontchartrain Basin ("Lake Pontchartrain …").

Increased salinity levels have negatively impacted the Louisiana oyster (*Crassostrea virginica*) fishery and its industry by shrinking the area within the seeding grounds that serve as ideal oyster habitat (Chatry et al., 1983). Chatry et al. (1983) developed an optimum salinity regime for oysters (see Table 1) by studying salinity, spatfall, and seed oyster production data from a 10-year time period. Meeting this established salinity regime at least 40 percent of the time has become a goal of the MRGO Ecosystem Restoration Plan.

The required salinity targets are shown in the Chatry report (reproduced in Figure 2) as monthly optimum salinity values, together with a standard error about the optimum value (+/- one standard deviation about the monthly mean). In addition, this graph depicts the range of values (denoted as range limits) analyzed to obtain the target value and standard error values (denoted as optimum limits). The graph was based on eight years of data which preceded years of good oyster production.

The optimum salinity around the mean is a very narrow range, much smaller than the daily variability in salinity due to tidal and other coastal forcing parameters such as river flow, winds, and atmospheric pressure. All of these parameters drive salinity values up or down by significant amounts, and depending on the specific conditions at a given time can have remarkable impacts on the salinity mean.

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Table 1. Salinity Targets for the Biloxi Marshes (in ppt).

Month	Chatry Target	Mean Ambient Salinity	Needed Reduction (in ppt)	Needed Reduction (in %)	Chatry Optimum Limits		Chatry Range Limits	
					Low	High	Lowest	Highest
Jan	16.5	19.5	3.0	15.4%	15.5	17.5	15.0	19.0
Feb	14.5	16.5	2.0	12.1%	13.5	15.0	11.0	17.0
Mar	11.5	15.0	3.5	23.3%	10.5	12.5	7.5	15.0
Apr	8.0	14.0	6.0	42.9%	7.0	9.5	2.0	13.0
May	7.0	15.0	8.0	53.3%	6.0	8.0	4.5	11.5
Jun	12.5	17.0	4.5	26.5%	12.0	13.5	9.0	16.0
Jul	13.0	20.5	7.5	36.6%	12.5	13.0	10.5	15.0
Aug	16.0	22.0	6.0	27.3%	15.0	16.5	13.0	17.5
Sep	17.0	23.0	6.0	26.1%	16.0	18.0	15.0	24.0
Oct	17.0	24.0	7.0	29.2%	16.0	18.0	13.0	18.5
Nov	16.0	24.0	8.0	33.3%	15.0	17.0	11.5	18.5
Dec	16.0	23.0	7.0	30.4%	15.5	16.5	13.0	17.0

Note: Salinity targets were estimated to the nearest 0.5 ppt using the graphical display in Chatry et at. (1983). Ambient salinities were rounded to the nearest 0.5 ppt using Pankow et al. (1989) Equation 10a and 50

The effects of freshwater diversions at various locations in the Pontchartrain Estuary have been studied previously (Haralampides, 2000; Georgiou, 2002; McCorquodale et al., 2004; Dortch et al., 2007). Each of these efforts has involved complex hydrodynamic and water quality models that simulate relatively short time periods (on the order of one year). The modeling effort identified in this study was conducted to support the MRGO Ecosystem Feasibility Study as a planning level evaluation of the potential salinity benefits of diverting freshwater from the Mississippi River through a hydraulic diversion structure in the vicinity of the Violet Canal through the CWA and Lake Borgne and into Biloxi Marsh.

The Central Wetland Area (CWA) formerly contained an extensive cypress swamp. Re-growth has been hindered by lack of fresh water, nutrients, and sediments. Lack of the natural overbank flow of the river lowers productivity and allows salt stress (http://www.masgc.org/gmrp/plans/LACIAP.pdf). The addition of freshwater with accompanying sediments and nutrients through the near Violet Canal Diversion will ecologically benefit the CWA. The USACE plans to conduct extensive restoration throughout the CWA. Details of the restoration project include wetland, marsh, and swamp

restoration and creation to restore the CWA to cypress swamp. Preliminary plans for the restoration project are included in Appendix F.

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2.2 OBJECTIVES

The goal of the hydrodynamic modeling described here is to determine if salinity targets in the Biloxi Marsh can be met by diverting freshwater from the Mississippi River through a hydraulic structure and conveyance system near the Violet Canal. The resultant flow regime would then be the basis of design for a new, or modification to an existing, hydraulic structure that would deliver fresh water to benefit the Biloxi Marsh. A secondary objective is the use of the proposed hydraulic modifications to introduce freshwater to the CWA in order to enhance cypress swamp and freshwater marsh restoration.

A final design will balance the efficiency of delivery of freshwater to the Biloxi Marsh region, and ecological restoration goals to the CWA. Considerations in the design are the available head in the Mississippi River and the potential negative impacts to the CWA that could result from inundations due to increased water levels.

2.3 METHODOLOGY

To meet the objectives, a modeling initiative was developed to establish details of a near Violet Canal diversion (Figure 3). This was undertaken as follows:

1. Collecting and collating data on flows, salinity, nutrients and future projects and evaluating their impact on the study area.
2. Modifying and re-calibrating the existing Pontchartrain Basin UNO Mass Balance model.
3. Undertaking a series of model runs to establish the feasibility of a diversion in the vicinity of the Violet Canal to meet Biloxi Marsh salinity targets and to determine flows and generalized flow regime details.
4. Developing a 2D detailed model of the CWA area using Mike21 to characterize the impacts of different alternative diversion locations on the area in terms of salinity, stage and flow.
5. Using UNO's FVCOM to consider the sensitivity of the UNO Mass Balance model results to wind shear and, if necessary, refine the error bands on selected alternatives from the model to reflect these results.
6. Run the UNO Mass Balance model with the final preferred alternative based on flow characterized in the detailed modeling to evaluate the effect on salinity in the Biloxi Marsh.

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7. Providing detail on any hydraulic structures or flood defenses which may be required to implement the final preferred alternative.

2.4 REGIONAL HYDROGRAPHIC SETTING

2.4.1 CLIMATOLOGY

The study area climate is warm and humid subtropical due to its latitude and proximity to the Gulf of Mexico. The area has mild winters, hot summers, heavy precipitation, and generally high humidity. Prevailing winds are southeasterly during the spring, southwesterly in the summer, and northeasterly in the fall and winter. In the coastal area, winds have a strong impact on coastal water levels. Winds from a southerly direction may push water into the bays and lakes, frequently raising water levels in the upper part of the estuarine zone. This also forces more saltwater into the upper reaches of the system, making the region saltier for the time period associated with the frontal activity. On the other hand, winds from a northerly direction may depress water levels and make some areas fresher.

Generally, the winds in the southern Louisiana estuaries are calm to light. However, there are occasional strong winds from two important sources: 1) tropical storms in the summer and fall and 2) the passage of frontal systems in the winter months.

Tropical storms, when approaching the region from the south, will have very strong winds from the east and southeast. These winds will push the shelf waters inland, piling up the water in a significant rise of water level, commonly called storm surge. These winds will push the more saline water from further out in the estuary, increasing the local salinity. However, this increase in salinity is temporary. Following the storm, water will flow out and salinity levels will return to roughly the same values as before the storm. The strong winds stack up the water but there is very little mixing of the water.

The effects of a frontal passage, on the other hand, are more permanent. The north wind preceding a frontal passage causes a set down on the continental shelf and this allows for gravity drainage of the estuary. The waters of the marshes flow out into the Gulf where there is mixing with the Gulf waters. When the north winds subside after the frontal passage, it is the more saline water of the Gulf that returns into the estuary. This increase in salinity is for a longer duration and will last until local rainfall and runoff reduce the salinity.

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Hurricanes or tropical storms originating in the North Atlantic and Caribbean Sea occasionally come into the study area during the hurricane season, June through October. These weather systems can cause considerable property and environmental damage and loss of human life. Historical data from 1899 to 2007 indicate that 30 hurricanes and 41 tropical storms made landfall along the Louisiana coastline ("NHC Archive…" and "NOAA Technical…").

Winds and waves generated by these storms have caused substantial damage to the marshes and have contributed to erosion and land loss. Table 2 presents a chronology of major hurricanes that have influenced the study area. Figure 4 presents the hurricane tracks.

Table 2. Major Hurricanes.

Storm	Date	Lowest Pressure	Sustained Winds
Hilda	10/3/1964	950 mb	115 mph
Betsy	9/19/1965	948 mb	125 mph
Camille	8/17/1969	909 mb	190 mph
Andrew	8/26/1992	956 mb	115 mph
Georges	9/28/1998	964 mb	104 mph
Katrina	8/29/2005	920 mb	125 mph

2.4.2 GEOGRAPHY

The Lake Pontchartrain Basin consists of Lake Maurepas, Lake Pontchartrain, Lake Borgne, the Biloxi Marshes, Chandeleur Sound, plus associated marshlands and waterways. Lakes Maurepas, Pontchartrain, and Borgne cover 55 percent of the basin. Lakes Maurepas and Pontchartrain are hydrologically connected by Pass Manchac, separated only by land bridges of cypress swamp and fresh/intermediate marsh. Lake Borgne is hydrologically connected to Lake Pontchartrain through Chef Menteur and Rigolets. They are separated by a brackish marsh land bridge. Lake Borgne is also hydrologically connected to Lake Pontchartrain via the MRGO and the Inner Harbor Navigation Canal (IHNC). This connection is the smallest of the three between Lakes Borgne and Pontchartrain and will be reduced once hurricane barrier structures currently being constructed are operational.

2.4.3 FRESHWATER INFLUENCES

The basin has several freshwater tributaries. The Blind, Amite, and Tickfaw Rivers flow into Lake Maurepas. The Tangipahoa and Tchefuncte Rivers and Bayous LaCombe and Bonfouca enter from the north shore of Lake Pontchartrain. The IHNC (making a connection between the Mississippi River and the Basin), the Bonnet Carré Spillway, and several stormwater drainage canals discharge

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into Lake Pontchartrain from the south shore. The annual freshwater flow into Lake Pontchartrain and Lake Maurepas averages about 3,800 cfs and 6,400 cfs respectively. This includes ungaged areas but excludes diversions at the Bonnet Carré Spillway.

The largest tributary to the basin, the Pearl River discharges about 13,200 cfs into Lake Borgne near the mouth of the Rigolets. Flow in the Pearl River is highly variable by season and meteorological events. Flows have been as low as 1,000 cfs and as high as 180,000 cfs.

2.4.4 TIDES

Tides in the basin are principally diurnal, with mean ranges of 0.3 ft (Lake Maurepas), 0.5 ft (Lake Pontchartrain) and 1.4 ft (Chandeleur Sound). Mean water levels are affected by winds, freshwater runoff, and seasonal trends in the Gulf of Mexico. Sustained winds can raise or lower peak astronomical tide levels by several feet for short periods of time. The mean water levels are lower in winter and midsummer while higher in spring and fall.

2.4.5 HYDRODYNAMICS AND THE MRGO, GIWW, AND IHNC

To facilitate navigation, three man-made waterways were constructed which may have modified the hydrologic regime of Biloxi Marsh (Sikora, 1985). These are the IHNC, Gulf Intracoastal Waterway (GIWW), and MRGO. The IHNC, connecting the Mississippi River and Lake Pontchartrain, was completed in 1923 with the construction of the IHNC lock at the Mississippi River. The lock allowed for navigation by preventing high stages in the Mississippi River from producing strong currents in the channel. In the 1930's the GIWW was constructed from the mid-point of the IHNC going east and later routed through the IHNC lock. The construction of the GIWW east of the IHNC allowed for additional tidal exchange with Lake Pontchartrain, in addition to the larger channels of the Rigolets and Chef Menteur Pass.

Of the three channels, the MRGO had the greatest impact upon the Biloxi Marsh, Lake Borgne, and adjacent areas. Beginning in 1958 construction of the MRGO took until 1968. From 1968 until its deauthorization the MRGO provided a deep draft shipping channel connecting the Gulf of Mexico to the GIWW. This channel allowed for a density flow of salt water to travel up the MRGO, changing the salinity regime in Lake Borgne and the CWA. As deep draft ships navigated the channel, salt water in the lower part of the water column would be disturbed in the water column by the ship propeller. This brought saltwater to the surface which had an impact on the freshwater vegetation. Concurrently, the ship's wake would erode the banks of the channel. In places the channel shoreline

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has receded over a thousand feet. The receding MRGO shoreline eventually met a receding Lake Borgne shoreline allowing for salt water exchange from MRGO into Lake Borgne and thus impacting salinities in the Biloxi Marsh area.

After Hurricane Katrina, the USACE recommended de-authorization of the MRGO. Congress appropriated funds and a closure structure consisting of a rock dike was constructed across the MRGO at the La Loutre ridge. The closure structure effectively closes the pathway for saltwater to travel up MRGO with the expected action of reducing salinity in Lake Borgne and the surrounding areas.

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3 DATA

3.1 AGENCY RESOURCES

An early task in this effort was to undertake a review of available water quality data. This review considered data collection/identification exercises undertaken by the USACE and the State of Louisiana together with data collected by the U.S. Environmental Protection Agency (EPA), the State of Louisiana, the State of Mississippi, the U.S. Geological Survey (USGS), and other agencies. A summary of the data is located in Appendix A.

3.2 RIVER/FRESHWATER DATA

Freshwater flow data was extracted from existing data sets as daily flow rates for rivers and diversions discharging into Lakes Maurepas and Pontchartrain, Mississippi Sound, Mobile Bay and the passes of the Mississippi River. Flow data for diversion structures such as Caernarvon, Blind River and Hope Canal, and flood control structures such as the Bonnet Carré Spillway are also available. Where gaged data were not available, the flow was established by considering the flow from a neighboring gaged area and assigning a flow based on the proportion of the two drainage areas, assuming similar rainfalls in the ungaged and gaged areas.

For the Lake Pontchartrain basin area, daily flow values from the USGS for the Amite, Tchefuncte, Tickfaw, Tangipahoa and Pearl Rivers were used. The ungaged areas around Lake Maurepas and Lake Pontchartrain were grouped into the following areas: ungaged South Lake Maurepas, ungaged Southwest Lake Pontchartrain, ungaged South Central Lake Pontchartrain (Jefferson Parish), ungaged Southeast Lake Pontchartrain (Orleans Parish), ungaged Northeast Lake Pontchartrain (Bayous Lacombe and Bonfouca), and ungaged South Lake Borgne.

For the Mississippi coast, daily flow values from the USGS were used for the Wolf, Biloxi and Pascagoula Rivers. Flow for the Jourdan River was apportioned according to its drainage area. Daily freshwater flows into Mobile Bay were also obtained from the USGS.

Daily flows for the Mississippi River were obtained from the USACE and were distributed into the various passes according to the average percentage of flow determined from more than two dozen surveys of discharges in the passes from 1970 through 2004.

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Flow data for the Bonnet Carré Spillway is also available for periods when the structure was being operated for flood control in 1997 and 2008. For other high Mississippi River conditions when the structure was not being operated for flood control, leakage through the needles of the structure is significant enough to be considered a freshwater input. Leakage was calculated using a slot flow equation and was checked against USGS flow measurements and a leakage curve supplied by the USACE.

The Pearl River has the largest freshwater flow and is the closest freshwater discharge to the Biloxi Marsh area. This flow regime is the largest contributor to salinity changes in the Biloxi Marsh region. Daily flows from 1990 through 2008 were used for input into the model; the entire record from 1938 through 2008 was analyzed to obtain monthly averages and statistics for the monthly averages. Figure 5 shows the monthly average, minimum and maximum flows of the Pearl River.

3.3 ANALYSIS OF HISTORIC SALINITY DATA

There are few data sets in the Lake Pontchartrain/Lake Borgne areas that have significant high frequency salinity data over long time periods. There are, however, many independent point measurements taken for single purpose applications by many different people and agencies. As a result, there are large numbers of these salinity data points collected over the period of interest at different depths, times and places.

The UNO Mass Balance model only provides valid information at monthly time scales and thus requires comparing datasets on a similar time scale. The USACE has collected the point data and provided the associated spatial descriptions (Figure 6). The data was set up in a sorted data base by latitude, longitude and date.

To generate data sets appropriate for comparison with model results, the data was aggregated together based on their locations relative to the grids that were generated for the UNO Mass Balance model. The aggregated cells were then averaged together over each month to generate monthly "mean" values in each year data was collected. If enough data is collected over each one month period then the average of all these data points over each aggregated grouping provides the best estimate of the average salinity for that month and year. A high number of data points will effectively filter out high frequency variability in the salinity data caused by winds and tides. Figure 7 is a depiction of the average horizontal salinity variation across the system from Manchac to the Chandeleur Islands.

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Salinity in the Biloxi Marsh can be represented by the aggregation of zones J and L (Figure 8) which represent the grouping of several monitoring stations that are in the vicinity of the Biloxi Marsh. Figure 9 shows the monthly average salinity for aggregated zones J and L against the Chatry limits. The historic salinity falls within or below Chatry's optimum upper limits during January, February, March, August, September, November and December. The average salinity falls just above Chatry's limits in June, July and October. In April and May, historic salinity levels are significantly higher than the target.

An analysis of the relationship between the freshwater discharges from the Pearl River system and salinity values in Biloxi Marsh can be developed (Figures 10 and 11). If there is a direct relationship, higher river flows would correlate with lower salinity values. To test this hypothesis, salinity data from the Biloxi Marsh area was aggregated together as described above from zones J and L. The monthly salinity values were plotted directly against the monthly river flows. The results illustrate that prior to the mid 1980s there seems to be a poor relationship between the river and salinity as demonstrated by lack of the expected inverse correlation (Figure 12). This poor relationship is probably due to lack of enough salinity data being available prior to 1989 which will create a bias in the data sets. For the data set from 1989 to the present which is consistent with the data set used in the modeling effort, the anticipated inverse relationship is present (Figure 13).

A multiple linear regression model was developed to describe the relationship between salinity in the Biloxi Marsh and 3 independent variables related to flow in the Pearl River. The equation of the fitted model is:

Monthly Mean Salinity = 53.0764 - 1.69051*logflow - 1.33071*loglf1 - 1.66414*loglf2

Where: logflow = log transformed mean flow for predicted month
loglf1= log transformed mean flow for month prior to predicted month
loglf2= log transformed mean flow for month two months prior to predicted month

The P-value from the analysis of variance (ANOVA) analysis is less than 0.05, indicating a statistically significant relationship between the variables at the 95.0% confidence level. The R-Squared statistic indicates that the model, as fitted, explains 69.09% of the variability in the salinity. The adjusted R-squared statistic, which is more suitable for comparing models with different numbers of independent variables, is 68.61%. The standard error of the estimate shows the standard deviation

of the residuals to be 2.50. The mean absolute error of 1.98 is the average value of the residuals. The Durbin-Watson statistic tests the residuals to determine if there is any significant correlation based on the order in which they occur in the data file. Since the P-value is less than 0.05, there is an indication of possible serial correlation at the 95.0% confidence level.

In determining whether the model can be simplified, the highest P-value on the independent variables is 0.0001, belonging to loglf1. Since the P-value is less than 0.05, that term is statistically significant at the 95.0% confidence level. Consequently, all variables should remain in the equation of the fitted model.

The analysis demonstrates that gage data in the Pearl River can, within the errors demonstrated, predict salinity in the Biloxi Marsh. With this relationship operational models may be developed to help managers predict those times when diversions of Mississippi River water may be needed. The analysis only touches on the functional scheme framework that would be required for a diversion. The result provides an initial piece of the overall data requirements and methodology necessary to create this management framework.

3.4 RELATIVE SEA LEVEL RISE DUE TO EUSTATIC SEA LEVEL RISE AND SUBSIDENCE

Sea level rise in southern Louisiana is a combination of eustatic rise (due to global factors), general land settlement and other local factors which have an impact on sea level and is significantly higher than either the global or regional average sea level rise changes.

Historic rates of relative sea level rise vary across Louisiana and can also vary depending on the methods used to estimate those rates. The two most commonly cited methods of estimating historic relative sea level rise rates in Louisiana are radiometric dating of organic deposits (mostly peat) and analysis of long-term tide gage data. Relative sea level rise rates are determined from tide gage data that are based on more recent (20th century) data than radiometric dating. The relative sea level rise rate determined from gage data is generally greater than the rates determined from radiometric dating.

Data from two local gages together with work from an earlier Louisiana Coastal Protection and Restoration (LACPR) technical report were reviewed as part of this study. The historic trend in sea level rise from the Shell Beach gage was adopted for this study. The historic trend was established as 10.2mm/year using a dataset of 42 years from 1961 to 2002.

The future rates of sea level rise were established in accordance with EC 1165-2-211 and produced three estimates into the future as detailed in Appendix B. The three estimates (low intermediate and high) are based on the following:

1. Low - continuation of the historic rate
2. Intermediate - accelerating rate of eustatic rise based on the National Research Council (NRC) Sea Level Curve I
3. High - accelerating rate of eustatic rise based on the NRC Sea Level Curve III

For the purpose of extracting the non-global eustatic sea level rise rates from the historic rate, a value of 1.7mm/year was used in accordance with the guidance.

When considering a study period from 2011 to 2065, the increases in sea level over this period were estimated as:

1. Low rate (based on a historic trend of 10.24 mm/yr) = 1.8ft (0.55m)
2. Intermediate rate (based on a NRC Curve I and 1.7mm/yr baseline eustatic) = 2.2ft (0.69 m)
3. High rate (based on a NRC Curve III and 1.7mm/yr baseline eustatic) = 3.7ft (1.12 m)

A plot of the sea level rise over the period is shown in Figure 14.

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4 LARGE AREA MODELING – UNO Mass Balance Model

The UNO Mass Balance model is a mathematical tool that performs first-order approximations of mass transfer due to physical inputs like water level, flow, and salinity. The modeling approach is valid if the results are interpreted in the appropriate manner and at the appropriate temporal and spatial scale. The UNO Mass Balance model is ideally used early in feasibility studies in order to look at large numbers of alternatives over long time frames. The model was selected for this planning study because it has been demonstrated to accurately characterize salinity variability on monthly time scales in the Lake Pontchartrain/Lake Borgne regions (McCorquodale, et. al., 2008). For this study, the model domain was modified to better represent the Biloxi Marsh and the Chandeleur Islands in order to characterize the effects of Mississippi River diversions near Violet Canal on salinity in the Biloxi Marsh/Lake Borgne area.

The UNO Mass Balance model has a coarse resolution with grid cells sized on the order of 10 x 10km. The model makes volume and salinity calculations for each box. There is no vertical gradient defined and the model is only capable of predicting large-scale (>> 10km) gradients in the salinity pattern because of its resolution. The model provides a reasonable representation of the spatial distribution of salinity over large areas at these low frequencies (monthly) of interest. The facility of this model is that it is readily available for use, has the ability to make a significant number of operational runs over long time scales, and is easy to modify to include new changes to the system such as the MRGO barrier. For the purposes of this study, the results of the model will be used to define discharge rates at the diversion necessary to meet the salinity targets in the Biloxi Marsh/Lake Borgne regions. The results will be expressed by a range with consideration of the model uncertainties. The model will not provide detailed flow diagrams, residual velocity fields or detailed constituent gradient information. A description of the details and mathematics of the UNO Mass Balance model is included in Appendix C.

Assumptions in the UNO Mass Balance model include:

- Study area is composed of well mixed cells
- Flow in the channels depends on difference in water levels between cells and friction
- Tides are diurnal (one maximum per day) with a lunar cycle
- Short-term wind effects are not included; seasonal Gulf water level is included
- Coriolis force (earth's rotation) is neglected

4.1 MODEL STRENGTHS AND LIMITATIONS

4.1.1 STRENGTHS

The UNO Mass Balance model is mass conservative and can simulate decadal periods in a few minutes. This permits the user to consider the long term impacts of many options and meteorological scenarios.

The UNO Mass Balance model, within the limitation of the cell and link resolution can simulate the water flux and the salinities on an hourly basis for several decades. The use here is to define low frequency variation such as months, which is consistent with the time frames identified in the Chatry salinity targets.

4.1.2 LIMITATIONS

The UNO Mass Balance model lacks spatial resolution and can not represent stratified flows. Stratified flows have been observed in a few locations in the model domain, e.g. in the MRGO channel, in Lake Pontchartrain at the outlet of the IHNC and seaward of the Chandeleur Islands. To partially overcome this disadvantage, the cells were designed to represent distinctive hydrologic and/or habitat areas. Additionaly, the model was calibrated to reproduce the depth-averaged salinities where data were available, such as the MRGO and Lake Pontchartrain. This model assumes that the constituent in each cell is completely mixed with the computed value of the state variable assigned to the centroid of the cell.

Wind shear is not included in UNO Mass Balance model calculations. The model assumes that the advective fluxes are primarily driven by gravity (pressure gradients) and resisted by friction that form drag.

The UNO Mass Balance model will have little or no value in providing hydraulic or salinity information pertinent to understanding the ecology in the CWA. A cell has been added to the model to capture the CWA, but the results will only be valid as a first order of magnitude because of the coarse resolution.

The model should not be used to examine the effects of relative sea level rise. The model geometry remains constant throughout the various runs and is unable to adapt to account for changes that would occur as a result of sea level rise.

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4.1.3 UNCERTAINTIES

Modeling efforts have uncertainties. The quantification, understanding, and minimization of these uncertainties are critical for the correct interpretation of model results. Uncertainty may arise in the input data, in the geometry of the model grid, and/or in the data used to verify and calibrate the model.

Uncertainty in the input data results from having to define freshwater flows from the rivers and streams in the Pontchartrain basin and along the Mississippi Coast. Input flows for the numerous ungaged areas were assumed to be similar to the input in the gaged areas. While this is a valid assumption, it adds some uncertainty to the model.

Uncertainties in the model geometry can be more significant than those in the input data. Large areas are approximated with an average depth and the boxes have an area for runoff and a contributing area for evaporation. All of these areas and depths are estimated based on the best available data.

Field data for calibration and validation can contribute the highest uncertainty to the modeling effort as data are critical in interpreting model results. Much of the data are spot data, and the exact time with respect to the tide and meteorological forcing is unknown. The ensemble of measurements was assumed to indicate average conditions. The UNO Mass Balance model had previously been validated for Lake Pontchartrain and Lake Maurepas, but was not validated for the Lake Borgne and Biloxi Marsh. The data was utilized to ascertain if the model reproduces seasonal trends.

The calibration and validation process for the expanded model was not thoroughly undertaken due to the limited data; therefore, uncertainty in the model results exists. Based on the model calibration error of 17%, a standard error in the prediction of the salinity in any cell can be +/-17%. Despite the uncertainties, the UNO Mass Balance model is a good, efficient tool to investigate the impact of proposed diversions.

4.2 MODEL INPUT PARAMETERS

The UNO Mass Balance tidal, salinity and water quality model requires extensive input datasets. The hydrologic and ambient data were obtained from the LADEQ, UNO, USGS, NOAA, LADNR, USACE and EPA. The inputs listed below and described further in the text are dominant in determining the salinity distribution in the cells:

- The freshwater budget (rainfall, evaporation, tributary flow and diversions)

- The open boundary conditions (tides and salinities)
- The cell and link bathymetry
- The link friction factors (Manning's n and eddy loss coefficients)
- The diffusivities for the links

4.2.1 MODEL GEOMETRY

The model consists of boxes (cells) and links. Figures indicating the cells and cell-link configuration are included in Appendix D. The dimensions of each cell and link as well as other preliminary data assignments are included in Appendix D. Appendix D also includes a table with the attributes of each cell including surface area, depth, hydraulically connected area, percent open area, initial salinity, and fetch length.

4.2.2 BOUNDARY CONDITIONS

The open boundary was located in the Gulf of Mexico in order to minimize its influence on the area of interest. Diurnal tides were imposed with a spring range of 0.66 m. The salinities at the Gulf boundary vary from 34 to 36 ppt with surface values on average less than deeper values. The model used 34 ppt which is more representative of mean surface salinities.

4.2.3 FRESHWATER INPUT

Freshwater flows were input into the UNO Mass Balance model as boundary conditions. The freshwater input data was comprised of daily flow data for rivers discharging into Lakes Maurepas and Pontchartrain, Mississippi Sound, Mobile Bay and the passes of the Mississippi River. Flow data for diversion structures such as Caernarvon and flood control structures such as Bonnet Carré were also inputs into the model. Salinity of the freshwater inputs was set at 0.2 ppt.

The USGS gage near Bogalusa, Louisiana has a continuous discharge record from October 1, 1938 to present. The USGS had a gage near the mouth of the Pearl River from October 1, 1963 through September 30, 1970. This gage was discontinued because the tidal flow made for difficulties in accurately determining the flow. Comparison of the two records where they coincided showed the Pearl River flow to be, on average, about 32 percent greater than the Bogalusa flow. The ratio of total basin surface area to basin area above the gage location is approximately 1.32. Thus, for the modeling period, the Bogalusa flows were increased by 32 percent and used as the Pearl River discharge in the model.

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Table 3 gives a summary of all the freshwater input flows for the UNO Mass Balance model and Figure 15 shows the location of input flows in relation to the cells.

Table 3. Freshwater Input Flows.

Location	Average Flow (cfs)	Min Flow (cfs)	Max Flow (cfs)
Amite River	2,005	132	79,600
Tangipahoa River	1,072	73	36,400
Tchefuncte River	137	25	4,667
Tickfaw River	493	55	20,760
Pearl River	10,277	1,140	97,400
South Lake Maurepas	1,042	69	35,980
Southwest Lake Pontchartrain	261	17	8,995
South Central Lake Pontchartrain (Jefferson Parish)	265	24	8,995
Southeast Lake Pontchartrain (Orleans Parish)	353	28	12,593
Northeast Lake Pontchartrain (Bayou LaCombe)	384	24	13,493
Northeast Lake Pontchartrain Bayou Bonfouca	385	26	13,493
Lake Borgne (Violet wetlands)	82	6	841
Wolf River	542	12	19,448
Jourdan River	667	15	23,936
Biloxi River	156	4	5610
Pascagoula River	8,474	898	103,000
Mobile Bay	17,533	128	157,788
Southwest Mississippi River (Southwest Pass, Grand Pass and West Bay Diversion)	179,728	45,115	433,500
Central Passes Mississippi River (Pass a Loutre and South Pass)	250,302	62,831	603,723
East Passes Mississippi River (includes Main Pass to Bayou Lamoque and Bohemia Spillway)	107,124	26,890	258,380
Caernarvon Diversion	1,300	0	9,267
Violet Siphon	100		
Bonnet Carré Diversion			240,000
Diversions at Maurepas Swamp (Convent, Blind River/Hope Canal, and Maurepas Swamp River Reintroduction)		0	4,500

4.2.4 BATHYMETRY

Bathymetry used for the UNO Mass Balance model was obtained from NOAA navigation charts, a previously compiled bathymetry mesh for ADCIRC model runs, and Barrett (1970).

4.2.5 METEOROLOGICAL INPUTS

Daily precipitation, evapotranspiration, air temperature, water temperature and daily wind speed were all input into the model as described. Figures 16 to 18 show the values input into the model.

4.3 MODEL CALIBRATION AND VALIDATION

The base model was originally developed, calibrated, and validated for Lake Pontchartrain/Lake Borgne area (McCorquodale, et. al., 2008). For this study, the model domain was extended to examine the Biloxi Marsh area.

4.3.1 SALINITY CALIBRATION

The extended model was calibrated using flow and salinity data for the period 1990 through 2008. This is the period for which the best, most comprehensive data sets are available. This base condition is not the same as the existing conditions, as existing conditions have changed with the closure of the MRGO at the La Loutre Ridge. Since the collected salinity data is from the period prior to the construction of the MRGO closure structure, the calibration effort was conducted using the conditions existing prior to the construction of the closure structure. Calibration values are included in Appendix D. Tidal fluxes were compared with data from the UNO/USGS Synoptic Survey, which uses an Acoustic Doppler Current Profiler at Rigolets, Chef, IHNC and Pass Manchac. Salinities from LDWF and MS Division of Wildlife, Fisheries and Parks were supplemented with salinities from NOAA, USACE, USGS, LADEQ, LADNR, UNO and LSU.

The freshwater inflows described previously were included as input into the calibration. Additionally, inflows from the Caernarvon and Bonnet Carré diversions which were present at the time of the calibration period were used for calibration. The Caernarvon diversion was modeled using an average flow of 1,300 cfs, maximum flow of 9,267 cfs, and minimum flow of 0 cfs. The Bonnet Carré Spillway Diversion was modeled using a maximum flow of 240,000 cfs, which occurred during the 1997 operation of the structure.

Figure 19 shows the tidal fluxes through the passes into Lake Pontchartrain and Lake Maurepas. Table 4 compares the spring ebb tidal fluxes in the model with measured values. The values for Pass Manchac into Lake Maurepas are within one percent. The values for the IHNC through Seabrook are within five percent. The model under-computes the peak spring tide flow in the Chef Menteur Pass by 23 percent and over-computes the Rigolets by eight percent (8%). However, the combined ebb flux into Lake Pontchartrain through the IHNC, Chef Pass and the Rigolets in the model is within 2.3

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percent of the observed value. The spring tidal range in Lake Pontchartrain is predicted within 4% of the observed range.

Table 4. Tidal fluxes during spring flood and ebb tide.

	Pass Manchac into Lake Maurepas	IHNC through Seabrook	Chef Menteur Pass	Rigolets	IHNC, Chef Menteur, and Rigolets
Observed	13,000	13,000	85,000	180,000	278,000
Modeled	35,300	12,400	65,000	194,000	271,400

Figure 20 is a plot of modeled data compared to collected data at Grand Pass, in the Biloxi Marsh area. This data represents the output from Box 14, which is in the western Mississippi Sound just north of the Biloxi Marsh area, over the time period shown. Box 14 is a "deeper" water region where a significant transfer of flow occurs along the Mississippi coast where water mixes with saltier gulf waters. The data sets show good agreement though the model does not agree with the extreme high and low salinity points probably due to the depth-averaged feature of the model and its weakness in calculating the higher frequency variability. The 14-day moving average provides a trendline of the measured data, which correlates well to the results.

Figure 21 is a plot of the modeled data compared to the measured data at Rigolets over the time period shown. The data is the output from cell 3, which is the area in east Lake Pontchartrain. Similar to the Grand Pass data, the model does not capture the high and low salinity values but is able to follow the trend of the data well.

Figure 22 graphs the maximum and minimum salinity values for the areas shown in Figure 23 versus the mean salinity value of the nearest cell in the model. Linear curves are given for the maximum, minimum, and calculated mean of the salinity points. The equation for the line in the middle indicating the mean values is Y=0.9975X. This line has a R^2 value of 0.9533 and an error of 0.17 percent (0.17%). Both of these numbers give confidence in the ability of the model to provide accurate estimates of average salinity values and thus to predict average salinity values due to proposed diversions.

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4.3.2 SALINITY VALIDATION

No formal validation of the results has been completed. Lack of enough salinity data taken after the closure of the MRGO did not allow for validation of model results. The construction of the MRGO closure has significantly changed (lowered) the salinity patterns in Lake Borgne that existed since the 1950s dredging of the MRGO. Therefore, validation of this condition is not possible until a reliable long-term data set is generated. The existing UNO Mass Balance model previously validated for Lake Pontchartrain was calibrated to analyze the effects in the Biloxi Marsh. Comparison of model output with existing data provides confidence in the model results.

4.4 SALINITY TARGET LOCATION AND CALCULATION

As discussed, the diversion of freshwater near the Violet Canal structure would be beneficial if salinity in Biloxi Marsh can be modified to meet the salinity targets of Chatry. The measure is defined as meeting these targets along a specified line (contour) in the Biloxi Marsh. The Salinity Target Line, is defined in the "Flood Control of the Mississippi River and Tributaries Mississippi and Louisiana Estuarine Areas, Design Memorandum No 1, Bonnet Carré Freshwater Diversion Structure, Appendix C, Salinity Study Results" and is the designated "point" in Biloxi Marsh where salinity from the model can be aggregated to compare against the Chatry limits.

This line passes through computational boxes 14, 13, 78, 74, and 28 in the salinity model. Box 14 has been excluded from the analysis as the majority of this box is deeper water and not marshland and is subject to higher salt gradients and skews the depth averaged value to the saltier side. Box 28 within the model represents the MRGO seaward of the Bayou la Loutre and is not thought to represent the salinity within the Biloxi Marsh. Although the line does not pass through Box 73 this has been included in the weighting as this is a significant part of the marshland. From the salinity values of the remaining four boxes, salinity along the Salinity Target Line was determined by dividing the line into twelve points and using an inverse distance weighted process to establish the average salinity along the line. Each salinity value is weighted inversely to the square of the distance of the centroid of each box from the line. All points weighting gives a single set of weights that can be used to represent the average value along the whole line. A distance weighting factor of 1 has been used. The line and points used are given in Figure 24 and Table 5.

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Table 5. Weighting Factors for Determining Salinity along Target Salinity Line.

Box	0	1	2	3	4	5	6	7	8	9	10	11	12	All points
13	0.41	0.45	0.49	0.43	0.33	0.27	0.20	0.13	0.10	0.10	0.13	0.15	0.17	27%
73	0.17	0.14	0.11	0.11	0.15	0.20	0.21	0.18	0.15	0.15	0.21	0.25	0.26	18%
74	0.14	0.12	0.10	0.10	0.15	0.24	0.37	0.56	0.66	0.66	0.54	0.45	0.40	32%
78	0.28	0.29	0.30	0.36	0.37	0.29	0.21	0.13	0.10	0.10	0.13	0.15	0.17	23%
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100%

4.5 METHODOLOGY FOR ESTABLISHING COMPLIANCE WITH SALINITY TARGET VALUES

The UNO Mass Balance model has been developed to demonstrate the effectiveness of different scenarios in achieving the salinity target. Neither the target nor results from the UNO Mass Balance model represent a single number but a range or averaging of values over spatial and temporal scales.

For the target values, the ranges have occurred due to the variability of the data analyzed to produce the results. The salinity values vary from year to year and the target ranges were statistical ranges about the mean value of selected years correlated to high oyster production. The optimum limits (which are the target of this exercise) are based on one standard deviation about this mean, whereas the range is the maximum and minimum values recorded in those months which were seen to contribute to optimize oyster production.

For the modeling results, there is a range in the values as a result of uncertainties within the model and also as a result of the averaging process to establish salinity values to compare against the target value. The model uncertainties were established as being around ±17% of the modeled salinity (e.g. a modeled value of 10ppt would have a model uncertainty of ±1.7ppt). In addition, a standard deviation associated with the averaging process defined in section 4.4 was established. These two values were combined as a vector sum to give a standard error for the modeled results.

Having established these standard deviations for both the target and modeled result it is then possible to plot the frequency distributions (based on a t-distribution) of the modeled salinity and the target value (an example of which is shown in Figure 25). This figure shows that for some percentage of the time the modeled distribution overlaps the target distribution. Significantly, most values are demonstrated to be lower in salinity than the upper optimum limit identified by Chatry. The results of

the distributions were plotted as cumulative, as shown in Figure 26. From Figure 26 it can be seen that the percentage time that the modeled results intersect with the Chatry limits is the models prediction against the target for that month. For this example the model generated salinity values in May along the target line below the Chatry Optimum uppper value 30% of the time and above the Chatry optimum upper value 7% of the time, therefore the overlap within the optimum range is 23%.

For compliance with the 40% criteria, freshening of the system is examined. Therefore, all values lower than the upper Chatry limit are considered. In this example, the UNO Mass Balance model has generated salinity values lower than the upper target for 30% of the Mays (over 19 years). Therefore, this scenario does not meet the 40% target.

4.6 MODEL RESULTS

The UNO Mass Balance model was run for a number of scenarios during the development of the diversion alternatives. All the model simulations used the same base bathymetry and links, together with the majority of the same fluvial inputs as the historic model developed and used for calibration. Table 6 provides the scenarios performed and the key differences. The historic scenario is the calibration run. The recently constructed MRGO closure and other structures recently built are expected to have a substantial impact on salinity in Lake Borgne and surrounding areas but no data have been collected since construction to date to evaluate this impact. To demonstrate the reliability of the model, the alternatives and their detail are discussed further in the following sections.

Table 6. Table of Elements for Model Runs.

Run	MRGO Closed	Seabrook Gate	IHNC Barrier	Modified and Future Diversion Flows	Near Violet Canal Diversion Flow
Historic					
Baseline (Closures)	X	X	X		
Future Without Project	X	X	X	X	
Future With Project	X	X	X	X	X

4.6.1 PRE MRGO CLOSURE (HISTORIC)

The calibration effort proved that the model is capable of predicting salinity within an identified error. The analysis of historic data from areas J and L in section 3.3 indicates that salinity falls within or below Chatry's optimum limits during January, February, March, August, September, November and December and the average salinity falls just above Chatry's limits in June, July and October. In April and May, historic salinity levels are significantly higher than the target. The historic condition model results indicate the same trend and show that the target has only been met 4% of the time in the critical month of May and only 24% in Aprils. The results for the historic condition run are seen in Table 7. July is slightly under the Chatry criteria. Figure 27 and 28 graphically compare the J and L data with the historic condition model run. The model agrees well with the physical data, especially in the months of April and May. These model runs point to the impact the MRGO had in the salinity character of Lake Borgne resulting in higher salinities in critical months (April, May) in the Biloxi Marsh.

Table 7. Historic Condition Model Results.

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	13.3	3.72	2.55	94%
February	10.6	3.92	2.10	98%
March	9.9	3.80	1.99	90%
April	10.8	2.94	2.05	24%
May	12.5	4.12	2.44	4%
June	13.5	3.78	2.58	47%
July	14.2	3.67	2.69	37%
August	15.8	2.94	2.93	59%
September	16.7	3.14	3.08	67%
October	17.8	2.68	3.26	48%
November	17.7	2.85	3.25	41%
December	16.2	3.33	3.01	50%

4.6.2 POST MRGO CLOSURE (BASELINE CONDITIONS)

Baseline conditions include the MRGO closure structure at the La Loutre Ridge, the Seabrook Gate and the IHNC Barrier (with openings for Bayou Bienvenue and the GIWW) all in place. During the Baseline model run, the salinity goal is now met for all months except May where the goal is met

only 6% of the time. The results for the baseline run are seen in Table 8. This model scenario indicates that the existing closures and other structural changes to the physical system will not be enough on their own to reduce salinities to the recommended target in May in the Biloxi Marsh and that additional freshwater will need to be input into the system via diversions. This alternative does tell us that May is the critical month and that diversions need to occur in that timeframe to meet the monthly salinity target identified.

April barely meets the criteria with salinity calculated below the upper limit 41% of the time. All other months are fresher than this upper limit over 50% of the time over the 19 year modeled record.

Table 8. Baseline Condition Model Results.

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	12.3	3.69	2.37	98%
February	9.4	3.85	1.91	99%
March	8.8	3.74	1.81	98%
April	9.7	2.86	1.86	41%
May	11.6	4.02	2.29	6%
June	12.7	3.77	2.45	59%
July	13.5	3.66	2.56	47%
August	15.2	2.85	2.80	68%
September	15.9	3.10	2.96	76%
October	17.1	2.63	3.14	57%
November	16.9	2.80	3.12	50%
December	15.2	3.35	2.85	63%

4.6.3 FUTURE WITHOUT PROJECT (FWOP)

Two FWOP conditions are examined based on the final disposition of future diverions. The FWOP and FWOPD scenarios include the baseline conditions, existing diversions at Violet Siphon, Bonnet Carré and Caernarvon, and planned diversions at Maurepas Swamp (Convent, Blind River/Hope Canal, and Maurepas Swamp River Reintroduction), Caernarvon, and the CWA Waste Water Treatment Program.

Planned diversions from the lower Mississippi River located below the Caernarvon Diversion were not included in the model. The Bertrandville Siphon, Bohemia Mississippi River Reintroduction, Delta Building Diversion (North of Ft. St. Phillip), White Ditch, Bayou LaMoque and the Benney's Bay Diversion were deemed to be sufficiently far from the study area to not have a significant influence on salinity conditions in the study area and there is little available information as to the proposed operational scheme for these diversions. The inflow due to existing cuts, overflows and diversions in the River reach from Baptiste Collette to Bohemia was approximated as 12% of the River flow.

The diversion value for the Violet Siphon is 100 cfs which is assumed to be the average. Bonnet Carré is the same as the calibration/historic run with a maximum flow of 240,000 cfs. The combined diversions into the Maurepas swamp area (Convent Diversion: 500 cfs, Blind River/Hope Canal: 1,500 cfs and Maurepas Swamp River Reintroduction: 1,000 cfs) have a potential capacity of 3,000 cfs in the FWOP scenario. These diversions are regulated to keep the Lake Maurepas salinity below 1 ppt. The model was operated in the FWOP scenario to open the diversion when salinity in Maurepas was greater than 1 ppt; if the salinity was less than 1 ppt, they are closed. This results in a condition where Lake Maurepas was always less than 1 ppt. The FWOPD condition is identical to the FWOP condition except that in the FWOPD scenario, the diversions at Maurepas Swamp total 4,500 cfs due to an increase in the Blind River/Hope Canal diversion to 3,000 cfs. The CWA Waste Water Treatment Program flow totals approximately 30 cfs.

Input flows for the Caernarvon diversion were increased by roughly 25 percent in line with the projected increase in the capacity of the structure. The increase is calculated by increasing the actual flows for 2007 and 2008, in which the structure was operated to pulse large flows, by 25 percent. The resulting flows were then smoothed so as to eliminate rapid changes that might induce numerical instabilities in the model. The resulting smoothed flow maintained the same volume of flow. Figure 29 shows the actual flows for 2007 and 2008 and the resulting smoothed flow curve. This resulting smoothed flow was then repeated on that two year cycle over 19 years to examine salinity variability due to the Caernarvon input flows for the 19 year period.

The model results indicate that the planned Caernarvon diversion and salinity constraint does modify the salinity regime in the Biloxi Marsh. For the month of April, salinity decreases over the baseline condition and the amount of time that the salinity is under the upper target increases from 41% to

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86.9% in the FWOP condition and 91.3 in the FWOPD condition. This reduction in salinity from the diversions infers that additional diversions may not be necessary during Aprils.

Salinities in the month of May were also lowered and the target salinity is now met 27.4% of the time in the FWOP condition and 33.7% of the time in the FWOPD condition with these planned diversions. This is a significant increase of 21% to 27% of the time that the goal is met over this new baseline conditions. This is a significant improvement, indicating that additional management changes may help meet the targeted goals. This scenario also verifies that additional freshwater diversions will be necessary in freshening the Biloxi Marsh to meet the 40% Chatry goal. The FWOP model results are seen in Table 9.

Table 9. Future Without Project Condition Model Results – FWOP.

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	11.04	3.50	2.14	99.6%
February	8.06	3.78	1.70	100.0%
March	7.29	3.59	1.55	99.9%
April	7.54	2.67	1.49	86.9%
May	9.04	3.63	1.83	27.4%
June	10.08	3.54	1.99	93.8%
July	11.15	3.36	2.15	83.1%
August	13.32	2.57	2.47	89.3%
September	14.60	2.88	2.71	89.1%
October	15.98	2.47	2.93	71.5%
November	15.91	2.65	2.93	63.3%
December	14.16	3.13	2.65	77.7%

The FWOPD condition adds in the diversions at Maurepas Swamp that is anticipated to be approximately 4,500 cfs year round. It has conditional approval as an authorized project. The result is a small change in the average salinity but boosts the before project to a fresher initial condition at Biloxi Marsh (Table 10).

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Table 10. Future Without Project Condition Model Results - FWOPD.

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Error (ppt)	Sigma (ppt)	
January	10.47	3.31	2.03	99.8%
February	7.77	3.54	1.62	100.0%
March	6.99	3.36	1.48	99.9%
April	7.25	2.49	1.42	91.3%
May	8.67	3.42	1.75	33.7%
June	9.64	3.33	1.90	96.5%
July	10.64	3.15	2.05	89.2%
August	12.69	2.41	2.35	93.9%
September	13.86	2.76	2.57	94.0%
October	15.14	2.37	2.78	81.2%
November	15.05	2.50	2.77	74.6%
December	13.38	3.00	2.50	86.5%

4.6.4 FUTURE WITH PROJECTS/PROJECT ALTERNATIVES (FWP)

The FWP scenario includes the closures and diversions outlined in the FWOP/FWOPD conditions and with the addition of near Violet Canal diversion scenarios. The UNO Mass Balance model is not resolved enough to differentiate between the specific diversion locations and scenarios are not defined as such. All results figures for the FWP scenarios are in Appendix E.

Initially, diversions between 7,000 and 30,000 cfs were discharged to Lake Borgne over the entire year to investigate the sensitivity to salinity reductions and the ability of a diversion in this area to affect salinity and meet the salinity target. To discharge this amount of water through the CWA it was physically necessary to anticipate a direct channel through the CWA and through a new structure in the Chalmette levee into the MRGO and Lake Borgne. These higher flows could not be released inside the CWA due to the potential of severe flooding. Alternatives of 7,000, 10,000, 15,000, 20,000 and 30,000 cfs were modeled in this fashion.

To facilitate environmental enhancement of the CWA, a second condition was established where discharges of between 1,000 and 10,000 cfs are diverted into the CWA, inundating this area prior to discharging through the Bayou Bienvenue and Bayou Dupre control structures (and potentially a third structure). For these scenarios a base flow of 1,000 was run for all months except April and May. In April and May, the flow was increased to 5000, 7,000, and 10,000 cfs. The 1,000 cfs base flow

provides hydration and is expected to create freshwater conditions in the CWA year round. Increased flows in April were included to account for the hydraulic residence time (approximately two weeks) in Lake Borgne to establish the freshest conditions possible to help meet the Chatry target in May.

To improve the flow dispersion to the Biloxi Marsh region these modeling scenarios were also run to include a closure of the MRGO/Lake Borgne connection, forcing additional freshwater south and out through Bayou La Loutre rather than discharging directly through Lake Borgne. The Lake Borgne channel has recently been structurally altered to reduce the opening to a 200m wide channel. In the Lake Borgne closed scenario this opening is now completely blocked. This closure does not completely block water from moving into Lake Borgne since there are several other smaller channels connecting the MRGO and Lake Borgne.

Table 11 lists the FWP model runs where the following denotes the type of run:

- A1 – Base flow is 1,000 and flow is increased in April and May. Lake Borgne is open.
- A2 – Base flow is 1,000 and flow is increased in April and May. Lake Borgne is closed.
- A3 – Flow is steady for all months. Lake Borgne is open.
- A4 – Flow is steady for all months. Lake Borgne is closed
- D – Includes diversions at Maurepas Swamp totaling 4,500 cfs (Blind River, Convent, and Hope Canal); otherwise, the diversions at Maurepas Swamp are regulated to maintain a salinity in Lake Maurepas below 1ppt.

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Table 11. Future With Project Alternatives.

Alternative	Base Flow (cfs)	April/May Flow (cfs)	Gap between MRGO and Lake Borgne - Open or Closed	Diversion at Maurepas Swamp
1A1	1,000	1,000	Open	< 1ppt
7A1	1,000	7,000	Open	< 1ppt
5A2	1,000	5,000	Closed	< 1ppt
7A2	1,000	7,000	Closed	< 1ppt
10A2	1000	10,000	Closed	<1ppt
10A3	10,000	10,000	Open	< 1ppt
15A3	15,000	15,000	Open	< 1ppt
20A3	20,000	20,000	Open	< 1ppt
30A3	30,000	30,000	Open	< 1ppt
7A4	7,000	7,000	Closed	< 1ppt
7A2D	1,000	7,000	Closed	4500 cfs
7A4D	7,000	7,000	Closed	4500 cfs

Operationally, there is an expectation that flows above the base levels of 1,000 cfs through the CWA would require construction of a structure in the levee south of the IHNC structure. The mass balance model does not need this level of specificity and flows were designated through the links represented in the box model as the Bienvenue and Dupre gates. All of the flows that would be directed through this third structure are included in the flow out of the Dupre gate. Based on the MIKE 21 results that are provided later; the distribution of flow exiting the CWA and included as the fresh water input in the FWP model runs is shown in Table 13.

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Table 12. Flow Distributions through the Central Wetlands.

Flow scenario (cfs)	Bayou Bienvenue (cfs)	Bayou Dupre (cfs)
1,000	500	500
5,000	450	4550
7,000	630	6,370
10,000	900	9,100

The flow distribution exiting the CWA through links in the model to other cells within the model is shown in Table 13 and provides an estimate of how much freshwater from the CWA is entering each geographic location. For Alternatives A1 and A2, water exits via the Bayou Dupre and Bayou Bienvenue control structures.

Table 13. Flow Distribution.

	% of Violet Flow Delivered		*% of Violet Flow Delivered*	
	Diversions up to 1,000 cfs		*Diversion of 7,000 cfs*	
System Compartment	*Lake Borgne Gap Open*	*Lake Borgne Gap Closed*	*Lake Borgne Gap Open*	*Lake Borgne Gap Closed*
Bayou Dupre	**50%**	**50%**	**91%**	**91%**
Biloxi Marsh	20%	25%	6%	46%
Lake Borgne	30%	25%	62%	46%
Bayou Bienvenue	**50%**	**50%**	**9%**	**9%**
Lake Pontchartrain via IHNC	14%	14%	2%	2%
Golden Triangle	6%	6%	1%	1%
Lake Borgne	30%	30%	5%	5%

The impacts of the 1,000 cfs diversion are examined in detail in the MIKE 21 section. The UNO Mass Balance model only examinesimpacts on the overall system including Biloxi Marsh. When compared to FWOP, the base level of flow will show a slight (<1ppt) reduction in the average salinity in Biloxi Marsh for April and May. Table 14 provides the results of the 19-year monthly averages over the period of simulations and associated statistics for that specific scenario. A similar table for every diversion scenario is provided in Appendix E as well as associated graphs and spatial plots of salinity results. Table 15 provides a summary of the results that are found in this appendix.

Table 14. FWP 1,000 cfs Condition Model Results – 1A1.

	Model Results		Model Uncertainty	
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	Below Chatry Target
January	10.73	3.27	2.07	99.8%
February	8.05	3.51	1.66	100.0%
March	7.32	3.36	1.53	99.9%
April	7.66	2.46	1.49	85.3%
May	9.07	3.40	1.81	26.7%
June	10.03	3.27	1.95	94.4%
July	11.04	3.10	2.11	84.7%
August	13.09	2.37	2.42	91.2%
September	14.24	2.74	2.64	91.7%
October	15.50	2.32	2.84	77.3%
November	15.35	2.45	2.82	70.9%
December	13.61	2.93	2.54	84.2%

The results demonstrate how the different conditions change the salinity character of Lake Borgne which each affects the salinity structure in Biloxi Marsh. The results also highlight the difficulty of translating a range of values over a spatial area of 600 square miles and using a transect line of over 30 miles long in an area that has relatively large salinity variability over tidal, synoptic, monthly and annual cycles.

The results are described in terms of how an alternative is able to modify the salinity structure at the Salinity Target Line to meet the Chatry Limits. To put the analysis in perspective, the upper Chatry Limit target for May is 8 ppt. All of the diversion scenarios (1,000 to 30,000 cfs) that will be discussed will decrease the salinity in Biloxi Marsh on the order of 3 to 4 ppt from the FWOP conditions.

Generally the results indicate that the full freshwater diversion over the entire year has a greater impact (approximately 3% increase) on meeting salinity targets in May than just applying a diversion in April and May. A closure of Lake Borgne can affect salinity in the Biloxi Marsh a significant amount. At 7,000 cfs the Lake Borgne closure is correlated to a 3% to 4% increase in time that the salinity target is met. As hypothesized, more flow does move south in the MRGO channel with the gap closed, discharging to Biloxi Marsh in a more efficient manner than through Lake Borgne alone.

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Year round flows via the diversions at Maurepas Swamp (set at 4,500 cfs) also impact salinity in Biloxi Marsh by an order of 4% increase.

Table 15. Results of diversion scenarios in terms of % of time salinity meets the upper Chatry Salinity Limit in May.

Flow (cfs)	Historic	Baseline	FWOP Scenarios		FWP Scenarios					
			FWOP	FWOPD	A1	A2	A3	A4	A2D	A4D
0	3.9%	6.1%	27.4%	33.7%						
1,000					26.7%					
5,000						33.7%				
7,000					31.7%	36.7%		43.6%	43.0%	48.1%
10,000						41.6%	46.2%			
15,000							55.2%			
20,000							63.3%			
30,000							75.4%			

The variety of diversion alternatives between 5,000 and 10,000 cfs will alter salinity in Biloxi Marsh relative to the 40% target goal. At 5,000 cfs, the target is met in the range of 32% to 36%. At 7,000 cfs we see alternatives range between 32% and 48%. At 10,000 cfs the range in meeting the Chatry targets is from 38% to over 50%. The operation of the diversion at 1,000 cfs year round and 7,000 cfs in April and May with Lake Borgne open, not considering an increased diversion at Maurepas Swamp, only meets the Chatry target 32% of the time. With Lake Borgne closed the 7,000 cfs diversion lowers salinity to meet the target 37%. By either increasing the diversion at Maurepas Swamp or allowing 7,000 cfs flow year round, the salinity meets the Chatry target 43% of the time. By increasing the diversion at Maurepas Swamp and allowing 7,000 cfs flow year round, the target is met 48% of the time. These relationships and a graphic representation of Table 15 are provided in Figure 30.

4.6.5 SALINITY TIME SERIES ANALYSIS OF FWP RESULTS

The primary objective of the UNO Mass Balance model is to analyze salinity at the Salinity Target Line, a specific location in the Biloxi Marsh. It can also be helpful to look at the salinity results surrounding the region encompassing the Salinity Target Line and compare them also to the salinity conditions derived by Chatry. Figures E2 to E27 in Appendix E provide time series of salinity generated at monthly time steps over the 19 year model runs of the FWP 7A2D scenario for those boxes in Lake Borgne (cell 1 and 2), the Biloxi Marsh (cells 13, 73, 74, 78) and along the Mississippi Coast (cells 80 and 14). The figures include the salinity time series, the Chatry Optimum upper limit,

and the delta or difference between the Chatry limit and the salinity value calculated for that month. These monthly time series demonstrate an annual cycle, much like the cycle represented by Chatry.

Examination of the salinity results should be reviewed in context to conditions during that timeframe. The drought monitoring program did not begin until the mid 1990's but rainfall/flow data from the Pearl River basin indicate that the area was in drought conditions in October to November of 1990 and again in the same months of 2000. The 2000 event is documented in the National Drought Monitor and occurs on drought maps. The data indicates that flows from the Pearl River leading up to this declaration were very low. Both the salinity data available for this area in this time frame and the model runs show the 2000 event. In addition to droughts hurricane Katrina struck the coast in August 2005 and had significant impact to the salinity regime.

4.6.5.1 LAKE BORGNE

Salinity in Lake Borgne (boxes 1 and 2) as modeled over the 19 years is substantially lower than the optimum Chatry values for all months. Even in drought periods, the system remains relatively fresh. Box 1 has a slightly higher level of annual variability through the period of record due to the proximity of freshwater flows from Lake Pontchartrain and is, on average, slightly more saline than box 2. Both boxes and therefore Lake Borgne is almost completely fresh every spring with salinity values between 0 and 2 ppt.

4.6.5.2 BILOXI MARSH

Biloxi Marsh is divided into four compartments as represented by box 13, box 73, box 74, and box 78. Box 73 is the closest to the near Violet diversion outfall and the freshwater in Lake Borgne. Box 73, as expected, becomes the freshest zone in this region with salinities generally between 3 and 10 ppt. The drought periods during 1990 and 2000, and the effect of Katrina appear clearly in the results. Box 13 is the next freshest and slightly saltier than box 73 by a couple of ppt. Boxes 74 and 78 are significantly saltier than the northern boxes with salinities ranging from 7 to 17 ppt with box 74 slightly saltier than 78. These relationships are reasonable considering the proximity of the northern boxes to the fresh Lake Borgne and the southern boxes to the open Gulf.

Boxes 74 and 78 demonstrate a monthly salinity signal that very closely matches the optimum signal of Chatry. The variability in salinity over a year is on the same order as Chatry with a salty component in the 16 to 17 ppt range with the freshwater component in 5 to 7 ppt range in the spring.

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The shape and the order of magnitude of the salinity signal is comparable between the boxes and the Chatry limit; however, the freshwater signal is often present earlier in the spring than shown by Chatry. This causes the month against month results to indicate that April is fresher than "needed" while May barely meets the Chatry requirement. It is only the fresher fractions contributed by boxes 73 and 13 in the calculation of the salinity along the Salinity Target Line that allow the composite of the entire region to meet the minimum criteria.

4.6.5.3 MISSISSIPPI COASTLINE

Box 14 of the original computational domain was segmented into 2 boxes for the 7A2D scenario. Box 80 follows the Mississippi coastline along the barrier islands, which is coincidently near the Mississippi state boundary. Box 14 represents the deeper water between the barrier islands and Biloxi Marsh. The plot of the salinity time series for each box is similar with box 80 generally running a few ppt fresher than box 14. This trend is expected due to the shallower waters and proximity to freshwater inflow. Box 80 ranges from around 10 ppt each spring to around 20 ppt in the fall with monthly averaged highs at 25 ppt during the 2000 drought event and elevated values after Katrina. The signal closely follows the defined Chatry values with a similar lag in the freshwater component by a month or so earlier in the system. The box 80 values are higher than those of boxes 74 and 78, an indication that the proposed diversion has a greater impact in the Biloxi Marsh area.

4.6.6 AREA OF INFLUENCE AND IMPACTS TO SALINITY

The area of influence where the reduction in salinity is due to diversions is shown in Appendix E in Figures E28 through E39. These maps are generated based on the 19 years of records so demonstrate the long-term impacts of the diversion. In any given year there is more or less impact. The calculations demonstrate that there is an influence of the diversion in the Lake Borgne/Biloxi Marsh region in all months of the year demonstrating that even the 1,000 cfs maintenance flows are felt. In April the change in salinity, as compared to FWOP, is in the northwest sector or box13 which is adjacent to freshest compartment of Lake Borgne. Boxes 73, 74 and 78 have relatively no change (<0.4 ppt) which may be a function of the freshening of this area in Aprils of many of the years of record. Box 73 is the region of greatest impact from the diversion alone and is the primary contributor to changes in the salinity target measured at the Chatry Line.

As seen in Figure 31, in Mays we can see that the near Violet Canal diversion most influences box 73 which is the closest to the CWA and benefits due to the influence of the fresher adjacent regions

depicted by box 8 (Carnarvon) and box 1 in Lake Borgne. This influence region extends along the northern boxes of Biloxi Marsh (73 and 13) and into boxes 14 and 80 along the Mississippi coasts barrier islands. Lake Borgne is significantly impacted by the diversions and is able to trap fresh water behind the raised Biloxi Marsh plateau which protects this region from the heavier salt water of the Gulf.

Box 13 in the Biloxi Marsh is less changed due to the near Violet Canal diversion. While this region benefits from the freshening of Lake Borgne, the deeper waters of Box 14 along the Mississippi Coast may result in saltier water influencing the depth averaged salinity generated by the model. This area is one that would probably be better represented by a 3-d hydrodynamic model due to the perceived stratification that is expected to occur from the influences of the fresher waters of Lake Borgne to the west and the Gulf to the south. The Biloxi Marsh stands as a barrier to some of the salt water exchange between the Gulf and Lake Borgne whereas box 14 provides the only "deep" water access for saltier gulf water to penetrate into Lake Borgne. In Junes there appears to be a residual effect of the diversion. Additional areas of influence in the months following June are associated with the 1,000 cfs maintenance flows.

Influence of the diversion along the Mississippi Coastline and territorial waters is shown to be limited in April (on average less than 0.5ppt) but is impacted in May with a lowering of the average salinity by up to 1 ppt with the near Violet Canal diversion.

4.7 DISCUSSION

Results from the planning level mass balance model developed for this study tell resource managers a number of things that are useful in understanding the salinity regime in the Biloxi Marsh., Data and model results demonstrate that the Biloxi Marsh region is at or fresher than salinities required for oyster seed production as recommended by Chatry for the winter months. The spring and months of April, May and June have historically been saltier than the optimum salinity ranges.

The MRGO closure, the construction of the IHNC barrier, and the Seabrook gate will have an immediate positive (lower salinity) impact in Biloxi Marsh relative to these three key months. This scenario, the baseline condition representing current conditions, appears to mitigate the long-term impact of salinity intrusion by freshening the system over historic conditions in all months on the order of 1 to 2 ppt. In May, the month of the year the fishery requires the greatest freshwater

enrichment, the baseline condition, which includes the major modifications of the system, now only meets the Chatry target 6% of the time, which is up from the historic 4%.

The USACE, the State of Louisiana, and others have studied and are implementing a number of planned freshwater diversions. The FWOP condition builds upon the baseline condition by acknowledging these new inputs to the system. These diversions, represented in the model as the FWOP conditions have a significant effect on the year round salinity in Biloxi Marsh with additional reductions in salinity on the order of 2 ppt. More importantly there is a considerable reduction in the salinity in May and the data now indicates that salinity will be reduced below the upper Chatry limit 26% of the time. This is a significant change in the conditions of this area. If we consider the Blind/Convent River diversion as a FWOP the salinity target is now met 31% of the time.

It should be noted that with these diversions most months now exhibit lower salinities (is significantly fresher) in the Biloxi Marsh and that these salinities are below the upper optimum Chatry limit. This study did not look at ways to alter (reduce) diversions in those months when there is an over-freshening. This needs to be refined once operational strategies are considered. The mass balance model predicts an overall freshening of the system as a result of the additional structures included in the baseline scenario. That freshening continues with the diversions discussed in FWOP scenarios. This condition (present today) along with the potential near Violet Canal diversion and the Blind/Convent River diversion becomes the condition from which managers could manipulate salinity to better address salinity (fishery) goals in the Biloxi Marsh area.

May continues to be the chronic month, even after accounting for the planned diversions, cited in the FWOP condition. Additional diversions near Violet Canal have been tested to see if supplementary freshwater will continue to drive salinity down in the Biloxi Marsh. A number of alternatives were modeled beginning at 1,000 cfs up to 30,000 cfs. The 1,000 cfs, 5,000 cfs, and 7,000 cfs diversions looked at a 1,000 cfs base flow condition year round with a planned pulse in April and May as well as the full diversion year round. The increased rate was added to the base flow on April 1st and turned off May 31st. These scenarios were examined in a Lake Borge open and closed condition. Diversions of 10,000 cfs, 15,000 cfs, 20,000 cfs and 30,000 cfs were also tested as a constant flow through the system during all months of the year. The 7000 cfs diversions were also tested in combination with a diversion from Blind/Convent River. Because of the monthly time scale of the model results and the global salinity targets there was little effort in fine tuning the results of the various diversion alternatives.

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A new freshwater diversion near Violet Canal in May is shown to freshen the system. As the level of freshwater is introduced into the system through this diversion, the percent of time the salinity target was met in the Biloxi Marsh is increased. This relationship is near linear above 1,000 cfs with an increase of time the Chatry limit is met of approximately 1.5% for every 1,000 cfs added to the system for those diversions scenarios that are considered with the Lake Borgne connection cut off or for those scenarios where the diversion is provided year round. The 1000/7000 cfs diversion scenario without the coincident Blind/Convent River diversion only meets the upper target in May 37% of the time and it would talk about 9000 cfs to meet the 40% criteria under this condition.

Adding the Blind/Convent River diversion the 1000/7000 cfs scenario meets the limit in May 43% and if we run the 7000 cfs diversion all year with the Blind/Convent River condition the salinity condition in Biloxi Marsh meets the Chatry criteria 48% of the time. Application of much higher diversions (on the order of 20,000 cfs) through the CWA without the benefit of the Blind/Convent River diversion will generate even lower salinities and will meet the May target on the order of 60% as modeled over the 19 years of record. Adding Blind River will further lower salinities.

To improve the efficiency of delivery of freshwater another set of diversion alternatives was modeled with the channel between the MRGO and Lake Borgne closed by incorporating a barrier. This forced the freshwater north and south through existing natural channels but more importantly it forced additional water south through the Bayou La Loutre. This created a more direct connection with the Biloxi Marsh than when flows are directed through Lake Borgne and then to Biloxi Marsh.

Flows in the Pearl control the ambient salinity in the Biloxi Marsh system. In 1989 and 2000, lower than normal flows correspond to high salinities (20 ppt and 17 ppt respectively) in May of those years. The existing and proposed diversions will modify (lower) this salinity condition but not enough to bring the salinity in May, and probably other months of those years, into compliance with the Chatry limits. If the Pearl River flow is low enough the diversions discussed here are relatively ineffectual in lowering salinity in the Biloxi Marsh.

Results of the timeseries analysis demonstrate that the diversion defined as FWP conditions contributes to a salinity regime that very closely mimics' the optimum signal as defined by Chatry. The northern portions of the marsh are fresher than required while the southern compartments have the same order of magnitude and annual cycle necessary for the oyster fishery. The timing of the

freshwater signal is often early by a month or so, coming in March or April where salinity in Biloxi Marsh is lowered to values required by Chatry. Even in drought years there is an appreciable reduction in salinity (even if not to the Chatry values). Care should be taken when interpreting monthly averaged timescales as variability in the data can skew averages toward one month or another. If the timing of the minimum salinity period is flexible, on the order of a month prior to the time Chatry designates, there an expectation that, if properly timed, an earlier diversion coincident with the freshwater event could have the potential of lowering salinity to or near to the Chatry low. The UNO Mass Balance model is very coarse in its definition of the flow regime through the CWA and another modeling effort is required to determine the specifics of flows in the CWA, MRGO, and to establish the value of a Lake Borgne closure. The flow distributions outlined in this report are an estimate of the distribution through the system and into the Lake Borgne/Biloxi Marsh basin.

A 1,000 cfs base flow was run as a management condition throughout the year. The 1,000 cfs was a condition that appears to provide the CWA sufficient freshwater to maintain the system as a cypress swamp. The salinity goal to meet proposed ecological conditions in the CWA is to maintain the salinity at all times below 2.6 ppt. The mass balance model is not of the resolution to describe the dynamics and other fine details of flow through the CWA but is sufficient to demonstrate that the 1,000 cfs base flow is an appropriate order of magnitude estimate to meet the salinity goals in the CWA. Higher resolution modeling using MIKE21 examines the effect of a 1,000 cfs diversion.

4.8 SENSITIVITY IMPACTS TO SEA LEVEL RISE

The UNO box model was run for two SLR scenarios: 1) a rise of 0.8 m over 100 years, and; a rise of 1 m over 100 years. The model was not modified to consider the effects of progressive land loss over the period of sea level change. The Gulf of Mexico mean stage was raised by 0.8 and 1 m respectively to represent the two SLR scenarios. The main changes that the model responded to were: a) an increase in the depth of the hydraulic links between the boxes and b) an increase in the mean storage in each box. No change in the rainfall-evaporation time series was made.

The example presented here is for the case with the near Violet Canal diversion in place at a peak flow of 7,000 cfs in April and May (FWP condition). The model was run for a hydrologic record of 19 years with diurnal lunar tides. The no SLR case was run as a basis of comparison [BOC]. Figure 34 shows the change [SLR-BOC] in salinity in the computated domain.

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Figure 34 shows that the inner boxes of Biloxi Marsh experience little change while the ocean side demonstrates a small increase in salinity. The box that showed the greatest increase was the intermediate marsh in the Caernarvon area. This may be due the width of the direct hydraulic link between the open water and the intermediate marsh. The model showed that the Upper Pontchartrain Estuary with SLR has a mean salinity slightly less than that for the case of zero sea level rise. Small changes in salinity due to SLR, as depicted by the UNO Mass Balance model, are probably due to the geometry of the system as modified by the condition if it is considered that the Biloxi Marsh will continue to act as a sill, cutting of the salt water flux into the Lake Borgne region. Concurrently, there is a larger reservoir of freshwater because of the increased hydraulic detention times that result from the 0.8 to 1 m increase in depth.

The UNO Mass Balance model has serious limitations when applying it to predict changes in salinity 100 years into the future. First of all, the model does not take into account the changes in the landform during this period. For example, the increase in the hydraulic conveyance due to erosion is not considered. Secondly, no changes in the hydrologic and meteorological inputs that could significantly impact the Upper Estuary have been considered. The possible increases in wind and wave energies that are often predicted to accompany climate change have been neglected.

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5.0 DETAILED MODELING OF THE CWA USING MIKE 21

5.1 INTRODUCTION

The UNO Mass Balance Model provided generalized hydrodynamic results in the CWA and coarse approximation of the effects of the diversion. To assess the effects and flow characteristics inside the CWA in more detail, the development of a detailed 2-dimensional hydrodynamic model was needed. The MIKE21-HD (MIKE21) model by the Danish Hydraulic Institute (DHI) is specifically for the purposes of investigating the hydrodynamic effect of the inflow of fresh water into the CWA for existing conditions and a restored scenario. The hydrodynamic module solves the shallow water equations, depth-averaged, over a 2-dimensional plane, which implies that the salinity is calculated as a depth averaged concentration. This approach is justified if vertical mixing occurs within short distances of the source and no significant stratification occurs, which is what is expected to happen with the introduction of the near Violet Canal diversion.

The impact of the flow through the diversion and how this affects the salinity and circulation in the channels are investigated using MIKE21. The model is used to examine two scenarios, a 1,000 cfs maintenance flow for the purpose of freshening the CWA in support of ecological enhancement of the area by transforming the 48 square miles into freshwater marsh and cypress swamp; and a 7,000 cfs diversion scenario that is the benchmark for freshening the Biloxi Marsh region.

A 1,000 cfs diversion from the Mississippi River was estimated by calculating the inflow from a typical tide through the two navigation gates into the CWA. This order of magnitude of flow generally outlined the magnitude that could be added to the CWA without vastly changing the hydraulic character of the gate. That flow magnitude was carried through and tested as part of the UNO mass balance modeling where FWP scenarios that included the 1,000 cfs diversion indicated that the CWA "box" was adequately freshened by this level of flow.

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5.2 OBJECTIVE

The results from the MIKE21 simulation runs address the following questions relating to the diversion of flows through the CWA.

1. What is the impact of the base flow through the diversion? How does it affect salinity in the CWA?
2. Does the proposed change in topography for the restored marsh impact the base flows, levels and discharges?
3. What happens during periods of peak diversion flows? Where does the water go? What is the flow split through the existing structures? Is a new outfall structure needed? How extensive is flooding (frequency, levels, etc) inside the CWA. Are new channels needed within the wetlands?
4. What are the impacts of localized flooding due to the new diversions?
5. What are the impacts of sea level rise on the marsh?

5.3 MODELING SCENARIOS

5.3.1 BASELINE - MB

This scenario (MB) reflects existing conditions by including the existing bathymetry, vegetation, control structures at Bayou Dupre and Bayou Bienvenue, and normal tidal flows through the inlets at Bayou Dupre and Bayou Bienvenue. The best available bathymetry was used for this scenario supplemented by specific information on channels and other features that were specifically collected for this effort. Calibration and validation of the model was completed for this scenario and is discussed further in Appendix G. The model domain includes the CWA and extends only as far into the MRGO to enable the flows within the gates to be established.

5.3.2 BASELINE WITH 1,000 cfs – MB1

The baseline condition with 1,000 cfs (MB1) is the baseline scenario with the existing bathymetry and the addition of a 1,000 cfs base flow from the Mississippi River through the new diversion channel. This scenario investigates the impacts of adding flows to the existing conditions in the CWA. This scenario introduces a new diversion channel that transfers flow into an open water areas of the CWA. This scenario investigates punching the new diversion channel through a new control structure in the Chalmette levee into the MRGO.

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For the MB1 run, the flow is split is as shown in Table 16.

Table 16. Location and Value of Flow for MB1

Location	Flow
New Diversion Channel	870 cfs
Existing Violet Siphon Diversion	100 cfs
WWTPs	30 cft

5.3.3 RESTORED WITH 1000 cfs – MR1

The restored condition with 1,000 cfs (MR1) is the baseline scenario with a restored bathymetry/topography and the addition of a 1,000 cfs base flow from the Mississippi River through the new diversion channel. This scenario investigates the impacts of increasing diversion flows with the restoration of the CWA. The restoration increased the bed levels in local areas and modifies the vegetation according the proposed plans developed by the USACE. The split in flow and configuration of channels and structures is identical to that of the MB1 run.

5.3.4 RESTORED WITH 7000 cfs – MR7

The restored condition with 7,000 cfs (MR7) uses the baseline scenario with the restored bathymetry/topography and the addition of a 7,000 cfs flow in April and May from the Mississippi River through a new diversion channel. This scenario includes a ramping up of flows from the baseline flow condition (1,000 cfs) to the peak over a timeframe of 14 days. It also includes a third control structure into the MRGO with controls to restrict outflow into the MRGO if required. The initial scenario will be established to divert approximately 6,000 cfs through the new control structure. This will force a similar amount of water to exit the Dupre and Bienvenue gates as in the maintenance case.

For the MR7 run, the flow into the CWA is as shown in Table 17.

Table 17. Location and Value of Flow for MR7

Location	Flow
New Diversion Channel	6870 cfs
Existing Violet Siphon Diversion	100 cfs
WWTPs	30 cft

5.3.5 SEA LEVEL RISE CONDITION – MR1S

The sea level rise condition (MR1S) is the baseline scenario with the restored bathymetry, the addition of a 1,000 cfs base flow from the Mississippi River through the new diversion channel, and

accounts for the impact of potential sea level rise on the stage and salinity within the CWA. A mid range Sea Level Rise value of 2.2ft (0.69m) was considered.

5.4 RESULTS

5.4.1 MODEL RUN MB

5.4.1.1 FLOW DISTRIBUTION

The discharges through the Bayou Dupre and Bayou Bienvenue control structures openings fluctuate with the tide as seen in Figure 38. The maximum discharge through the Bayou Bienvenue structure is much larger (about 1,500 to 3,000 cfs) than through the Bayou Dupre structure (300 -700 cfs).

The average discharges are low, about 9.3 cfs at Bayou Dupre and -19.2 cfs at Bayou Bienvenue. Positive discharge is defined as flowing into the MRGO. Negative discharge is defined as flowing into the CWA. Although the values appear to show a small net inflow into the CWA, this is within the tolerances of the model and is effectively balanced.

5.4.1.2 WATER LEVELS

The results indicate a small water level gradient from north to south exists with water levels higher near Bayou Bienvenue (maximum at 1 to 1.05 feet) than at Bayou Dupre (maximum at 0.95 to 1.0 feet).

Inside the CWA there is not much variability in water level, except the western part. In that area the maximum water levels are limited to 0.6 to 0.8 feet. These lower water levels are probably due to the effect that Paris Road has on blocking flow into and out of this area.

5.4.1.3 CURRENT VELOCITIES

The maximum current velocities are generally low. The maximum velocities in the channels are low ranging from approximately 0.3 ft/sec to 0.6 ft/s. In the small channels, as well as the open water areas, the current velocities drop to almost 0 ft/s.

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5.4.1.4 SALINITY

Figure 39 shows the average salinity during the simulation period for the baseline scenario. Within the central wetlands, the mean salinity is typically about 4 ppt. In the Violet Canal the mean salinity drops to 2 ppt in the most western part.

5.4.2 MODEL RUN MB1

5.4.2.1 FLOW DISTRIBUTION

Figure 40 shows the temporal variation and the average discharge distribution over the Bayou Dupre and Bayou Bienvenue control structures. The maximum discharge through Bayou Bienvenue is larger (1,800 to 3,400 cfs) than through the Bayou Dupre (300 to 1,000 cfs). On average about 385 cfs flows through the Bayou Dupre structure and 596 cfs through Bayou Bienvenue. The discharge distribution is roughly 40 % through the Bayou Dupre structure and 60 % through the Bayou Bienvenue structure.

The total outflow into MRGO is approximately 1,000 cfs. This flow is the same as the total discharge input on the model boundaries. This concludes that the water that flows into the CWA also flows out to the MRGO and that no storage occurs during the simulation period.

5.4.2.2 WATER LEVELS

At the end of the new diversion channel, the water level increases significantly. In the actual situation only during high waters is the area flooded. In the baseline scenario with 1,000 cfs, the water levels increase 0.3 to 1.1 feet and the tidal range is about 0.1 to 0.5 feet at that location.

At Paris Road and at the Bayou Bienvenue structure there is little change in water levels. However, at the Bayou Dupre structure, the water level increases by approximately 0.1 to 0.5 feet and, during high waters, the tidal range decreases by almost 0.3 feet.

The maximum water levels are found in the new diversion channel (above 1.2 feet) and in the adjacent wetlands (1 to 1.1 feet). The mean water level increases in the wetlands by approximately 0.6 feet.

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5.4.2.3 CURRENT VELOCITIES

The current velocity inside the new diversion channel is approximately 2.5 ft/s. At Paris Road no changes in velocities were observed. At the Bayou Dupre and Bayou Bienvenue structures there are some changes. At Bienvenue the maximum velocity increases by 0.1 ft/s during ebb flow (flow going towards the MRGO). Overall the velocities during ebb flow are larger than during flood flow (flow going towards the CWA). During flood flow the current velocities decrease by almost 0.2 – 0.3 ft/s at the Bienvenue structure. This can be explained by the extra freshwater outflow from the CWA into the MRGO which increases the ebb flow and decreases the flood flow. At the Bayou Dupre structure flood flow is not easily distinguished due to this freshwater outflow.

Maximum velocities observed in the new diversion channel are on the order of 1.5 ft/s to 2.5 ft/s. In the adjacent wetlands, the maximum velocities are approximately 0.5 ft/s.

5.4.2.4 SALINITY

The salinity in the new diversion channel is 0 ppt, whereas in the baseline scenario during high water peaks of 2 – 5 ppt were computed. At Paris Road the salinity fluctuates around 1 to 3 ppt as compared to 4 to 7 ppt in the baseline scenario.

At the Bayou Bienvenue structure, the salinity drops to 1 to 2 ppt during ebb flow (due to fresh water outflow), but does not change (with respect too the baseline situation) at flood flow. In the baseline scenario, values of 6 to 8 ppt were found.

At the Bayou Dupre structure, the salinity drops to almost 0 ppt. Only at high water inflow do the salinity levels increase locally, but do not reach the baseline values of 6 to 8 ppt.

Mean salinity can be seen in Figure 41. Compared to the baseline scenario, the wetland area in the center of the CWA almost becomes fresh with salinity values of 0 to 0.5 ppt. Also, the main channels in the systems become fresh with a mean salinity of 0.5 ppt. Near the Bayou Bienvenue structure, the mean salinity is around 4 – 5 ppt.

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5.4.3 MODEL RUN MR1

5.4.3.1 FLOW DISTRIBUTION

Figure 42 shows the discharge distribution over the Bayou Dupre and Bayou Bienvenue including the mean discharges. The restored scenario slightly modifies the discharge distribution over the two control structures with 377 cfs (38 %) flowing through the Bayou Dupre structure and 626 cfs (62 %) through the Bayou Bienvenue structure. In the baseline scenario, the ratio was 40 % - 60 %. The discharge through the opening to the MRGO from the new diversion is 0 cfs.

5.4.3.2 WATER LEVELS

The results of the water levels are similar to the MB1 scenario. At the end of the new diversion channel the water levels increase to 0.2 to 1.1 feet. The tidal range increases slightly by 0.1 to 0.6 feet.

At Paris Road the tidal range slightly increases by approximately 0.1 to 0.3 over the MB1 results to 0.5 to 1.6 feet. At the Bayou Bienvenue structure, there is little change in water levels. At the Bayou Dupre structure, the water level increases by approximately 0.1 to 0.5 feet and the tidal range decreases by almost 0.3 feet during high waters.

The maximum water levels are found in the new diversion channel (1.1 feet) and in the adjacent wetlands (1.1 feet). Compared to the MB1 scenario, a larger area is affected by the fresh water outflow, but the maximum level in the new channel is lowered by 0.1 feet. The maximum water level in the Violet Canal is 1.0 to 1.05 feet. The mean water level increases in the channel to 0.55 to 0.60 feet and in the wetlands to 0.40 to 0.60 feet.

The higher water levels in the northwestern part of the CWA can the explained by the wastewater outflow, which flows onto a piece of land at a higher elevation and roughness coefficient used in the model. This results in less flow to the neighboring channels and the water is stored in the area.

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5.4.3.3 CURRENT VELOCITIES

The mean velocity is about 0.3 to 0.35 ft/s at the end of the new diversion channel. Due to the restoration of the wetlands, the velocity also decreases at Paris Road to about half that seen in the baseline scenario.

At the Bayou Bienvenue structure, the same pattern is observed as in the MB1 scenario. The maximum velocity slightly increases by 0.1 ft/s during ebb flow and decreases by almost 0.2 to 0.3 ft/s during flood flow. The velocities during ebb flow are larger than during flood flow.

Compared to the MB1 scenario, the most significant changes are found in the new diversion channel. The maximum velocity is limited to approximately 0.3 ft/s, whereas in the MB1 scenario the maximum velocities were about 1.5 to 2.5 ft/s.

5.4.3.4 SALINITY

The water in the new diversion channel is completely fresh, 0 ppt. At Paris Road the salinity fluctuates around 1 to 2 ppt, which is slightly lower than in the MB1 scenario. At the Bayou Bienvenue structure, the salinity drops to 1 to 2 ppt during ebb flow (due to fresh water outflow), but does not change at flood flow. In the baseline scenario values of 6 to 8 ppt were found. At the Bayou Dupre structure, the salinity drops to almost 1 ppt. Only at high water does the salinity increase, but does not reach the value of the baseline scenario of around 6 to 8 ppt.

Figure 43 shows the monthly averaged salinity for the whole area. The overall picture is the same as in the MB1 scenario. The fresh water discharge from the Mississippi River causes a decrease in salinity, not only in the wetland area in the center of the CWA, but also in the main channels like the Violet canal.

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5.4.4 MODEL RUN MR7

5.4.4.1 FLOW DISTRIBUTION

Figure 44 shows the discharge distribution over the Bayou Dupre, Bayou Bienvenue and the new diversion for this scenario, as well as the mean discharges. Due to the opening of the new diversion channel 5,660 cfs flows through the new channel. Approximately 1,260 cfs flows through the other two openings (479 cfs through the Dupre structure and 781 through the Bienvenue structure).

Including a structure at the end of the new channel will potentially result in lower discharges through the channel and will increase the discharge through the Bayou Dupre and Bayou Bienvenue.

5.4.4.2 WATER LEVELS

Near Paris Road the water levels increase during high water by about 0.2 to 0.3 feet but decrease during low water (about 0.2 feet) when compared to the baseline scenario. At the Bayou Bienvenue structure a small increase of 0.1 feet was found. At the Bayou Dupre structure, the effect appears to be larger.

The maximum water levels are higher in the new diversion channel (above 1.2 feet) and in the adjacent wetlands (also above 1.2 feet). The extent of the area affected by the freshwater inflow is the greatest in this scenario. Mean water levels in the channel and the surrounding wetlands are above 0.7 feet.

Although the water levels in and near the new channel increase significantly, no flooding of the higher wetlands areas occur. This means that the water levels do not reach the level of the banks of the channel.

5.4.4.3 CURRENT VELOCITIES

The current velocity in the new channel fluctuates around 2.5 feet/second, which is almost the same as the velocity in the smaller channel in the MB1 scenario. Although there is a larger discharge, the channel also has larger dimensions which limit the velocities. The current velocities at the other

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locations show the same results as in the other scenarios with additional fresh water inflow. Inside the new diversion channel, the flow velocities increase to above 2.1 ft/s, which is significantly larger than in the other channels within the CWA.

5.4.4.4 SALINITY

The large fresh water diversion turns the CWA area almost completely becomes fresh. The mean salinity in all major channels and wetland areas is 1 ppt or below. At the MRGO a plume of fresher water is found at the outflow of the new diversion. Only at the main channel near the Bayou Bienvenue structure do higher salinity values penetrate slightly into the area.

At the point in the new channel and near the Bayou Dupre structure, the salinity drops to 0 ppt. At Paris Road the salinity drops to an equilibrium value of 0.2 to 0.3 ppt. At the Bayou Bienvenue structure, the salinity fluctuates with the tide and drops to 1 to 2 ppt during ebb flow (due to fresh water outflow). Salinity does not change noticeably at flood flow. Mean salinities are seen in Figure 45.

5.4.5 MODEL RUN MR1S

5.4.5.1 FLOW DISTRIBUTION

Figure 46 shows the discharge distribution over the Bayou Dupre, Bayou Bienvenue and the new diversion for this scenario, as well as the mean discharges.

Sea level rise affects the maximum discharges through the Bayou Dupre and Bayou Bienvenue structures significantly. Through the Dupre structure, the maximum discharge is to 3,000 to 5,000 cfs or about five times greater than the MR1 results of 600 to 1000 cfs. The maximum discharge through the Bienvenue structure is 5,000 to 9,000cfs when sea level rise is considered. Without the consideration of sea level rise, the maximum discharge is about three times less or 1,500 to 3,500 cfs in the MR1 scenario.

The mean discharges are on the same order as the MR1 scenario regarding no change in total fresh water outflow. However, the flow split over the Dupre and Bienvenue structures changes. When considering sea level rise, 680 cfs flows through Dupre (57.5 %) and 502 cfs flows through

Bienvenue (42.5 %). The ratio is 38 % Dupre and 62 % Bienvenue with the MR1 scenario. Sea level rise causes a shift in discharge distribution such that the majority of the discharge is through the Bayou Dupre structure.

The discharge through the opening in the new diversion channel is 0 cfs, as the channel is closed by a weir structure.

5.4.5.2 WATER LEVELS

The water levels increase significantly in this scenario. A large part of the CWA area is flooded due to the 3.7 feet increase of sea level. At all locations the water levels increase by almost 3.7 feet. The tidal range inside the CWA decreases. In the new diversion channel, the tidal range becomes 0.1 to 0.5 feet. In the MR1 scenario, the tidal range was 0.1 to 0.6 feet.

At Paris Road, the tidal range is completely dampened. It becomes 0.1 to 0.5, whereas it was 0.5 to 1.6 feet in the MR1. This is also the case at Bienvenue where the tidal range in this scenario is 0.2 to 0.8 feet. In the MR1 scenario it was 0.4 to 1.7 feet. The same holds for the Bayou Dupre outflow.

Peak water levels are found at 4.3 - 4.4 feet for all locations.

5.4.5.3 CURRENT VELOCITIES

The current velocities increase at both Bayou Dupre and Bayou Bienvenue. Peak velocities inside the Bienvenue structure are approximately 2.7 ft/s, at Dupre it is 2.1 ft/s. In the MR1 scenario this is respectively 1.5 ft/s and 0.5 ft/s. Inside the Dupre structure outflow the velocities increase significantly. This is also due to the increased discharge through that opening.

Velocities of 0.8 – 1.0 ft/s are found in the channels which run to Bayou Dupre and Bayou Bienvenue. In the remaining portions of the CWA, velocity does not exceed 0.5 ft/s.

5.4.5.4 SALINITY

Salinity is able to penetrate more easily into the CWA due to sea level rise.

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Figure 47 shows the mean salinity in the CWA. Near Bayou Dupre and Bayou Bienvenue, the mean salinity becomes 4 to 6 ppt. The central CWA is influenced by the fresh water inflow from the new diversion channel and the salinity is 0 to 2 ppt). In the area west of Paris Road, the water becomes saltier with a mean salinity of 3 to 4 ppt.

Near Paris Road the salinity fluctuates with the tide. At peak flood the salinity is 6 to 7 ppt and during ebb the salinity drops to 3 to 4 ppt.At both the Bayou Dupre and Bayou Bienvenue structures, the salinity during flood matches the values of the MB scenario at 6.5 to 8 ppt. During low tide the salinity drops at Bayou Dupre to 3 to 4 ppt and Bayou Bienvenue to 4 to 5 ppt.

The salinity inside the CWA fluctuates with the tide. Figures 48 and 49 show the salinity during high water and low water. During high water salinity values of above 7 ppt are found west of the Paris Road. During low water the maximum salinity is approximately 4 ppt. Also notice the number of white cells during low water (Figure 49), which indicates that these cells have become dry.

5.5 SUMMARY OF RESULTS

The following tables summarize the MIKE21 results for all scenarios.

Table 18. Discharge distribution summary.

	MB	MB1	MR1	MR7	MR1S
Discharge (cfs)					
Dupre	9.3	385	377	479	681
Bienvenue	-19.2	596	626	781	502
Diversion	-	-	-	5660	-
Discharge %:					
Dupre	-	39.2 %	37.6 %	3.9 %	57.5 %
Bienvenue	-	60.8 %	62.4 %	11.3 %	42.5 %
Diversion	-	-	-	81.8 %	-

Table 19. Water levels, current velocities and salinity results summary.

	MB	MB1	MR1	MR7	MR1S
Water levels (ft)					
Dupre	-0.55 – 0.9	-0.1 – 0.9	-0.1 – 0.9	-0.2 – 1.1	3.3 – 4.4
Bienvenue	-1.1 – 1	-1 – 1.1	-1 – 1	-1 – 1.1	3.1 – 4.4
Diversion	Dry – 0.9	0.1 – 1.1	-0.15 – 1.1	0.7 – 1.4	3.4 – 4.4
Paris Road	-0.9 – 0.9	-0.7 – 0.95	-1 – 1.1	-1 – 1.1	3.4 – 4.4
Currents (ft/s)					

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Dupre	Max 0.5	Max 0.45	Max 0.45	Max 0.55	Max 2.2
Bienvenue	Max 1.4	Max 1.5	Max 1.5	Max 1.5	Max 2.8
Diversion	Max 0	Max 2.7	Max 0.35	Max 2.7	Max 0.3
Paris Road	Max 0.8	Max 0.8	Max 0.55	Max 0.55	Max 0.85
Salinity (ppt)					
Dupre	6 – 8	0 – 7	1 – 7	0	2 – 8
Bienvenue	6 – 8	0.5 – 8	0.5 – 8	0 - 8	3.5 – 8
Diversion	Peaks 2 – 5	0	0	0	0 – 0.5
Paris Road	4 – 7	1 – 3	1 – 2	0.3	3 – 7.5

5.6 *CONCLUSIONS*

The following provides responses to the five objectives formulated above relating to the MIKE21 modeling effort.

1. **What is the impact of the base flow through the diversion? How does it affect salinity in the CWA?**

The base flow (1,000 cfs) generally lowers salinity levels within the CWA but raises levels and flow rates to some degree. The increase in water levels is generally less than 0.25ft across the wetlands. See Figure 50.

2. **Does the proposed change in topography for the restored marsh impact the base flows, levels and discharges?**

The change in topography due to marsh and swamp recreation has little impact on the flows, levels and salinity values within the CWA, particularly with the increased channel designed to transfer the higher flows from the Mississippi River to the MRGO.

The water level increase is greatest to the west of Paris Road where the impact of the sewage treatment works discharge is felt together with the increase in marsh and wetland. See Figure 51.

3. **What happens during periods of peak diversion flows? Where does the water go? What is the flow split through the existing structures? Is a new outfall structure needed? How extensive is flooding (frequency, levels, etc) inside the CWA. Are new channels needed within the wetlands?**

Initial screening before developing the Mike21 model suggested that a third structure would be needed to prevent excessive flows in the existing channels and extensive flooding.

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Therefore during periods of peak flow the water was directed to the MRGO via the new channel. The flow split through the existing structure followed the same proportions as with the 1000cfs background flow. There is some increase in water levels with the 7,000cfs flow in the area immediately adjacent to the new and existing channels when the majority of the flow was passed directly to the MRGO. See Figure 52. Even at high tide the water levels are below the proposed marsh elevation and will generally in the channels.

Reducing the discharge through the new structure would force water to the Dupre and Bienvenue gates and raise water levels but would increase the velocity through these gates with the increased flows. A variety of scenarios can be generated with the MIKE 21 model to examine impacts to the system by modifying the discharge through the third opening. Water levels would need to be raised on the order of a foot to flood the swamp areas at high tides only. To totally inundate the system the water levels would need to be increased by over 2.5 feet to keep the system we during low tide.

4. What are the impacts of localized flooding due to the new diversions?

The new diversions have little influence on the water levels outside of the channels. For the 1000cfs scenario, in the central area the effect is less than 0.5ft, for the 7000cfs scenario, the effect is less than 1ft. Flow velocities increase within the channels.

5. What are the impacts of sea level rise on the marsh?

About 80% (rough estimate) of the area will flood during high waters for the SLR scenario. This will change drastically the hydrodynamic behavior for the whole area and will likely indirectly induce morphological changes to the area. More areas will experience larger salinity levels.

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6 DETAILED MODELING – FVCOM

The study objectives of the FVCOM modeling effort where to:

1. Better understand and quantify high frequency variability of the salinity field in open water using a numerical model, and
2. To understand the transient salinity field during a transition from low to high hypothetical flow magnitude and distribution between sites at Bayou Bienvenue and Bayou Dupre in the Central Wetlands Area (CWA).

The Finite Volume Coastal Ocean Model (FVCOM) was selected for this study because it is a prognostic, unstructured-grid, finite-volume, free-surface, 3-D primitive equation coastal ocean circulation model developed by CHEN ET AL., (2003). The model consists of momentum, continuity, temperature, salinity, and density equations and is closed physically and mathematically using turbulence closure sub-models. FVCOM is solved numerically by a second-order accurate, discrete flux calculation in the integral form of the governing equations over an unstructured triangular grid. This approach combines the best features of finite-element methods (grid flexibility) and finite-difference methods (numerical efficiency and code simplicity) and provides a much better numerical representation of both local and global momentum, mass, salt, heat, and tracer conservation.

For a more detailed description of model development and other capabilities the reader is directed to CHEN ET AL. (2003). The model was used in three-dimensional mode due to the episodic and seasonal stratification that the estuary experiences (ABADIE AND POIRRIER, 2000; GEORGIOU, 2002; LI ET AL., 2008) and to capture additional stratification potentially induced near freshwater input sources. Finally, the freely available source code for FVCOM does not readily offer salinity transport under the two-dimensional mode without code modifications.

A detailed report including the background, model inputs, calibration, verification, and results can be found in Appendix H.

6.1 SIMULATION MATRIX

The following simulation matrix was considered to address the objectives of this study. First, two simulations, one with wind and one without wind were conducted to compare the high frequency variability in the open water areas of the basin (Lake Borgne and Mississippi Sound in the vicinity of the Biloxi marshes). These simulations were conducted with realistic winds, did not include a closure

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at the connection between Lake Borgne and the MRGO, and without a new diversion. The second set of simulations, were performed using reconstructed winds, an no closure at the connection between Lake Borgne and the MRGO, and a 7,000 cfs diversion. Lastly, a longer simulation of 45 days was performed to investigate the time-dependent evolution of the salinity field resulting from a diversion of 1,000 cfs (split at 50/50 between Bayou Bienvenue and Bayou Dupre) to 7,000 cfs (with a split of 10/90 respectively). During this simulation, the MRGO closure structures were includes and connection between MRGO and Lake Borgne was closed. Table 20 shows a summary of the FVCOM simulations performed.

Table 20. Case name and initial and boundary conditions for each simulation performed.

Case name	simulation time (days)	MRGO closure @ La Loutre	MRGO closure @ Bienvenue	Gap @ MRGO and Lake Borgne	Wind stress	Diversion flow
OPT1	5	yes	No	open	Yes, realistic	no
OPT2	5	yes	No	open	No wind	no
OPT3	5	yes	yes	open	Yes, realistic	yes
OPT5	10	yes	yes	closed	Yes, constructed	yes/7,000
OPT6	10	yes	yes	closed	No wind	yes/7,000
OPT7	45	yes	yes	closed	No wind	yes/(1,000-7,000)
OPTF	45	yes	yes	closed	No wind	yes/(1,000-7,000)

6.2 MODEL RESULTS AND DISCUSSION

6.2.1 SIMULATED SALINITY DISTRIBUTION UNDER WIND STRESS

Initially the model was used to investigate the short term high frequency variability in open water (in Lake Borgne and the Mississippi Sound). This was accomplished using realistic wind fields. Two simulations were performed, one with wind and one without wind. Figure 50 shows the depth-integrated distribution of salinity averaged over the 5 day simulation period for the case with wind. Figure 51 shows the same solution without wind. By comparison these two simulations look very similar. An initial conclusion would be to infer that there are negligible changes between the two simulations. When comparing the variance or dispersion in the system, however, by means of calculating the standard deviation of each node (in time) and plotting the results in two dimensions, a different pattern emerges. Figure 52 shows that wind induced circulation within Lake Pontchartrain will cause variation in the salinity near the coastlines where currents are larger. Similarly, higher variability, although small, is observed in the Mississippi Sound near Half Moon Island , at the location of interaction of the Pearl River freshwater plume in that vicinity, and within the Biloxi Marsh area.

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In an attempt to investigate intermittent or transient conditions, the closure of the MRGO at Bayou Bienvenue was not included in simulations opt1 and opt2. Another simulation was performed (opt3), which was similar to opt1 (i.e., with frontal actual winds, and other boundary conditions), but included the closure of the MRGO near Bienvenue gates. Figure 54 shows that the average depth-integrated salinity for this simulation looks identical to that of opt1. Moreover, the distribution of the standard deviation for scenario opt3, shown in Figure 55, very closely compares to that of the simulation without the closure. Some obvious and expected differences exist between the two simulations and are largely in the MRGO itself, and as a result additional rather small difference in Breton Sound, and within the Biloxi Marshes. The differences however outside the navigation complex are rather small.

A second set of simulations with and without winds were conducted with constructed and more persistent west and northwest winds during the post frontal phase of the storm. This wind pattern would have the tendency to push or force water seaward of the Basin, and in the process help spread and disperse the salinity. As a subsequent result, salinity targets in Mississippi Sound, Biloxi Marshes and other areas of interest could be met faster than anticipated. These simulations, namely opt5 and opt6, have the same initial and boundary conditions as opt1 through opt3, with the exception of the winds which are constructed. An additional difference between these simulations is that there is a diversion at Violet with a constant flow of 7,000 cfs throughout the simulation. These simulations are slightly longer and last for 10 days. Comparatively, Figures 56 and 57 look again very similar, with average depth-integrated salinities fairly similar through the computational domain. When inspected closely, there is a small wind induced variability that shows in the averaged salinity field. This can be seen in Lake Pontchartrain, where the wind induced currents produce more mixing and hence more variability near the coast. Additional differences include small deviations in the Mississippi and Chandeleur sounds; however, when looking at the average salinity field these differences do not appear to be large.

When we examine the variance by looking at the standard deviation in time for every node (Figure 58 and 59), the variability due to wind stress is great. Up-estuary, in Lake Pontchartrain, there appears to be very small variability due to tidal forcing alone (Figure 59). Moreover, in the Mississippi Sound standard deviations are of the order of 3 ppt, and are largely in areas where tidal range is high. In the area of interest, and within the Biloxi Marsh area, there is evident change, although most of this change can de attributed to freshwater input at Violet, which naturally flows seaward through Bayou

La Loutre. When we compare Figure 58 to Figure 59 (frontal constructed wind stress), we notice that there is additional variability explained only by high frequency response to wind stress. Wind induced currents within Lake Pontchartrain cause, as previously observed, salinity to respond along the coastline. Furthermore, within the Biloxi Marsh area, the standard deviations appear to rise to 6 ppt or more. Similarly, Figure 15 also shows that open water bodies such as Breton, Chandeleur, and Mississippi Sound respond to wind stress rapidly. The areas, when compared to no wind simulations, showed double the variability in the presence of wind stress.

6.2.2 TRANSIENT SALINITY RESPONSE TO A DIVERSION

The second objective of the study was to investigate the transient response of the salinity field from 1,000 cfs to 7,000 cfs during spring, with three closures implemented: (1) MRGO at Bayou La Loutre; (2) MRGO at Bayou Bienvenue; and (3) the connection between Lake Borgne and the MRGO. Two simulations were conducted. The first included the same boundary condition for salinity as in all previous simulations. The second included an open boundary obtained and forced from the UNO Mass Balance model simulations during spring. No wind was considered for this longer 45 day simulation.

Figure 60 and Figure 61 show the average depth-integrated distribution of salinity over the period of the simulation (45 days). The average value for every node (in time) is computed based on the hourly output. It is evident from the average salinity field that up-estuary (such as within Lake Pontchartrain) lower salinities in Breton Sound as a result of diversions in the Caernarvon Basin have little or no impact. This is the same for Lake Borgne and for parts of Biloxi Marsh and the Mississippi Sound. Average salinities however start to be considerably different within Breton Sound, the Chandeleur Sound, and the eastern part of Mississippi Sound. Within the Biloxi Marsh however, the change is rather small, perhaps due to the short simulation period.

Looking at Figures 62 and 63, on the other hand, large differences in the standard deviation can be seen, which can explain areas that are more dynamic. For instance, the small and rather insignificant change up-estuary as a result of a diversion in Breton sound directly can be explained easily by direct comparison of Figures 62 and 63, where we see that these two images are very similar. Similarly, the freshwater diversion at Violet (through Bayou Dupre) is unaffected by additional input into Breton Sound. This is explained by the similar standard deviation within the Biloxi Marsh area between Figures 62 and 63. Finally, as expected and as shown to some extend in the average salinity field from Figures 60 and 61, the eastern portion of the Mississippi Sound, Breton Sound, Chandeleur

Sound, and the eastern portion of the Biloxi Marsh can be affected by lower salinity in Breton Sound as shown in Figure 63.

Most of this change and variability can be explained by either tidally induced circulation or freshwater induced circulation as a result of diversions. The large variation seen in Figure 63 can also be explained relative to the initial condition. Since the initial condition is somewhat saltier than the future and imposed boundary condition, this part of the domain responds to the forcing by rapidly mixing the forced salinity inside the domain. This may be somewhat unrealistic, and will be largely a function of the initial condition. However, the model predicts that this area will respond to a lower salinity in Breton sound, and would in fact, given sufficient time, reach within the area of interest.

Time-series results of the evolution of the salinity field during the longer simulation of 45 days, starting from 1,000 cfs and going through 7,000 cfs are shown in sequential plots in Appendix H as Figure 22 through Figure 27. The figures show the evolution of the salinity field as a function of time. Figure 64, on the other hand, shows the evolution of an instantaneous surface salinity at two locations, one in the MRGO channel upstream of Bayou La Loutre, and the other in the center of the Biloxi Marsh. The figure shows that initially, when the diversion in the system is of the order of 1,000 cfs using a 50/50 split between Bayou Bienvenue and Bayou Dupre, the instantaneous salinity at both locations is dominated by tidal induced circulation. Both signals respond to tidal forcing by showing diurnal oscillations. The salinity within the MRGO (green solid line), although small, shows some response to diurnal oscillation. This is so small and cannot be seen with the salinity time-series but is seen in the gradient term. The gradient term responds to diurnal oscillations during the low diversion flow but they are rather negligible. However, once the flow starts to rise to 7,000 cfs there is a rather rapid response. The absence of the diurnal oscillation in this term also deems this area now dominated by river-water rather than tides.

In the Biloxi Marsh, despite the obvious decline in instantaneous salinity as a result of the diversion (black trend line, Figure 64), there seems to be a slightly different response. There is an obvious phase or lag in the system. For example, during the early part of the simulation, the area responds only to tidal forcing, as the local average or trend is a horizontal line up to hour 240 and above. By this time, the diversion has already been operating and is fully ramped to 7,000 cfs, but has not produced a measurable change in this area. Subsequently, and coinciding with a neap cycle, the system responds with a sudden reduction in the salinity, verifying the small dominance of river-

induced circulation in the absence of strong tidal induced flow. By this time, the diversion flow is fully developed and the declining trend in the salinity appears to be linear in time.

6.3 Conclusions to FVCOM Modeling

The model simulations showed that wind stress resulting from frontal weather can produce high frequency variability in the Pontchartrain Basin within just three days of the application of the wind. In 5 day simulations with half a day of spin up time, the model predicted double the variability. The model also predicted that when only using the averaged salinity field, one would tend to underestimate this variability and high frequency response, primarily because the response is rapid. The model also predicted that in longer simulations, the high frequency response would tend to be smaller due to the natural tendency of wind to cancel this response. This is largely a function of wind climate, basin geometry, duration and intensity of each event, and the relaxation scale of the basin.

Finally, a longer simulation of a diversion from 1,000 cfs to 7,000 cfs showed that the MRGO-La Loutre pathway is largely dominated by tidal currents when the flow is near the low 1,000 cfs magnitude. When the flow is near 7,000 cfs, the basin in this area is dominated by the diversion flow. Furthermore, the model predicted a lag time of the order 4-7 days for this flow to reach the Biloxi Marsh area through this direct route. It is emphasized that for this simulation, the Lake Borgne connection to the MRGO was closed, which further ensures that the conveyance is maximum through this pathway. The model also showed that the Biloxi Marsh area is largely tidally influenced when the flow at Violet is near 1,000 cfs. Although tidal flows continue to cause strong diurnal oscillations in the salinity, when the flow reaches 7,000 cfs and dynamic equilibrium after the lag period, there is a steady decline in the salinity.

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7 HYDRAULIC DESIGN

In terms of channel configuration, diversions into and through the CWA will require four components. First, there must be a structure through the Mississippi River Levee; second, a sediment basin will trap particulates from the water; third, there must be sufficient conveyance through the CWA; and fourth, exit structures in the Chalmette levee must be capable of passing the diversion to the MRGO within acceptable impacts to the CWA and infrastructure. These four components will be addressed from the downstream end of the system.

There are numerous ways to route the design flow of 7,000 cfs through the Central Wetlands. As a first approximation, a straight channel with confined flow was investigated using the following assumptions: culverts at the river would be 500 feet in length (i.e. long enough so that the Mississippi River levee as well as the river road and the railroad could pass over them); the culverts under the back levee would be 200 feet in length (i.e. long enough to allow them to pass under the levee); and the length of the direct channel between the two culverts is 21,300 feet. It is further assumed that the velocity head (energy) through the culverts is lost due to using a settling basin downstream of the culvert at the Mississippi River and again with the deep water of the MRGO downstream of the second set of culverts. The channel size was manipulated so as to maintain a velocity of two feet per second with a 7,000 cfs flow. The channel design is a twelve foot deep channel with one on three side slopes; a 250 foot bottom width; and an almost imperceptible gradient of one foot over the 21,300 foot length of the channel. The five culverts at the River are sized as 13 feet by 13 feet gated concrete box culverts. The culverts at the east end of the channel will be five 13 feet by 12 feet gated culverts. The head loss through the MRGO culvert would be 1.58 feet. This configuration will satisfy the need to route the proposed amount of water through the Central Wetlands. The channel dredging for this proposed configuration will involve the removal of an estimated 2.7 million cubic yards of material.

The design configuration given above uses a relatively small width channel so that the velocity for the 7,000 cfs would be slightly greater than 2 feet per second, thus reducing the potential for sedimentation. The calculations also assume a sedimentation basin at the head of the channel (i.e. the velocity head through the River culverts is entirely lost in the sedimentation basin). This channel could be constructed so that the 12 foot depth is below the marsh elevation and thus dikes confining the flow would not be required. By slightly throttling the exit culverts the water elevation in the channel could be adjusted to where it overflowed onto the marsh.

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For the background flow of 1,000 cfs, the gates at the back would be adjusted (or totally closed) so that flow is forced to go overland toward the Bayou Dupre and Bayou Bienvenue structures. If all of the flow were forced to exit through these two structures there would be an average seaward flow of slightly less than one foot per second in the structures (56 feet wide by 10 foot deep).

Appendix I provides additional design including an analysis of the design configuration considering sea level rise. Figures and cross-sections of the proposed design are provided in Appendix I. The future CWA restoration efforts are considered.

4.7 DESIGN CONSIDERATIONS

The following points should be considered during design of the channel and structures. Appendix J provides details on the potential impact to navigation and shoaling.

- The diversion goal will need to be met under significantly different Mississippi River head conditions.
- Diverting a flow greater than 10,000 cfs can be accomplished via a direct hydraulic connection (canal w/ berms and gate) to Lake Borgne. If the flow is less than 10,000 cfs, the connection is into the CWA.
- Freshwater could be diverted into CWA from the channel if needed for ecological restoration of the CWA.
- Depending upon the duration of the diversion, flooding may be detrimental to the marsh plant communities. If this is the case, this leaves two equally unappealing alternatives – either 1) segregate the channel flow from the marsh with side dikes so as to prevent flooding of the marsh or 2) tolerate flooding the surrounding marsh.
- Waters discharging from the Bayou Bienvenue structure will be released north of the IHNC structure and may affect the lock.
- Head of a few feet will likely be necessary to increase the water elevation of the marsh to flood levels which would therefore increase the volume of water discharging through the Bayou Bienvenue and Dupre control structures. Thus the velocities through these structures could be quite high. Consideration must be given to navigation through the structures.
- Higher flows may require an additional opening in the MRGO levee which would decrease velocities through the Bayou Bienvenue and Dupre control structures. This would also decrease the detention time for water in the marsh and reduce period of inundation.

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7.2 OPERATIONAL ISSUES

By demonstrating that the Chatry salinity targets can be met or exceeded through diversions, an operations scheme can be developed to control discharges. Operationally, two indicators can be evaluated: 1) the gaged river flows in the Pearl River; and 2) a real time salinity gage strategically placed in the Biloxi Marsh area.

Operational schemes can be developed because of the good relationship found between the Pearl River flow and salinity variability in the Biloxi Marsh. Caution must be exercised however, because the relationship as defined in this report will change now that the MRGO structure is in place and other structures coming on line.

A salinity gage should be placed in the Biloxi Marsh to capture real time salinity, temperature, water levels, and potentially nutrients and sediment concentrations. This gage should be continually monitored and compared to the Pearl River gage. Estimates can be made over the same time frame for each.

Other potential issues that need to be investigated include:

- Localized flooding
- Drastic changes in volume of water on a month to month time frame
- Ecological impacts (good or bad)
- Effect of location on shoaling and navigation
- Impact on surge with increase of water levels in marsh and adaptive management schemes ahead of surge producing weather events to lessen the impact from surge

7.3 OPERATIONAL GUIDELINES

This numerical modeling effort did not include any management of the diversion flows. For the large scale diversions, there were continuous flows at a set rate; for the smaller diversions, where the gap between Lake Borgne and the MRGO was closed, there were diversions of 5,000 cfs, 7,000 cfs, or 10,000 cfs in the months of April and May and a maintenance diversion of 1,000 cfs in the other months to maintain a freshwater system in the CWA. These diversion flows were not adjusted in terms of the measured salinity in the target area or the anticipated freshening from flood events in the Pearl River. The modeled diversion flows were not managed because of the time frame and scope limitations of the modeling effort.

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In reality, the diversion flows will be managed. When measured salinities are at or below target levels, the flow amounts can reduced accordingly; when salinities are high, the diversion flow will be increased. Likewise, diversion flows can be adjusted in terms of flood flows in the Pearl River. When a major meteorological system produces copious rainfall in the Pearl basin, the diversion flow may need to be adjusted, particularly if the salinities are near the target levels.

An analysis of the monthly average Pearl River flow and the average monthly salinity showed a statistical relationship with a moderate correlation. An equation was obtained that gives the average monthly salinity in terms of the average monthly average Pearl River flow for the present month and the two preceding months with an R^2 value of 69 percent. This relationship was determined using the data for the 19 year period from 1990 through 2008 in which there was data for salinities in the target area. The same analysis will be done using modeled salinities for the future without project conditions. This new analysis is necessary because the previous analysis was conducted with the conditions prior to the MRGO closure at the La Loutre ridge and the IHNC barriers at the GIWW, Bayou Bienvenue and Seabrook.

Although there is a good correlation ($R^2 = 0.69$) between the Pearl River flow and salinities in the target area, there are other important contributors to the salinities as well. One of these factors is wind, which can be a dominant mechanism for inducing circulation patterns in shallow water. Generally, the winds in the southern Louisiana estuaries are calm to light. However, there are occasional strong winds from two important sources; these are tropical storms in the summer and fall and the passage of frontal systems in the winter.

Tropical storms, when approaching the region from the south, have very strong winds from the east and south east. These winds push the shelf waters inland, causing a significant rise in water level commonly called storm surge. These winds will push the more saline water further into the estuary, increasing the local salinity. However, this increase in salinity is temporary because as soon as the storm subsides the water will flow out and salinity levels will return to roughly the same values as before the storm.

The effects of a major frontal passage, on the other hand, can last longer. The north wind preceding a frontal passage causes a set down on the continental shelf and this allows for gravity drainage of the estuary. The waters of the marshes flow out into the Gulf where there is mixing with the saltier Gulf

waters. When the north winds subside, it is the more saline water of the Gulf that returns into the estuary. This increase in salinity is for a longer duration and will last until local rainfall and runoff reduce the salinity.

The influence of wind on salinity is mentioned here because it is a mechanism that could explain some of the variability not captured in the correlation between the Pearl River flows and the salinities in the Biloxi Marsh. It is also mentioned because when the diversion study is implemented, there may be real-time gages in the target area that will reflect the increases of salinity resulting from a frontal passage. The manager of the diversion could accordingly increase diversion flows to counter this affect. Similarly, when the diversion has been flowing and a system produces large rainfall in the Pearl basin, the operator may reduce diversions if salinities are already near target levels.

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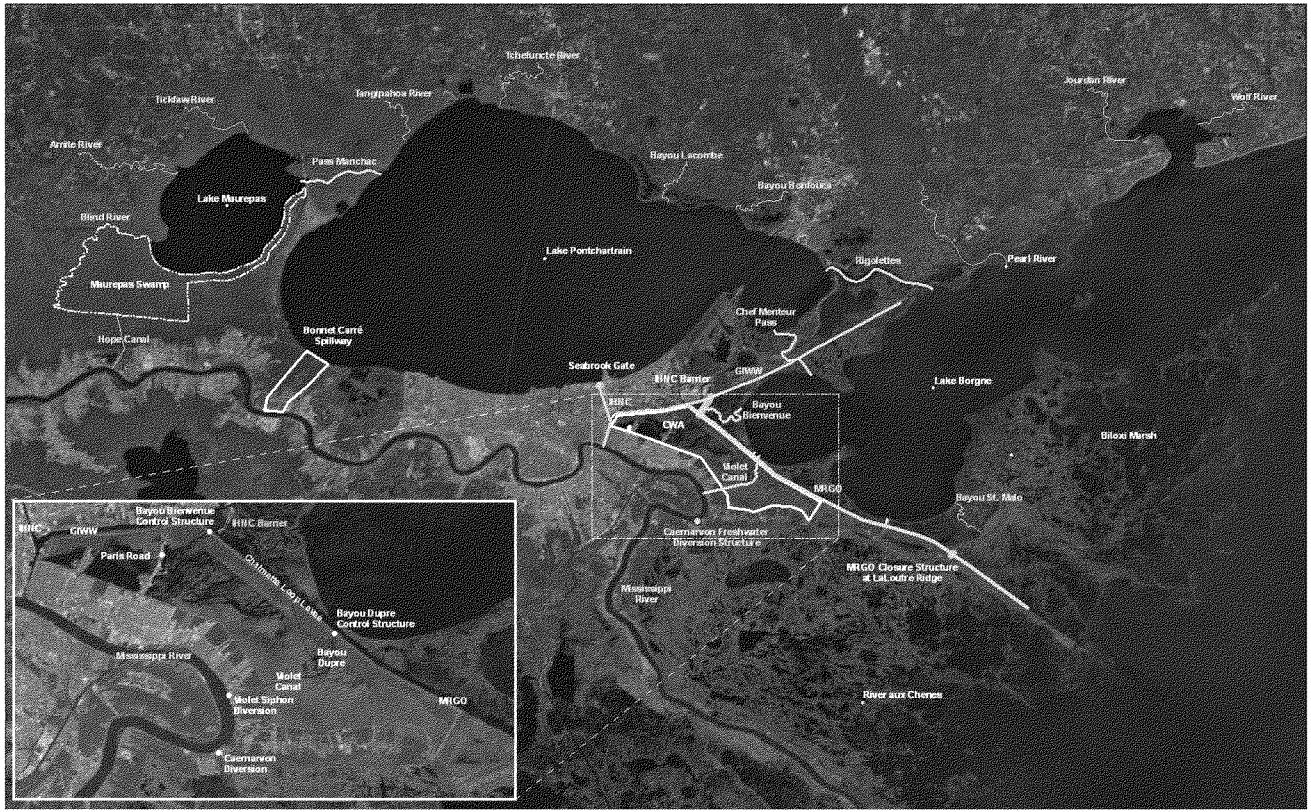

Figure 1. Map of study area with important features.

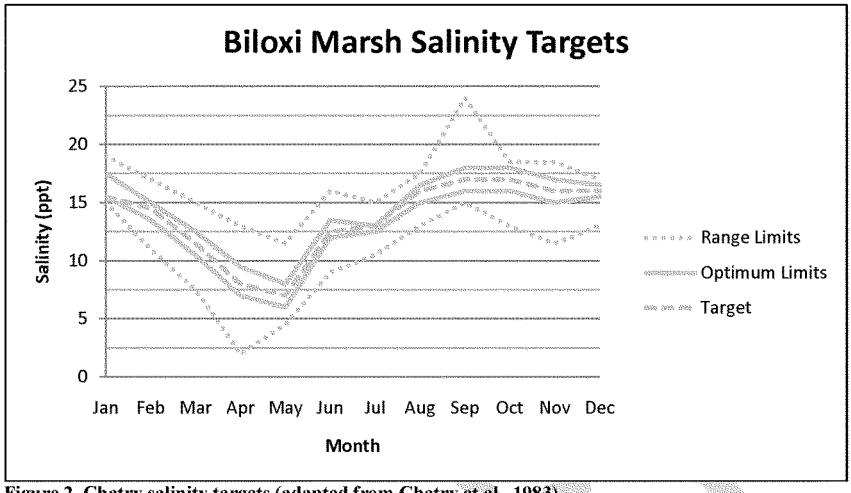

Figure 2. Chatry salinity targets (adapted from Chatry et al., 1983).

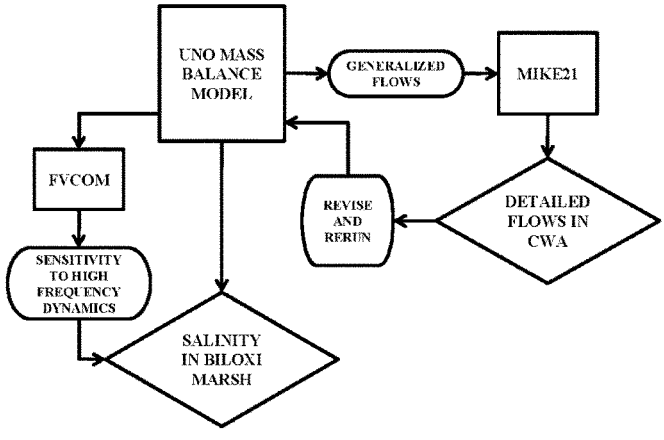

Figure 3. Methodology flowchart.

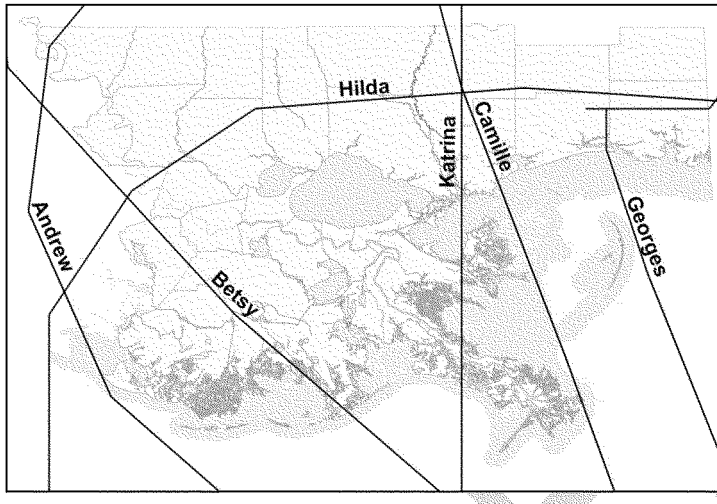

Figure 4. Major hurricane tracks.

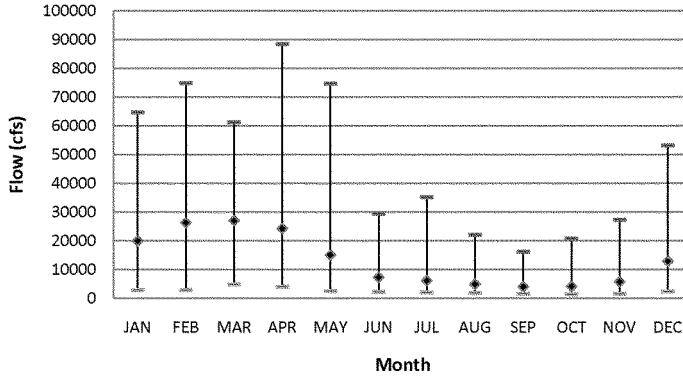

Figure 5. Monthly flow values (average, minimum, and maximum) for the Pearl River data set.

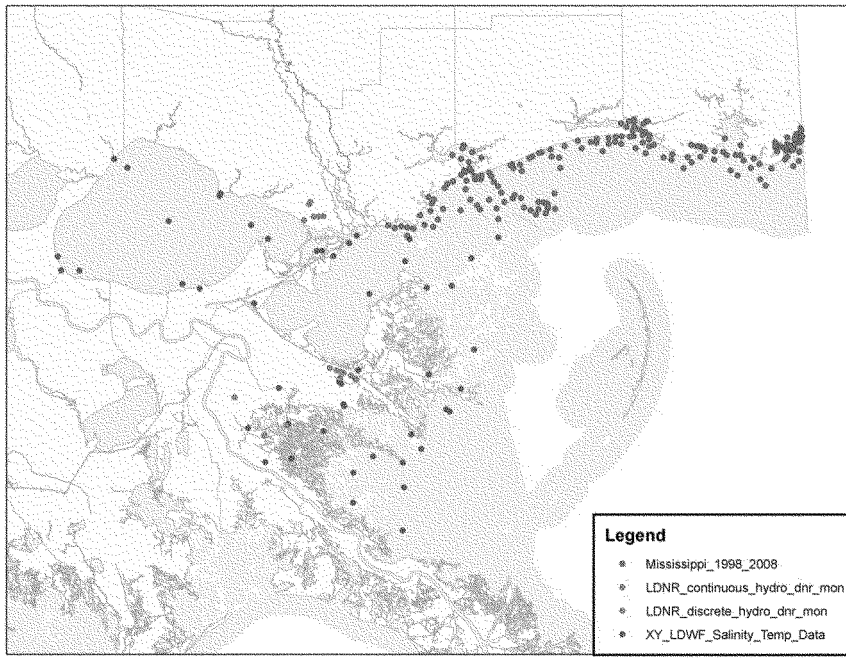

Figure 6. Water quality data collection points in study area.

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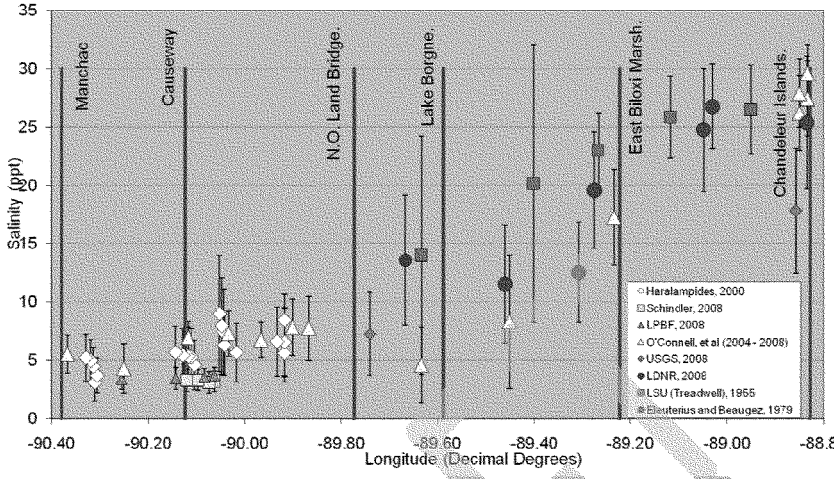

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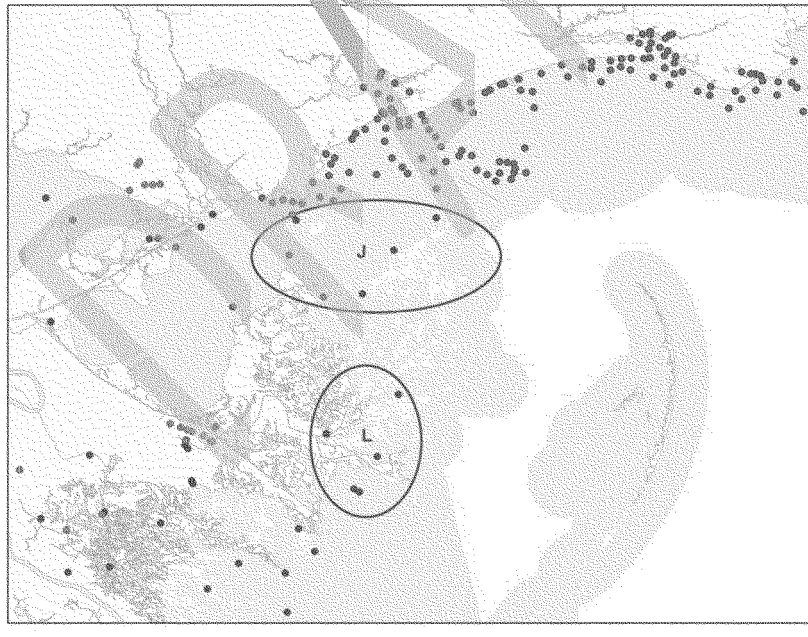
3 **Figure 7. Salinity level and location of historic data.**



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5 **Figure 8. Location of J and L data points.**

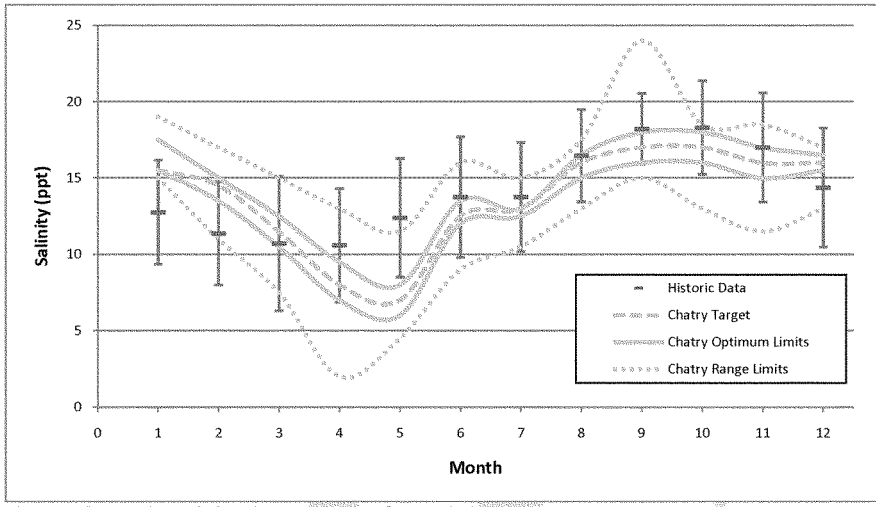

Figure 9. Comparison of historic data with the Chatry limits.

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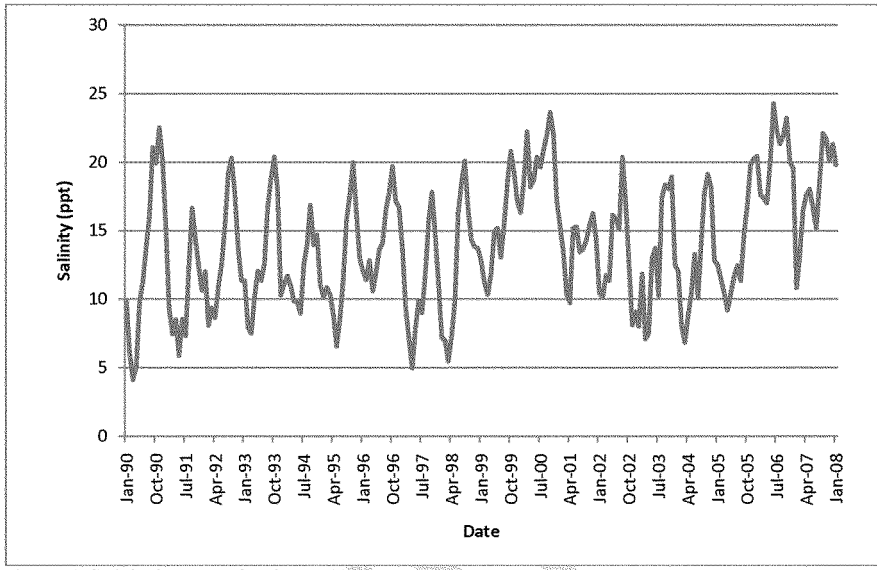

Figure 10. Salinity in zones J&L since 1990.

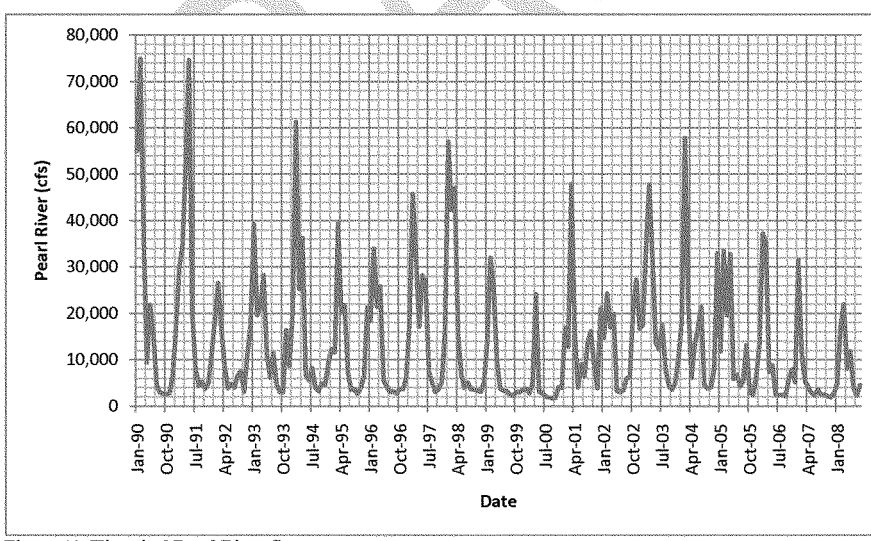

Figure 11. Historical Pearl River flow rates.

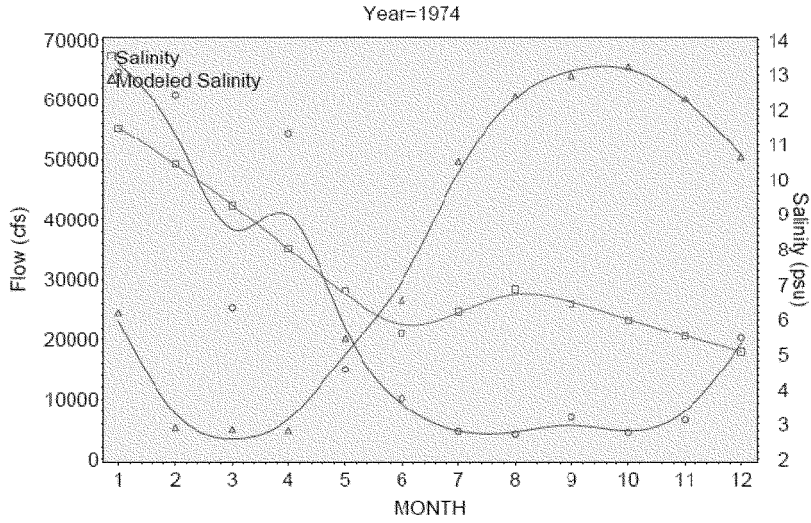

Figure 12. Example of poorly correlated data (1974).

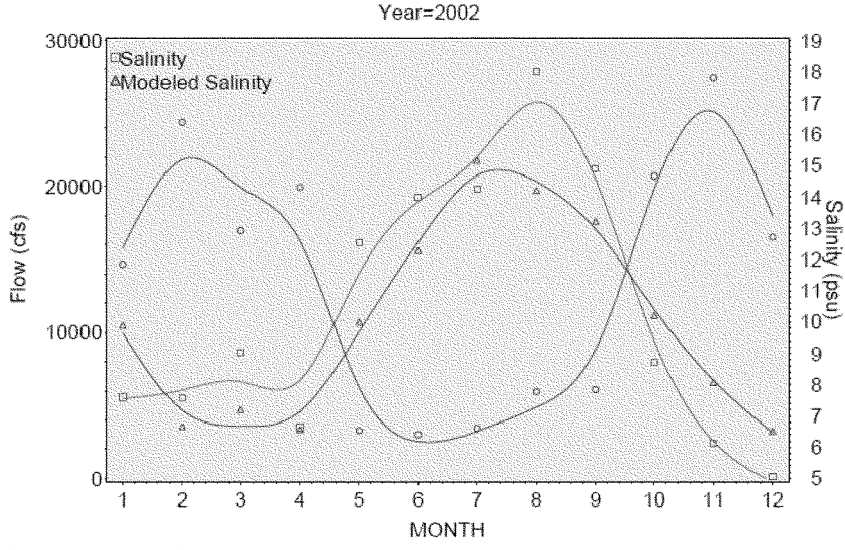

Figure 13. Example of well correlated data (2002).

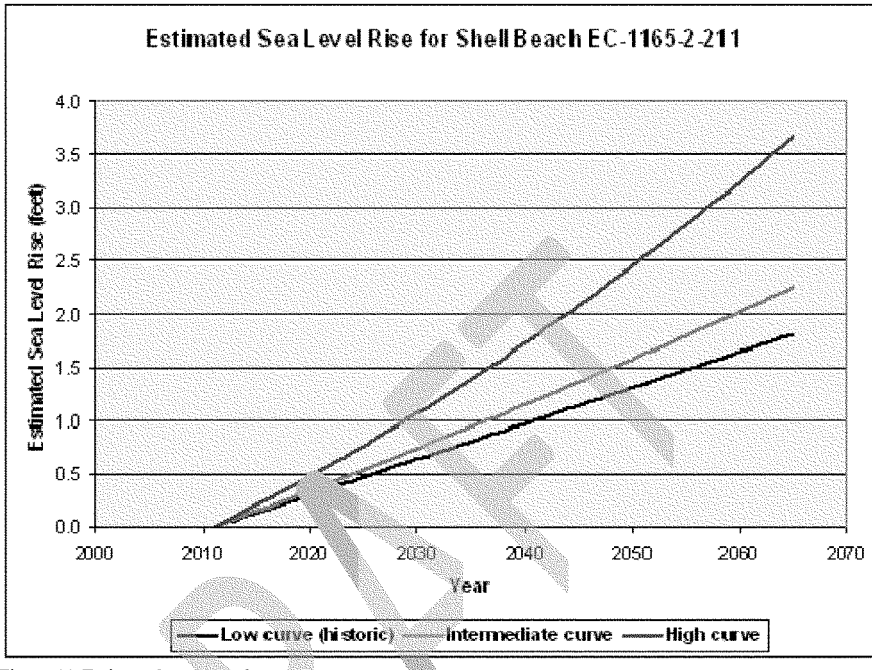

Figure 14. Estimated sea level rise curves.

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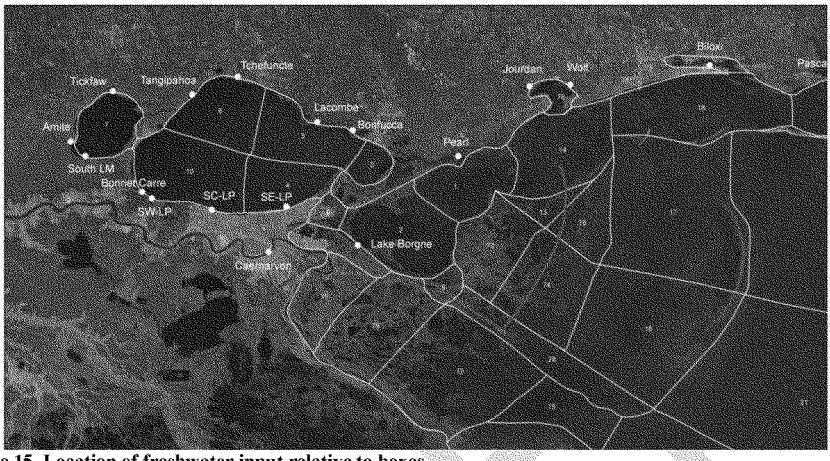

Figure 15. Location of freshwater input relative to boxes.

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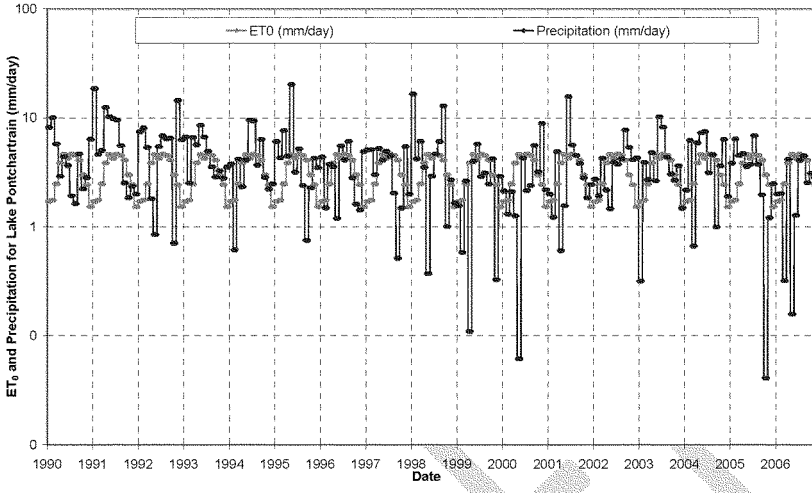

Figure 16. Daily precipitation and evapotranspiration rates input into the UNO Mass Balance model.

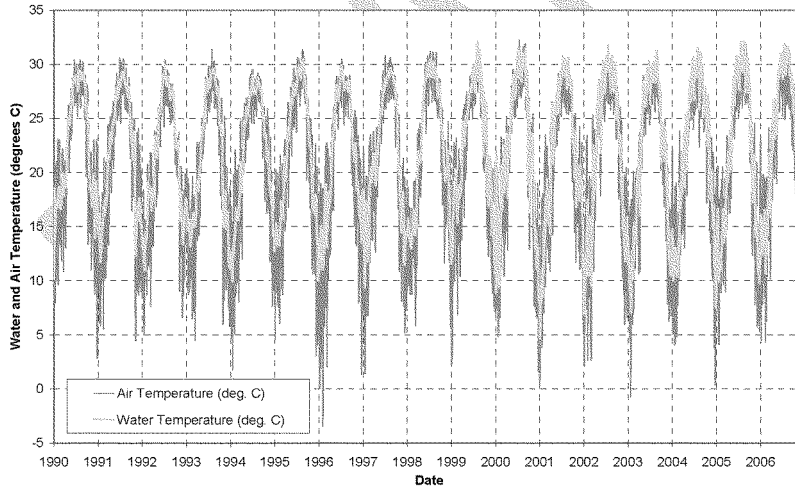

Figure 17. Daily air and water temperatures input into the UNO Mass Balance model.

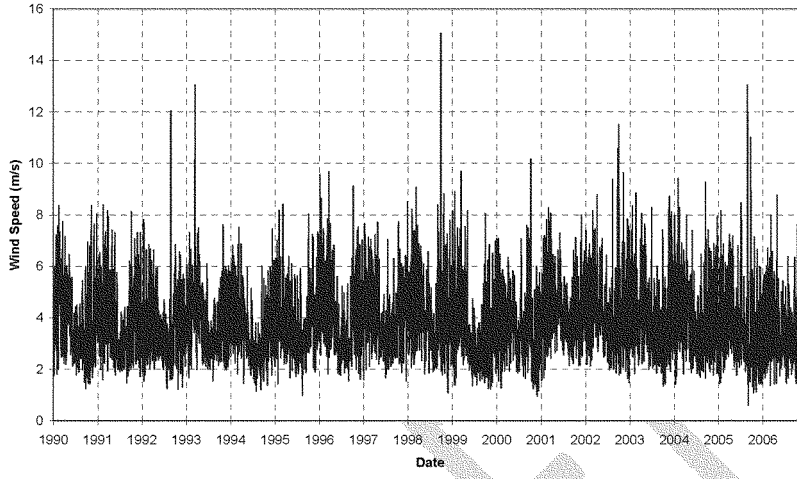

Figure 18. Average daily wind speed input into the UNO Mass Balance model.

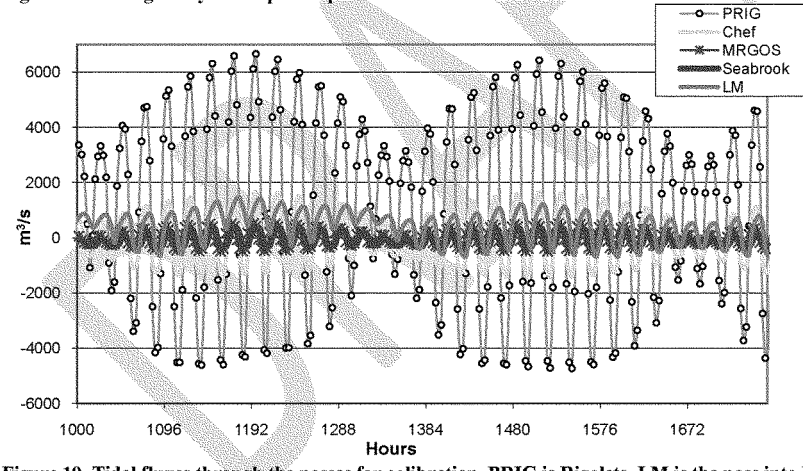

Figure 19. Tidal fluxes through the passes for calibration. PRIG is Rigolets, LM is the pass into Lake Maurepas.

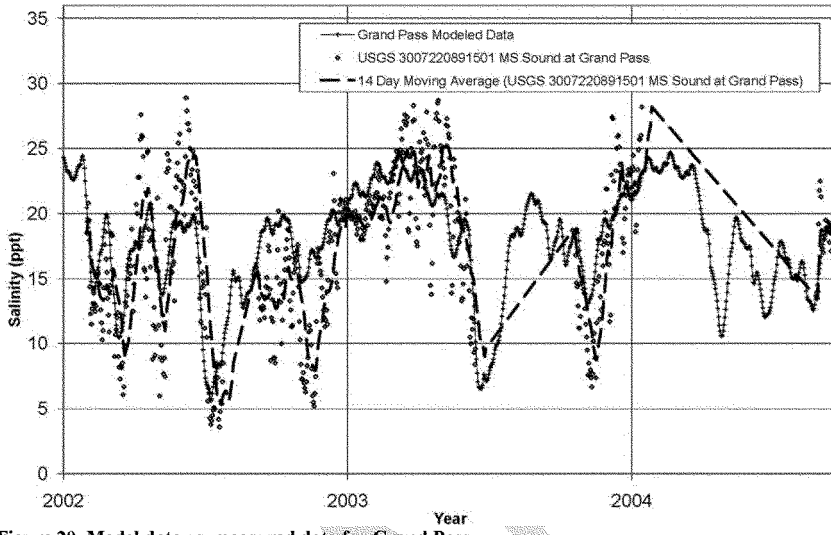

Figure 20. Model data vs. measured data for Grand Pass.

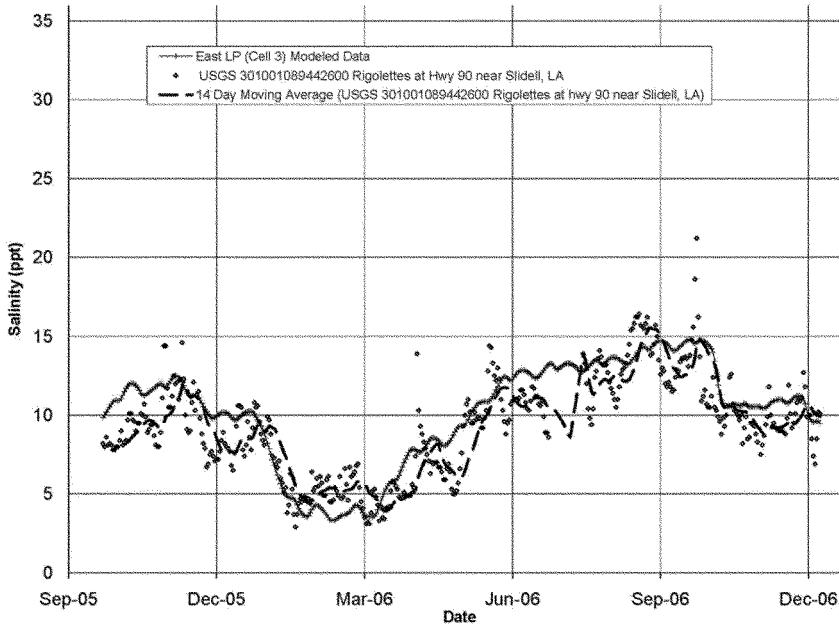

Figure 21. Modeled data vs. measured data at the Rigolets.

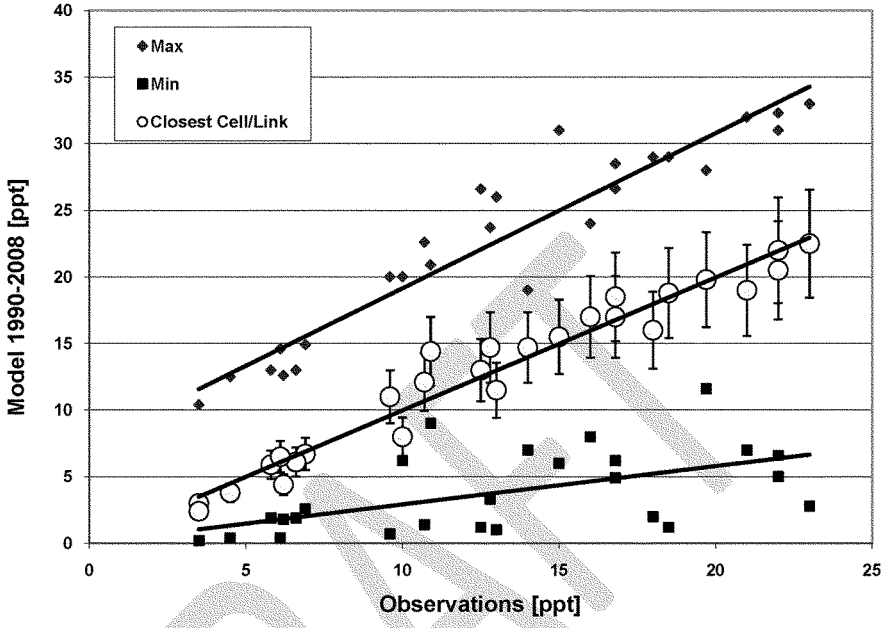

Figure 22. Plot of modeled data versus observed data.

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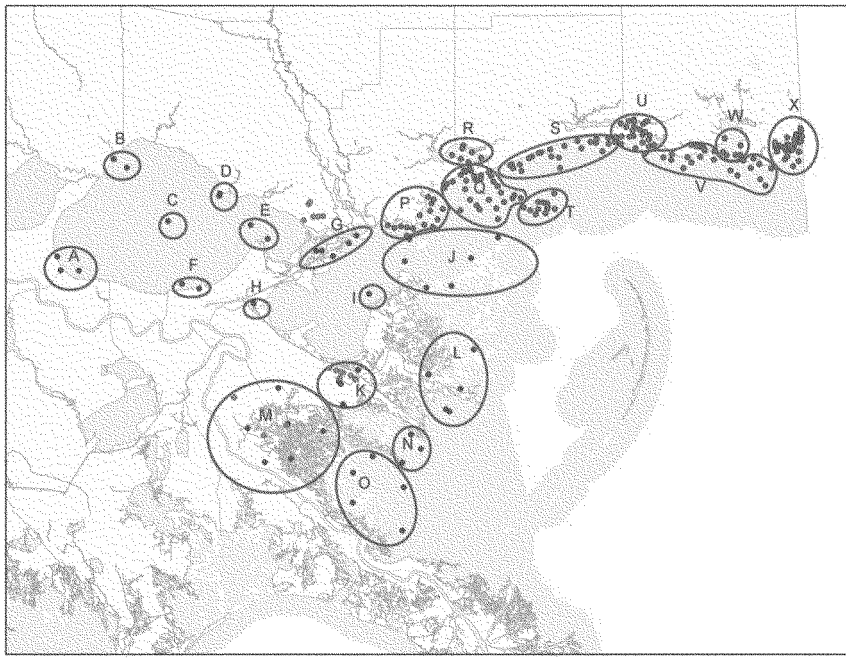

Figure 23. Locations of salinity data.

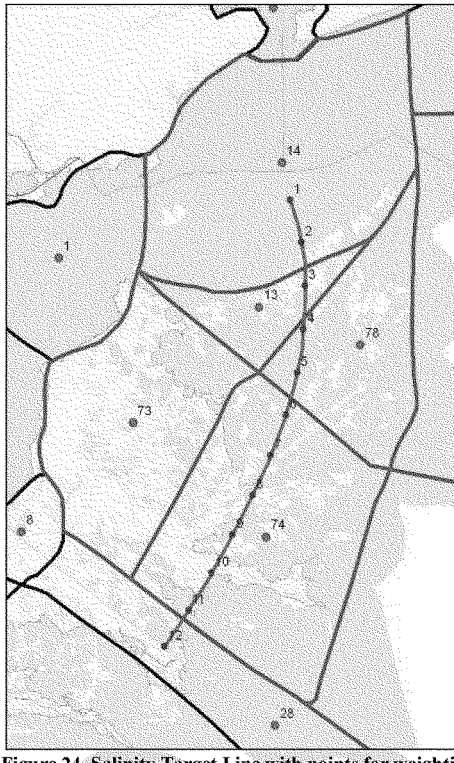

Figure 24. Salinity Target Line with points for weighting salinity.

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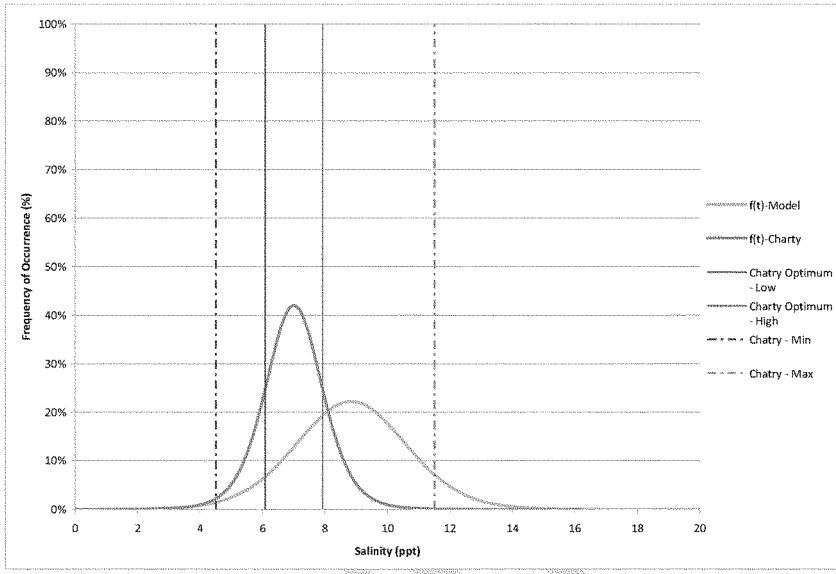

Figure 25. Salinity targets and modeled results plotted as t-distributed about the mean values.

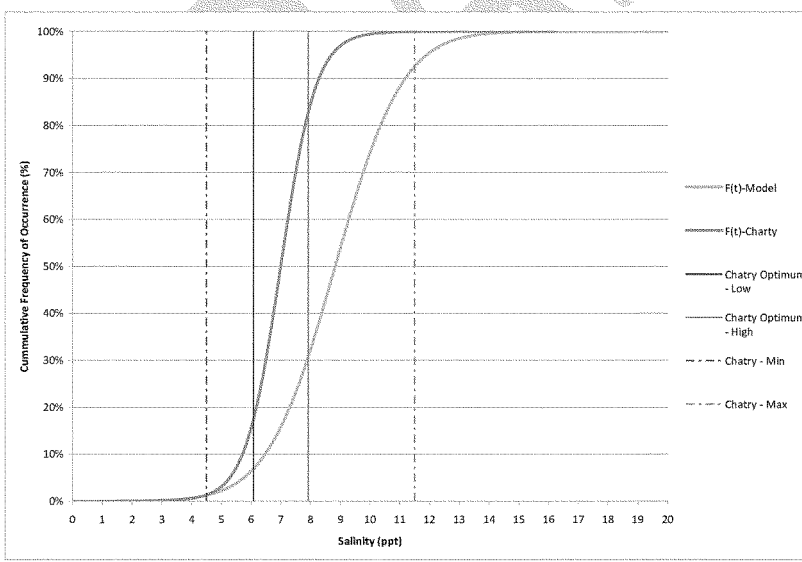

Figure 26. Salinity targets and modeled results taken as cumulative frequencies about the mean values.

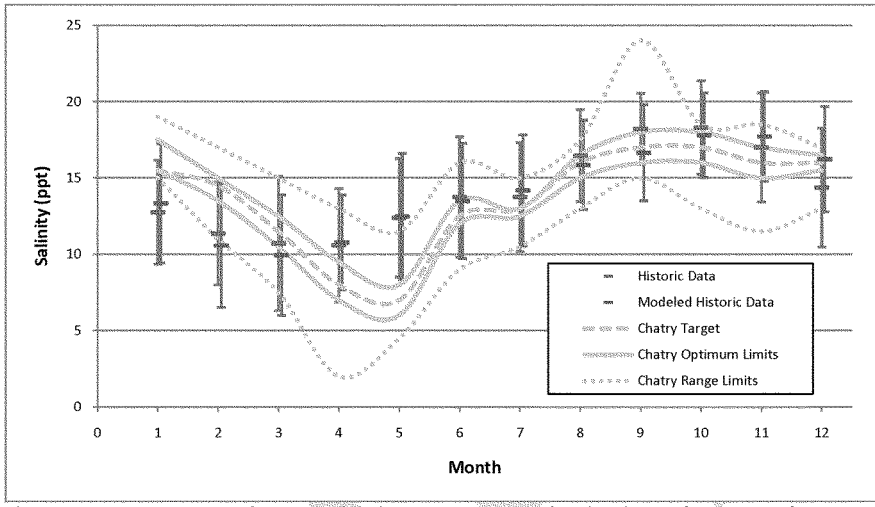

Figure 27. Monthly averages of modeled historical data compared with historic data from zones J&L.

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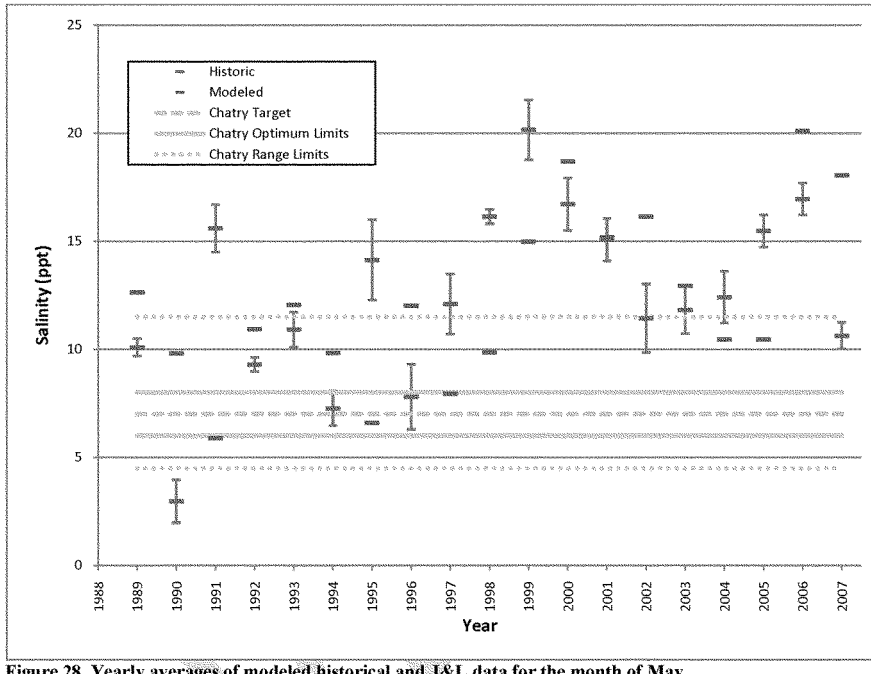

Figure 28. Yearly averages of modeled historical and J&L data for the month of May.

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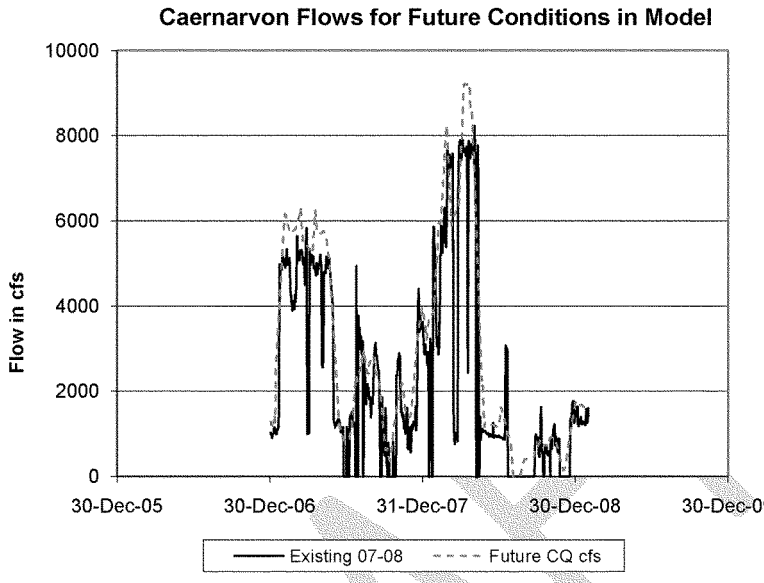

Figure 29. Caernarvon input flows based on increase of 2007 – 2008 pulsing.

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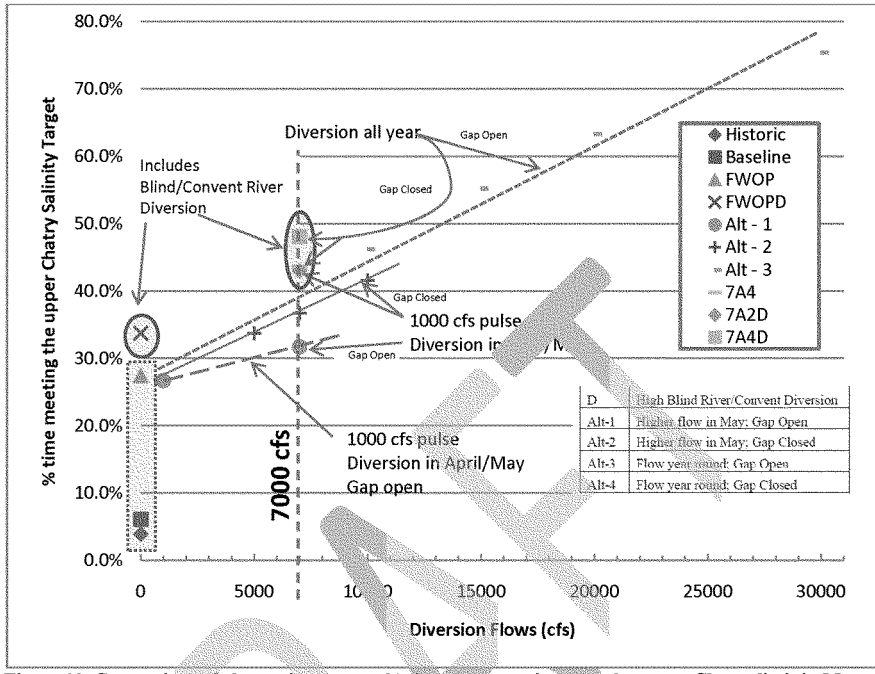

D	High Blind River/Convent Diversion
Alt-1	Higher flow in May; Gap Open
Alt-2	Higher flow in May; Gap Closed
Alt-3	Flow year round; Gap Open
Alt-4	Flow year round; Gap Closed

Figure 30. Comparison of alternatives versus % time the scenario meets the upper Chatry limit in Mays.

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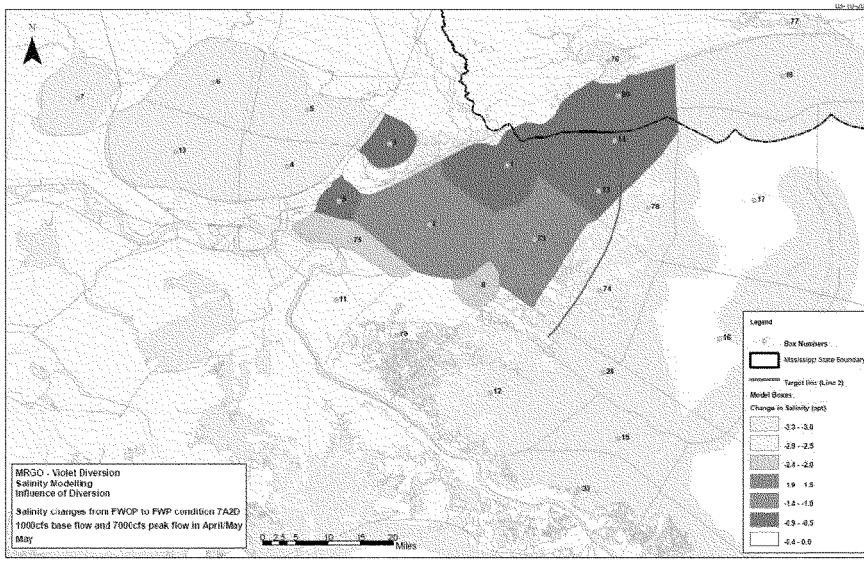

Figure 31. Area of influence of the 7A2D diversion in May (7,000 cfs in April and May with the Gap at Lake Borgne closed and the 4500 cfs diversion at Blind/Convent River).

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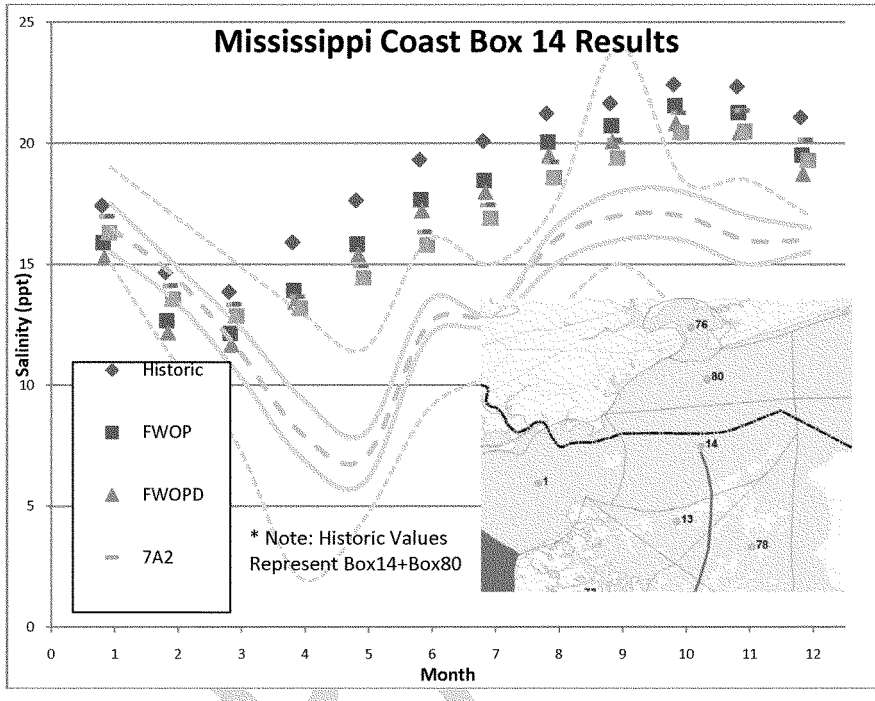

Figure 32. Changes in salinity along the Mississippi Coastal related to diversions near Violet Canal with an inset of the location of box 80 and box 14.

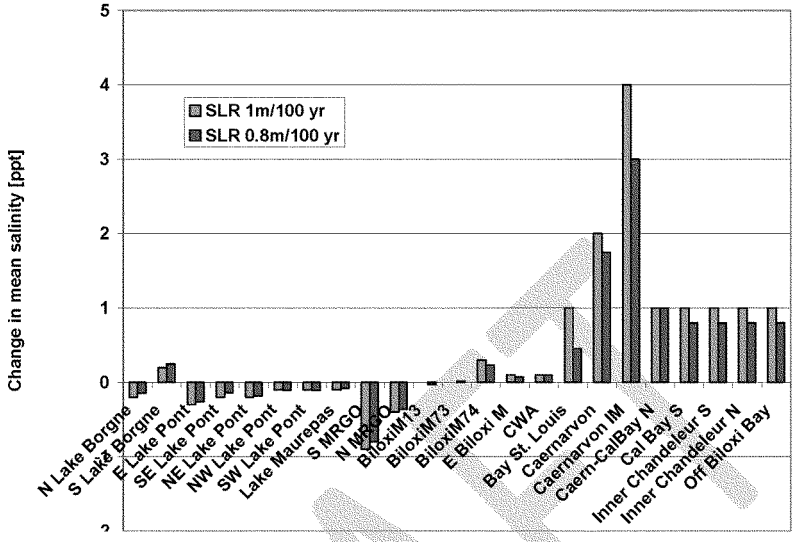

Figure 33. Preliminary Salinity Responses to Relative Sea Level Rise.

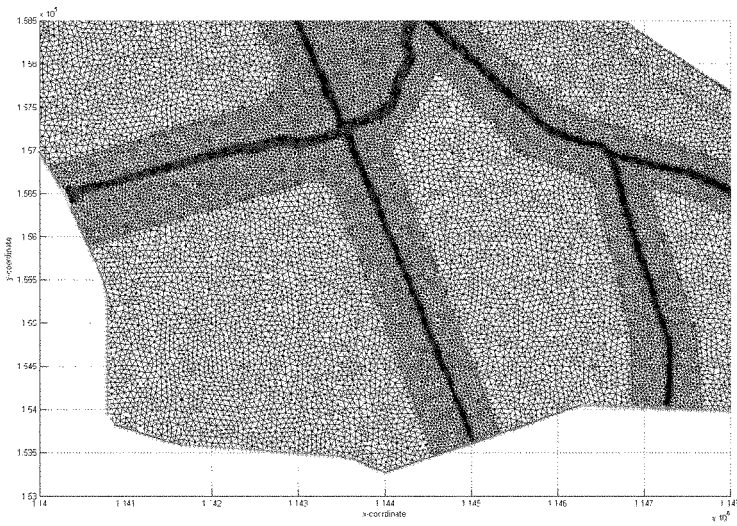

Figure 34. Part of the computational grid and the open boundaries.

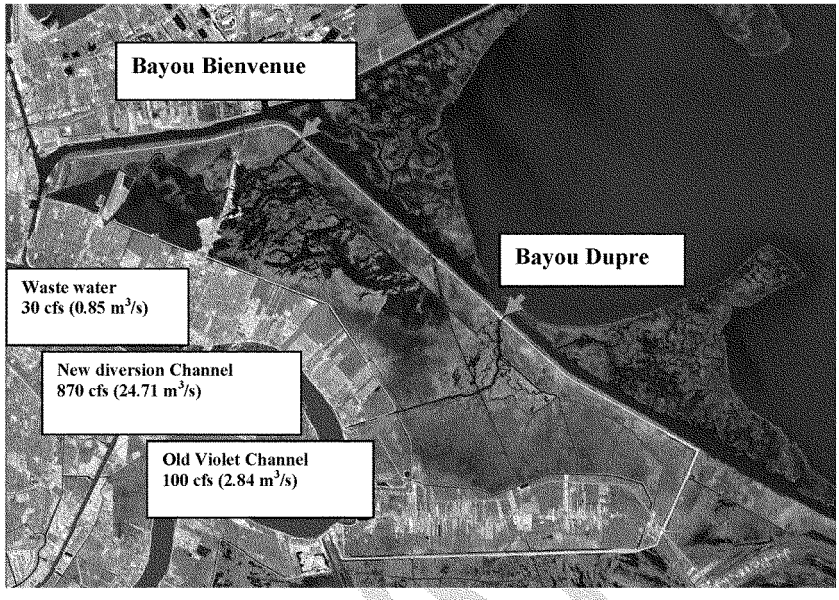

Figure 35. Flow stations in the CWA for this baseline scenario with 1000 cfs.

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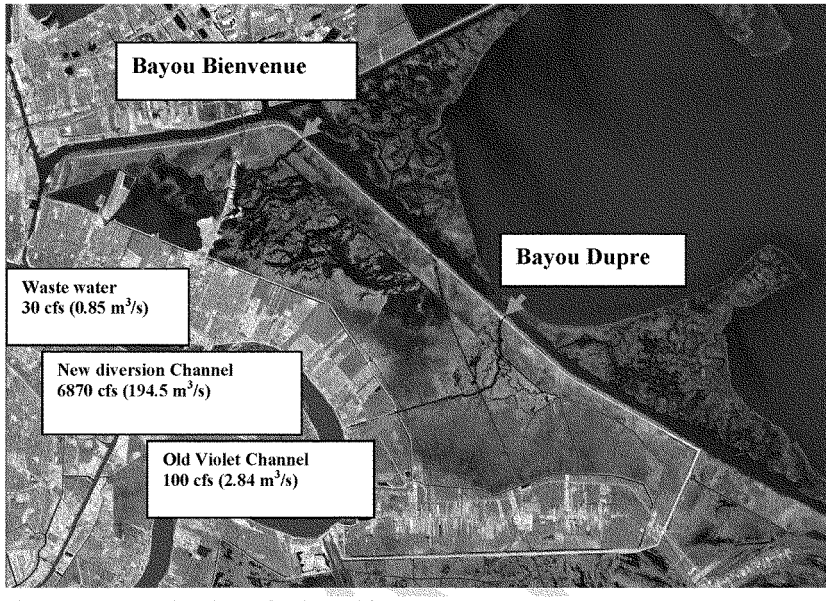

Figure 36. Flow stations in the CWA condition MR7.

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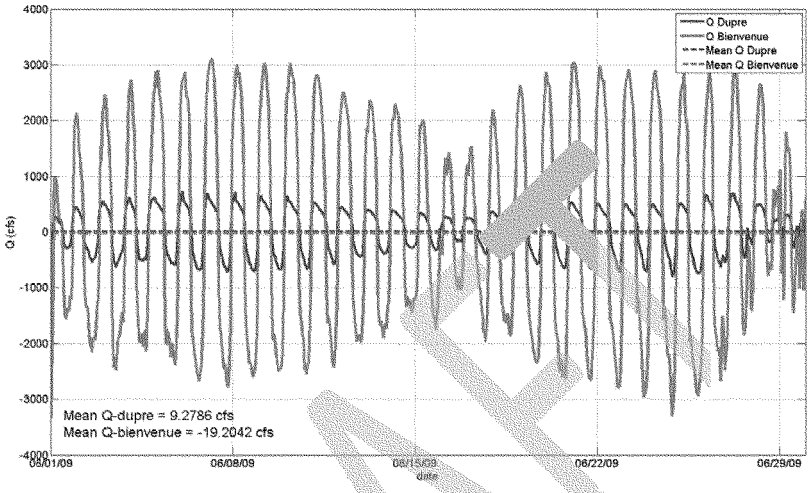


Figure 37. Discharge distribution over the Bayou Dupre and Bayou Bienvenue for the MB scenario.

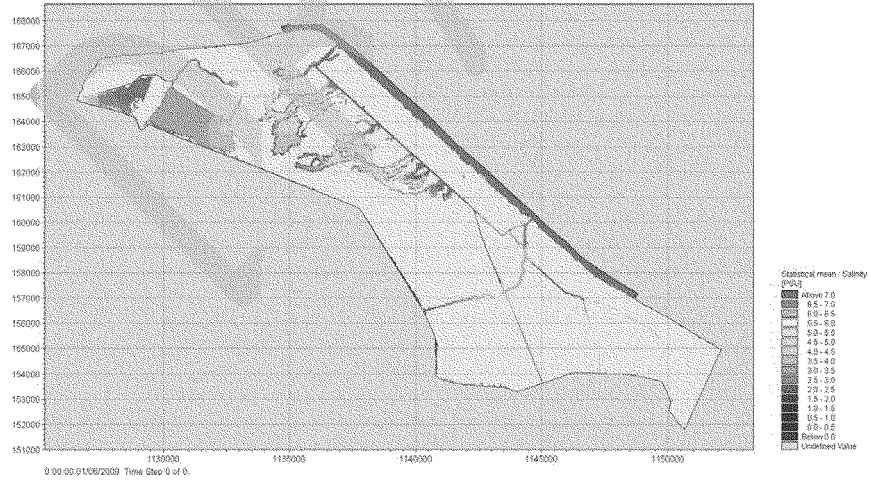


Figure 38. Average salinity in the MB scenario.

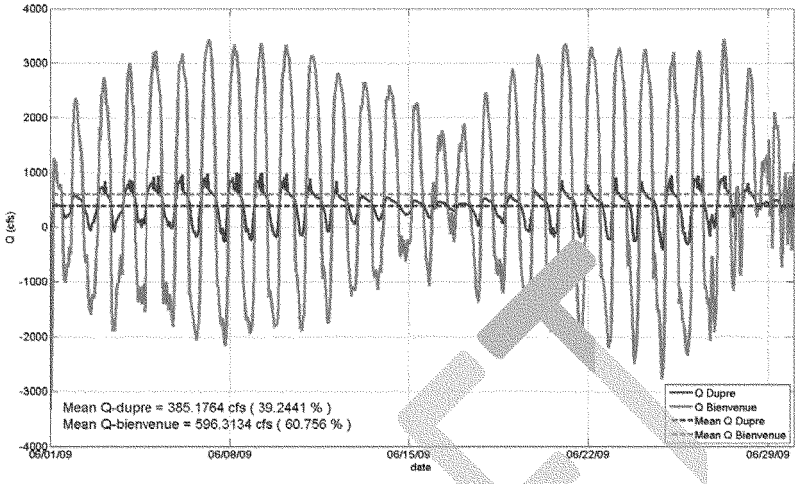


Figure 39. Discharge (cfs) through the Bayou Dupre (Blue) and Bayou Bienvenue (red) gates for the MB1 scenario. Dashed line indicates the mean discharge through the gates.

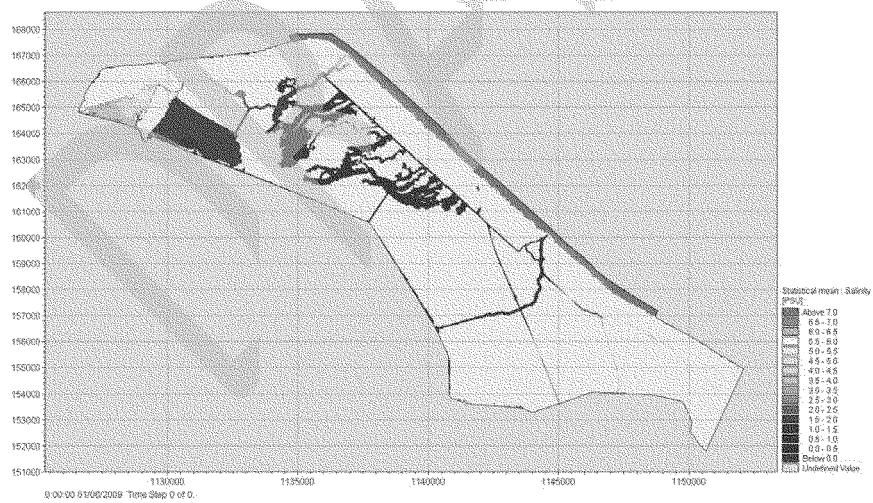


Figure 40. Mean salinity during June 2009 for the MB1 scenario.

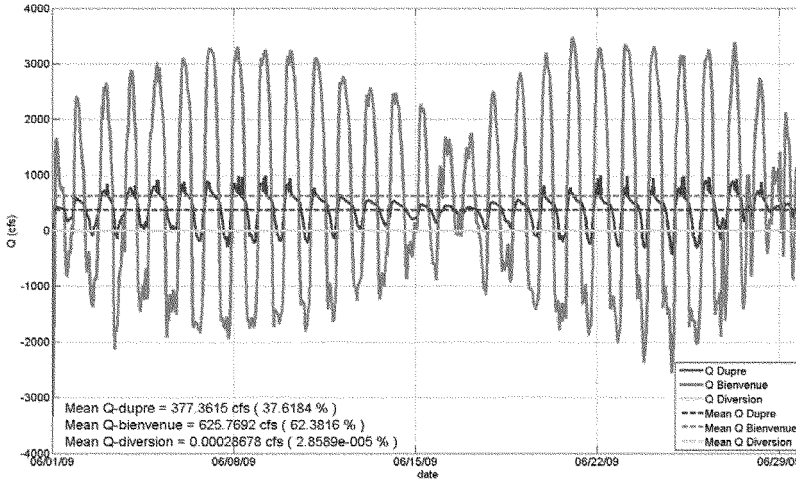


Figure 41. Discharge (cfs) through the Bayou Dupre (Blue), Bayou Bienvenue (red) and new Diversion (green) gates for the MR1 scenario. Dashed line indicate the mean discharge through the gates.

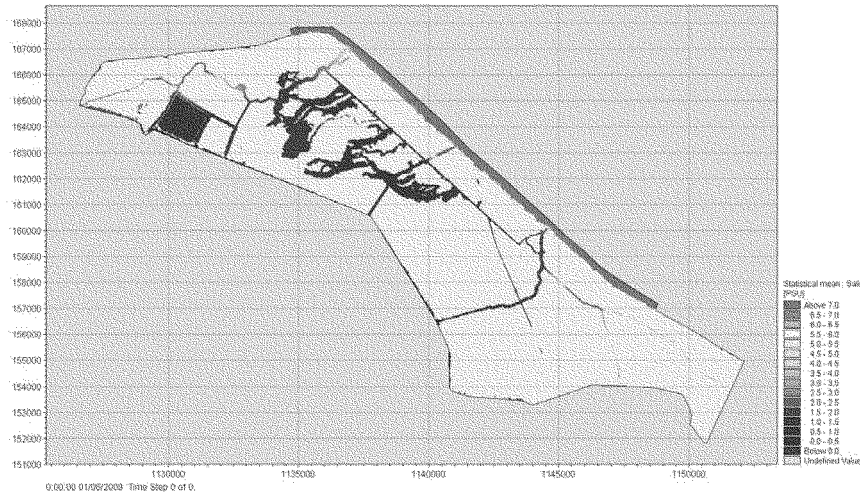


Figure 42. Mean salinity during June 2009 for the MR1 scenario.

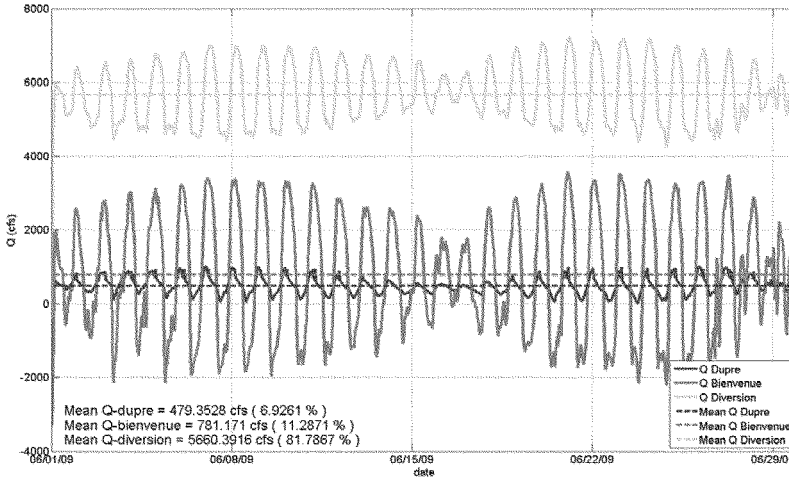


Figure 43. Discharge (cfs) through the Bayou Dupre (Blue), Bayou Bienvenue (red) and new Diversion (green) gates for the MR7 scenario. Dashed line indicate the mean discharge through the gates.

Figure 44. Mean salinity during June 2009 for the MR7 scenario.

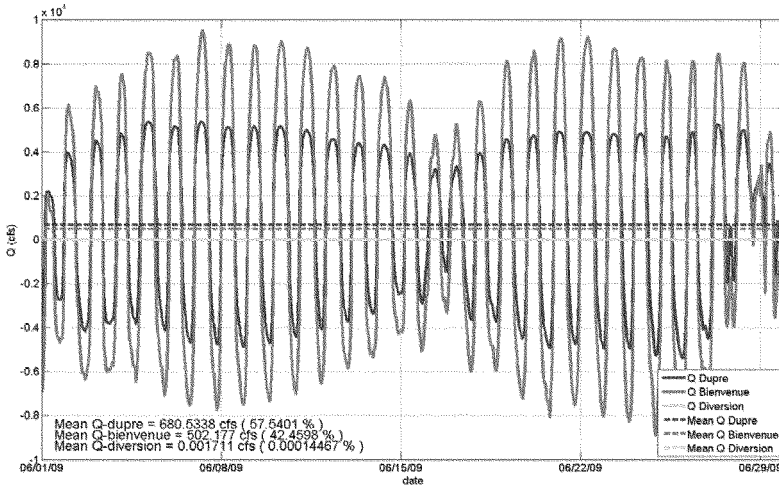


Figure 45. Discharge (cfs) through the Bayou Dupre Structure (Blue), Bayou Bienvenue Structure (red) and new Diversion (green) gates for the MRS1 condition. Dashed line indicate the mean discharge through the gates.

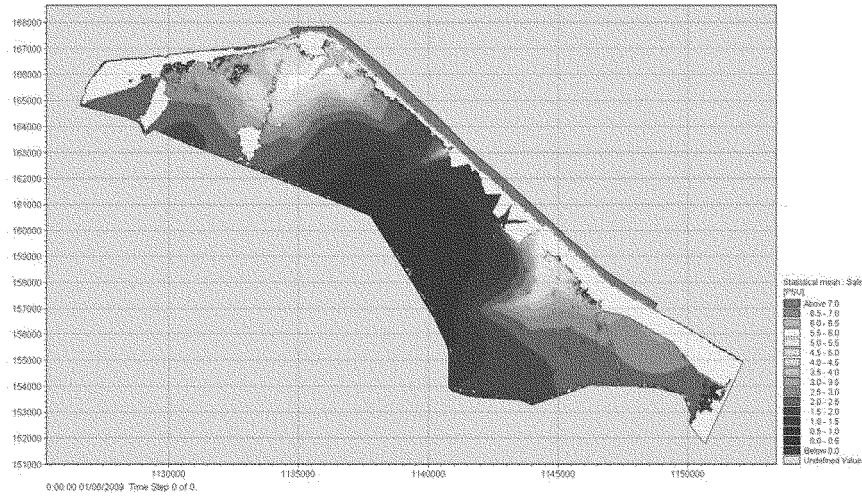


Figure 46. Mean salinity during June 2009, restored scenario with 1000 cfs including Sea level rise.

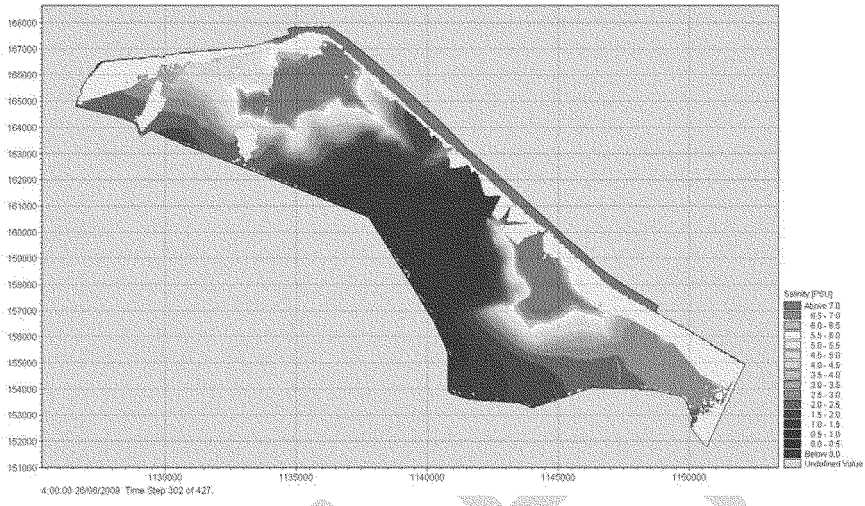


Figure 47. Salinity during high water, 26th June 2009, 4h00.

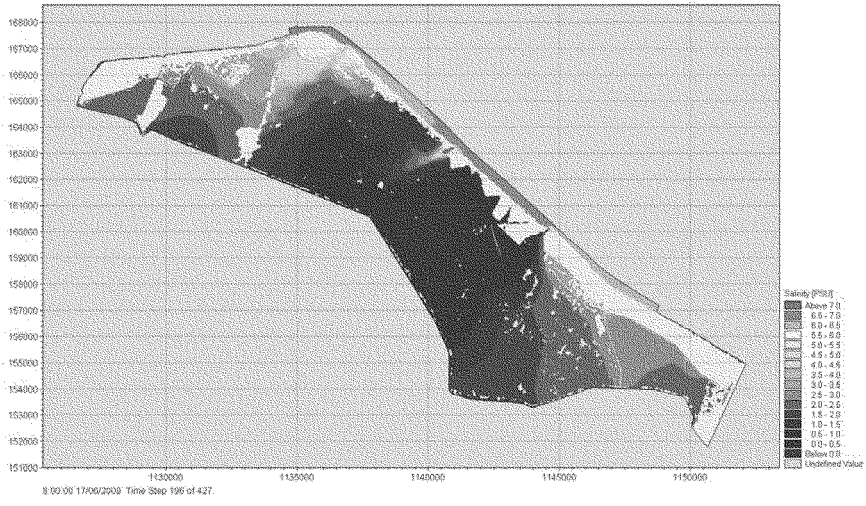


Figure 48. Salinity during low water, 17th June 2009, 8h00.

Figure 50. Comparison of the MB1 and MB Scenarios for Peak Water Level.

Figure 51. Comparison of MR1 with MB Scenarios for Peak Water Level.

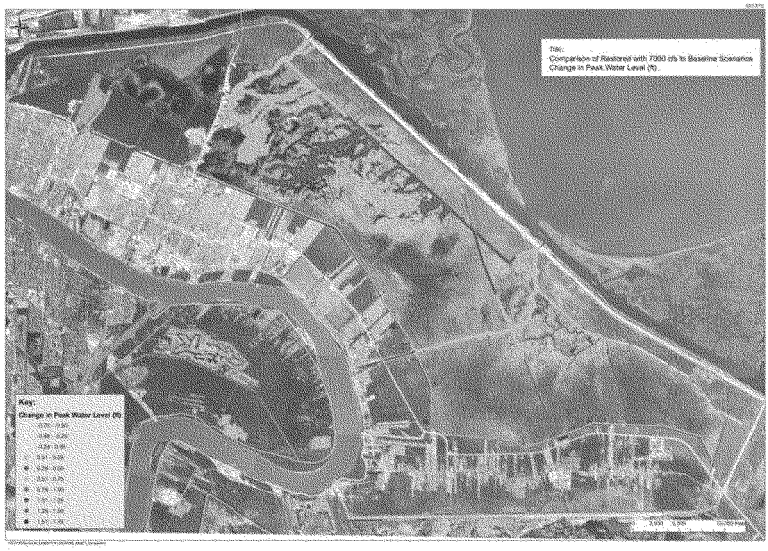


Figure 49. Comparison of MR7 with MB Scenarios for Peak Water Level.

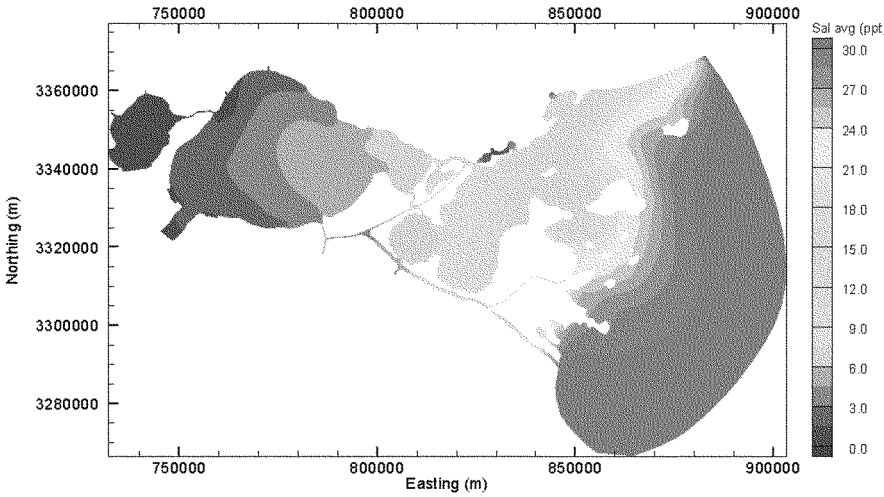


Figure 50. Model simulated depth-integrated salinity distribution averaged over 5 days (case opt1; frontal wind).

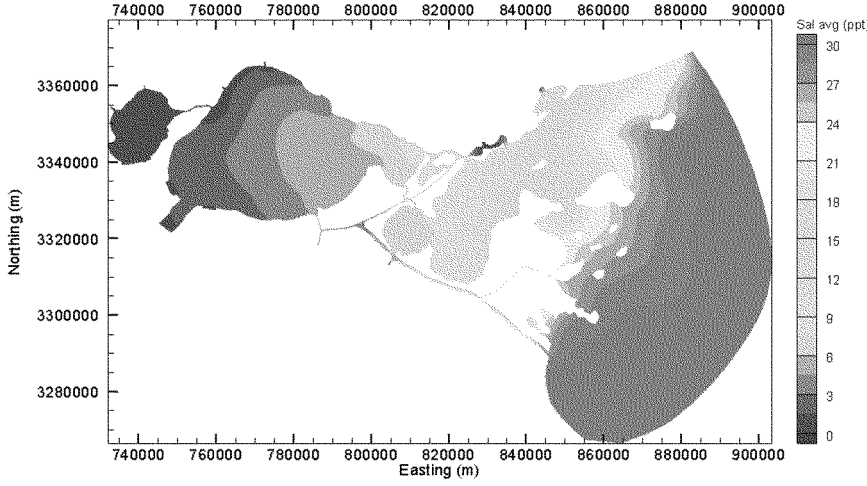


Figure 51. Model simulated depth-integrated salinity distribution averaged over 5 days (case opt2; no wind).

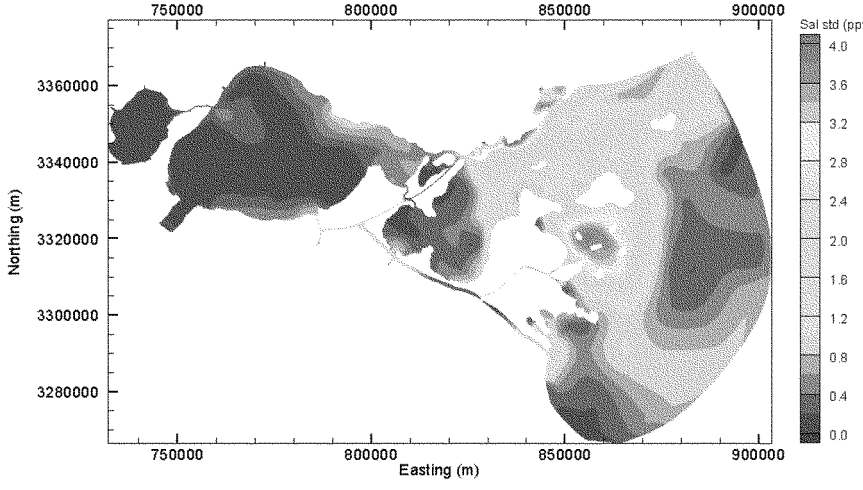


Figure 52. Model simulated depth-integrated standard deviation distribution for 5 days (case opt1; frontal wind).

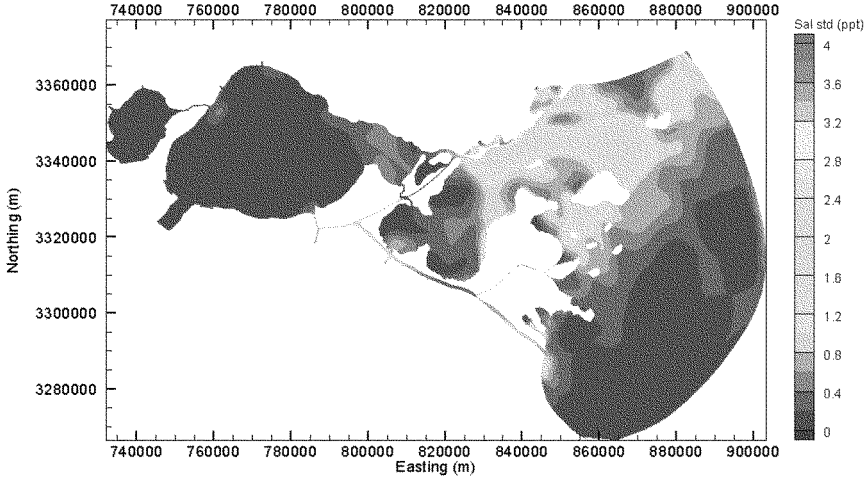


Figure 53. Model simulated depth-integrated standard deviation distribution for 5 days (case opt2; no wind).

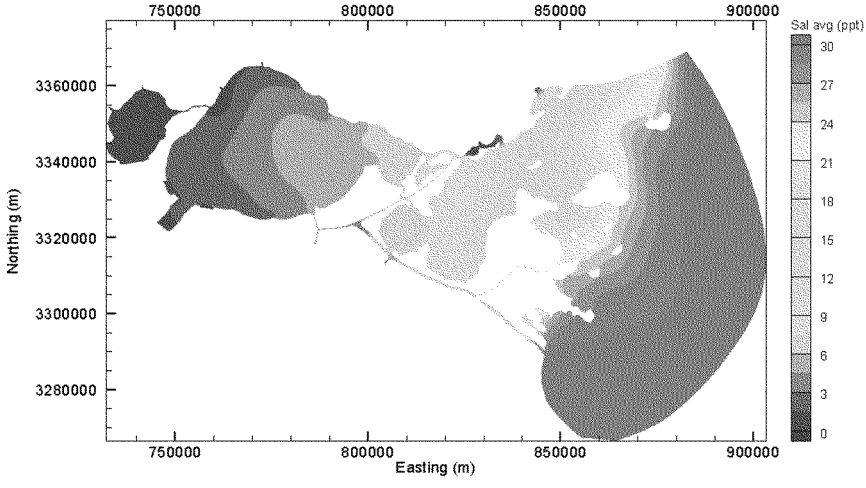


Figure 54. Model simulated depth-integrated salinity distribution averaged over 5 days (case opt1; frontal wind).

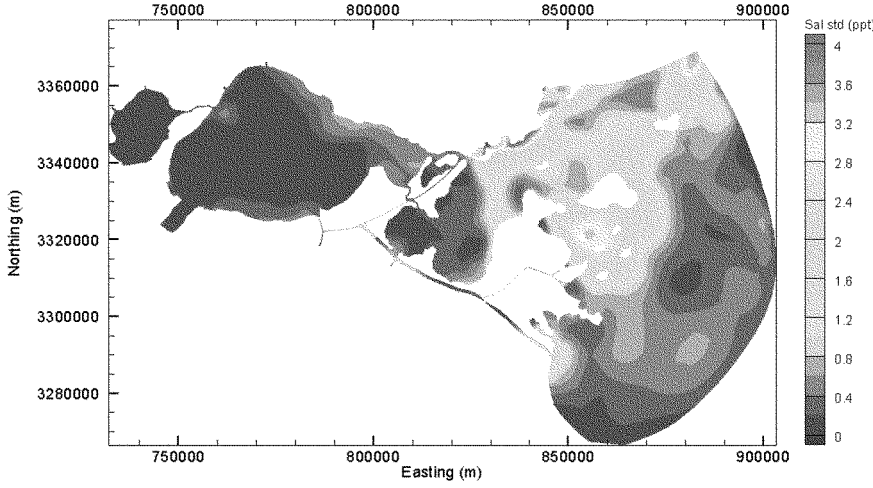


Figure 55. Model simulated depth-integrated standard deviation distribution for 5 days (case opt3; frontal wind).

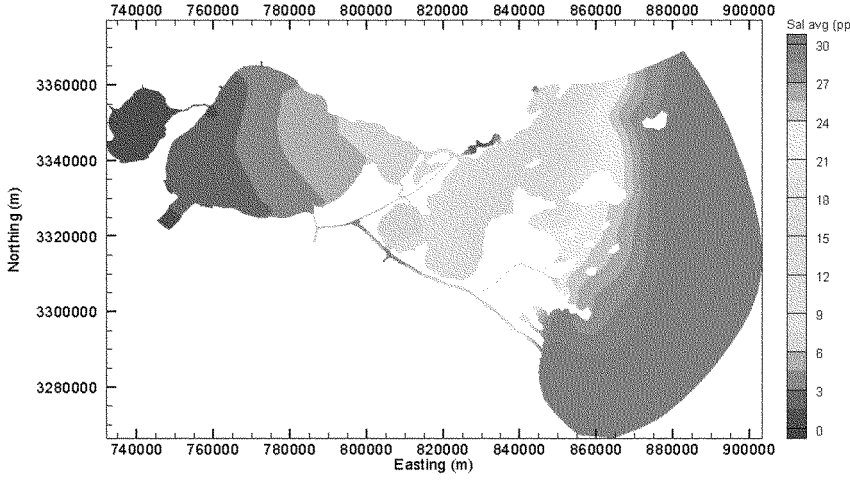


Figure 56. Model simulated depth-integrated salinity distribution averaged over 5 days (case opt5; frontal wind).

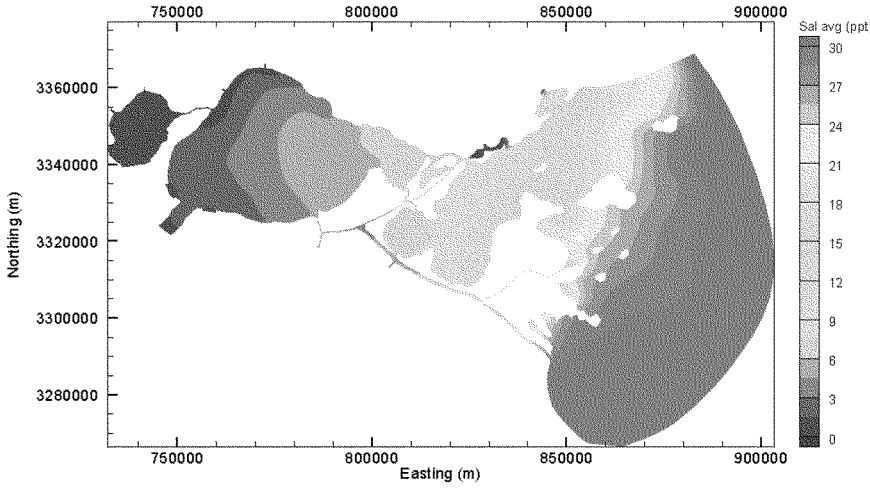


Figure 57. Model simulated depth-integrated salinity distribution averaged over 5 days (case opt6; no wind).

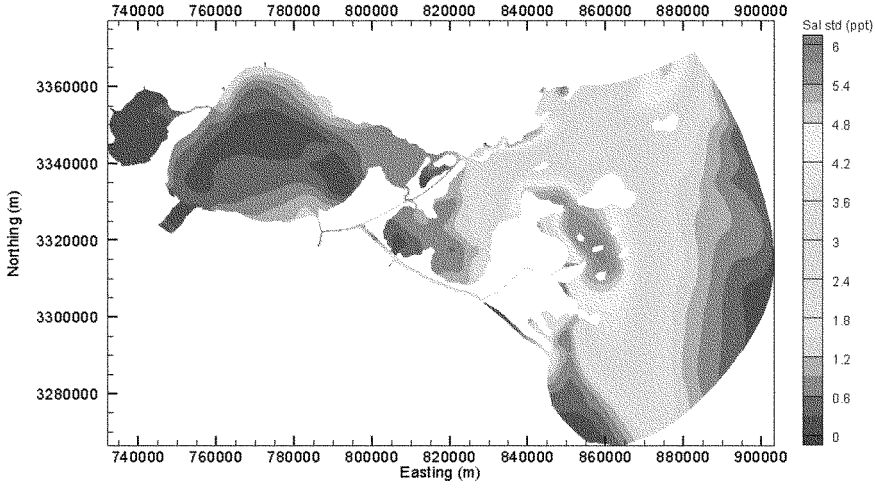


Figure 58. Model simulated depth-integrated standard deviation distribution for 5 days (case opt6; frontal wind).

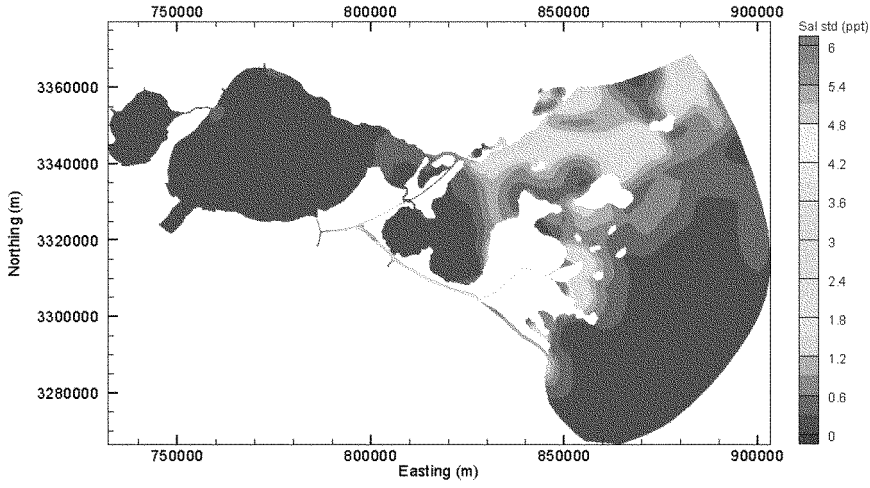


Figure 59. Model simulated depth-integrated standard deviation distribution for 5 days (case opt6; no wind).

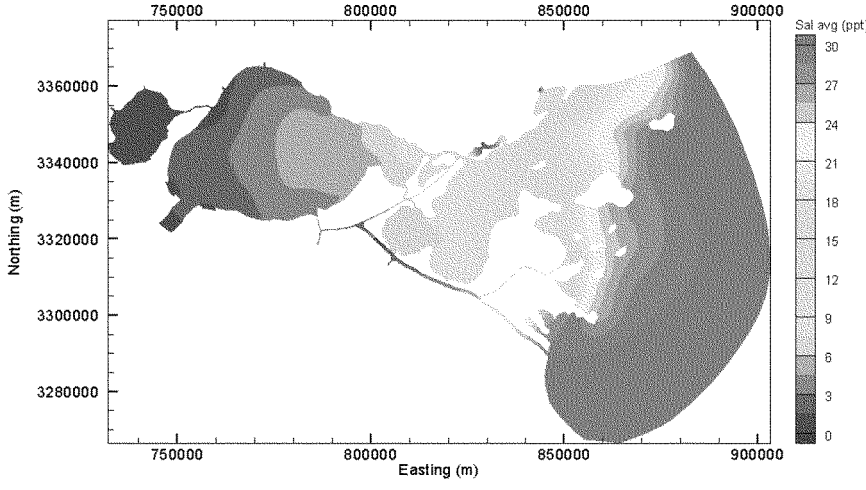


Figure 60. Model simulated depth-integrated standard deviation distribution for 45 days (case opt7; no wind)

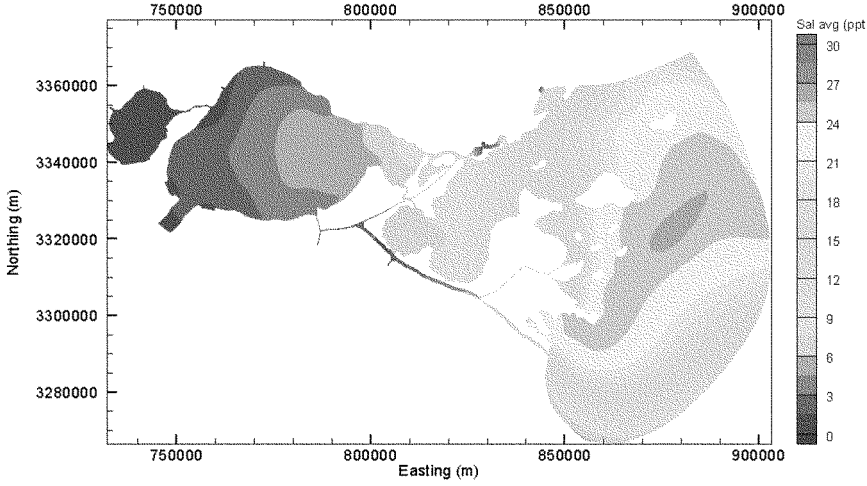


Figure 61. Model simulated depth-integrated standard deviation distribution for 45 days (case optf; no wind)

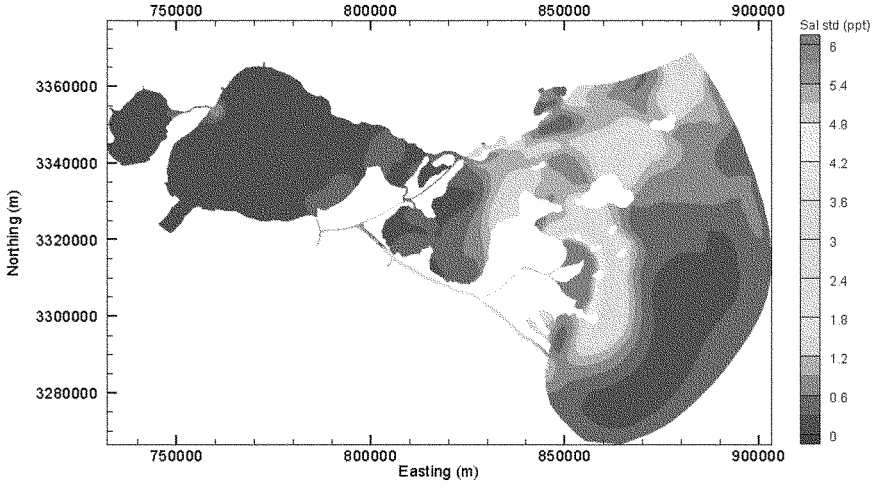


Figure 62. Model simulated depth-integrated standard deviation distribution for 45 days (case opt7; no wind).

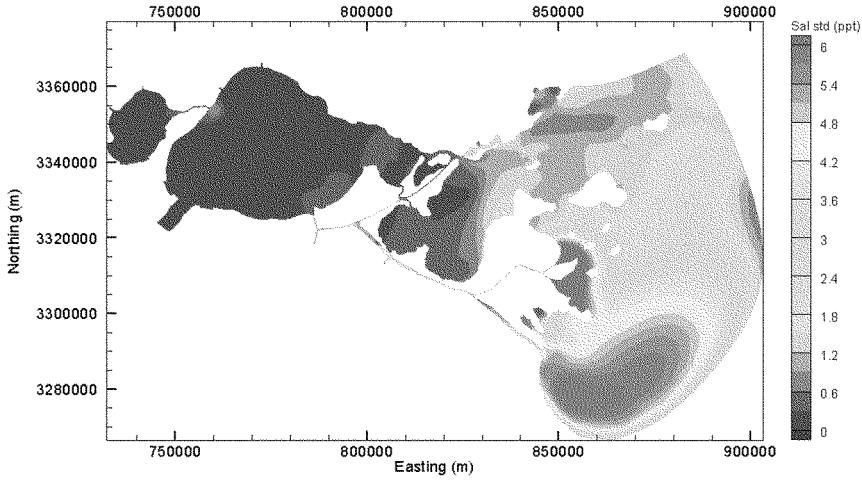


Figure 63. Model simulated depth-integrated standard deviation distribution for 45 days (case optf; no wind)

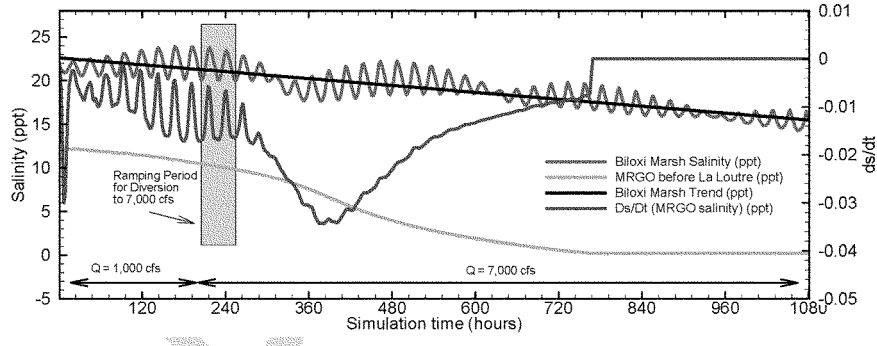


Figure 64. Instantaneous surface salinity for simulation optf, showing the salinity in the central Biloxi Marsh)red line) and within the MRGO channel upstream of Bayou La Loutre (green solid line).

APPENDIX A

REVIEW OF EXISTING DATA STUDIES

REVIEW OF EXISTING DATA STUDIES

A Reference Guide for Available Data in Eastern Louisiana and Mississippi Coastal Waters is the USACE guide of available data in Eastern Louisiana which provided indication of resources where data could be obtained, extent of records and parameters available at each station. The USACE document lists the following resources:

1. United States Geological Survey (USGS)

The USGS stations are located over a large portion of the study area both inland and in the coastal region. Most the stations, however, are within freshwater rivers rather than the tidal environment and do not measure salinity. Five sites are identified as measuring salinity. Of these, two have only 3 records, whilst the other three have extensive records. Data is recorded daily although the data is not necessarily complete. The data available from these stations includes station name, location (latitude/longitude), description of site, gage datum and water variables.

2. Louisiana Department of Natural Resources (LA DNR)

The data collected from the LA DNR database provides information describing the station name, location and water variables. These monitoring stations are distributed more densely over the study area but only provide data from 1996 to 2008. The data collection frequency varies from site to site from multiple times daily to monthly.

3. Environmental Protection Agency (EPA)

The Environmental Protection Agency database provides data for stations within each of the Parishes bordering Lake Pontchartrain, Lake Borgne and the Gulf. The extent of data varies from Parish to Parish in terms of both number of stations monitored and length of records. The data is split into two parts, legacy and modernized. The modernized data appears to be only available for a short period with monthly records. Information on the location, variable, number of samples and beginning and end dates of the samples are available from this database.

The legacy data is less well described in the document with only summaries for each Parish, showing the number of stations observing salinity and the total number of records over a period.

This suggests monthly recording of data at the sites. A few stations have data dating back to 1957. There are limited sites in St. Bernard Parish and Orleans Parish, but many in Plaquemines.

4. Louisiana Department of Environmental Quality (LA DEQ)

The Louisiana Department of Environmental Quality database has numerous water quality monitoring stations all over the study area and provides various data from 1963 to 2008. The data available to use for this model includes project number, assessment subsegment ID, site number, site name, latitude and longitude, variable name, number of samples and sample begin and end dates.

The majority of these sites have short data records and data appears to be collected monthly or less frequently.

5. Batelle Gulf Nutrient Data Management Platform (GNDMP)

The GNDMP data are mostly located in the Mississippi sound from Lake Borgne to Gulfport and east to the Pascagoula area. This database can be downloaded from their website and provides information such as the station ID, station name, location, variable, number of samples and the first and last dates of the samples taken, from 1965 to 1998.

6. Mississippi Data

The Mississippi data was sampled by the Mississippi Department of Environmental Quality. Most of the stations are located along the Mississippi coastline, in the Mississippi Sound with a few stations in the Sound and inland. There are few sites with long term data sets, and the frequency of samples on these longer sets appears to be monthly or less frequent.

7. Louisiana State Data Collection Draft Report (Moffat & Nichol Engineers)

This is a working draft by Moffat & Nichol Engineers (Baton Rouge) containing a data collection summary with information on salinity measurements for the study area. Section 2 of the report lists stations measuring salinity from DNR, USGS, NOAA, and Dauphin Island Sea Lab. It splits the data into hourly or less time steps and daily or longer time steps. A total of 120 stations are available with hourly time steps. The majority of these sites were also listed in the

USACE report as part of the LA DNR and USGS datasets, but not necessarily with the same time step or data intervals. The included stations recorded measurements in an hourly or 15-minute time steps. The gages measure salinity in parts per thousand and the period of available data varies for each location.

8. Other Data

A further 55 sites were identified in the daily or greater time step, and these were all listed as inactive stations with no data range. Some of these sites are the same as those in the USACE report.

DATA SOURCES SUPPLIED

1. Louisiana Department of Wildlife and Fisheries (LDWF)

Data from the Louisiana Department of Wildlife and Fisheries (LDWF) was received from the USACE as an ArcView shapefile with salinity data attached. This covered 59 stations across the Lake Pontchartrain, Lake Borgne and Biloxi Marsh area. The data is available as random sample dates (i.e. not true monthly or daily).

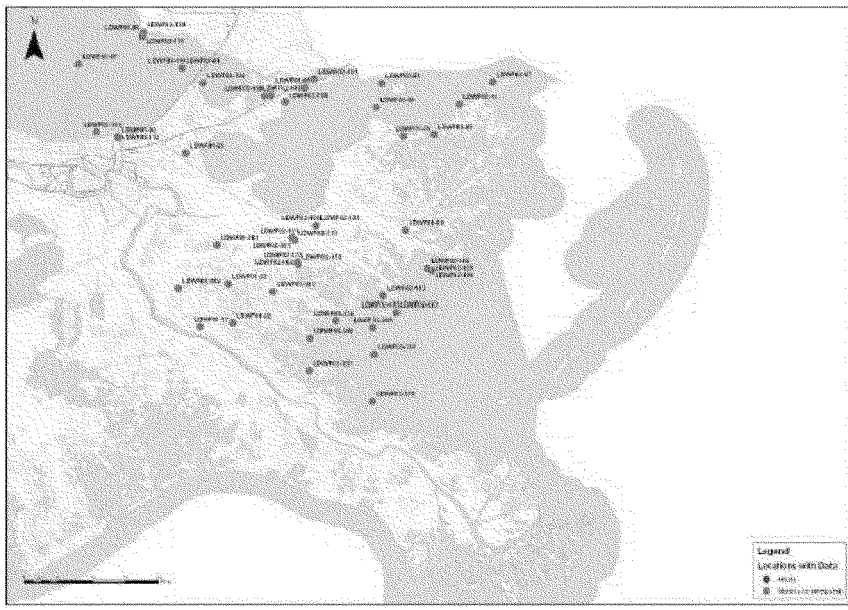


Figure 1.1 Louisiana Department of Wildlife and Fisheries sampling locations (RH memo dated 6-29-09).

2. *Mississippi Department of Marine Resources (MDMR)*

Data from the Mississippi Department of Marine Resources (MDMR) is available for 270 stations along the Mississippi coastline; however, only 147 stations have been selected as being potentially useful. The stations were selected based on the number of records available at the station (generally less than 50 readings). Data records are available from 1998 to 2008 with some gaps. The data is available as random sample dates (i.e. not true monthly or daily).

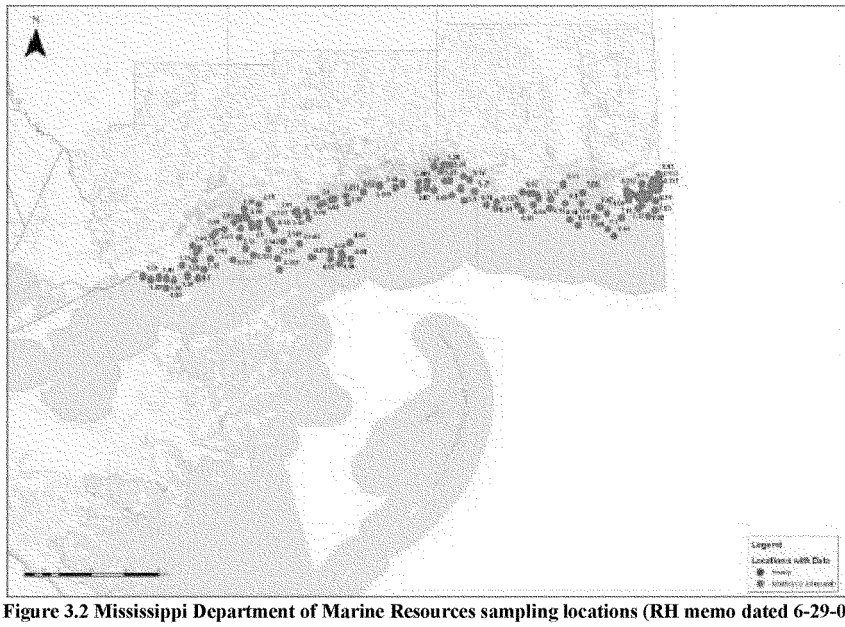


Figure 3.2 Mississippi Department of Marine Resources sampling locations (RH memo dated 6-29-09).

3. *Louisiana Department of Natural Resources (LA DNR).*

A geodatabase was supplied with data for some sites from the Louisiana Department of Natural Resources (LA DNR).

DATA EXTRACTED AS PART OF THIS INITIATIVE

1. USGS Stations

Three daily water quality data sets have been obtained from USGS stations. The locations of the stations are: Caernarvon Outfall Channel at Caernarvon, Mississippi Sound at Grand Pass, and Rigolettes at Hwy 90 near Slidell.

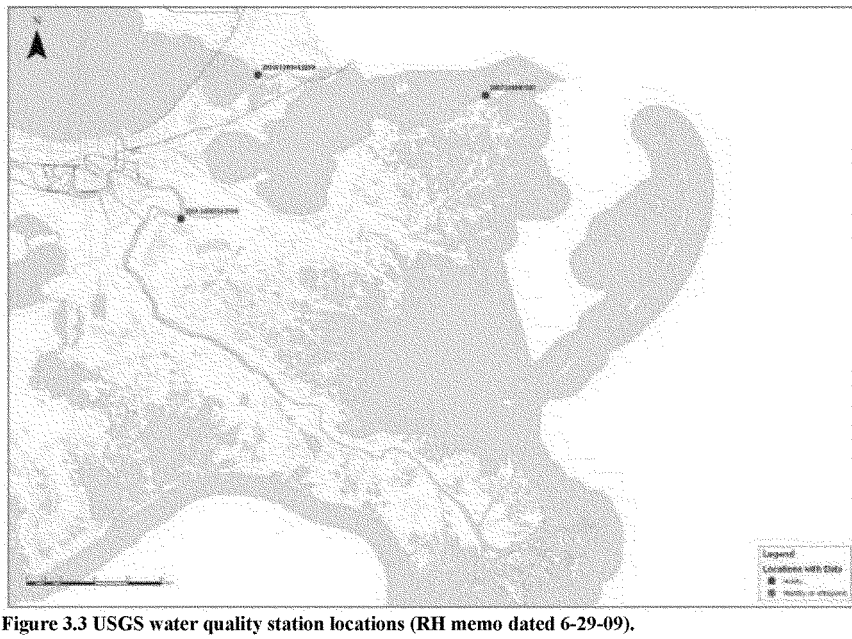


Figure 3.3 USGS water quality station locations (RH memo dated 6-29-09).

2. Coastwide Reference Monitoring System (CRMS)

Data from the Coastwide Reference Monitoring System (CRMS) sites encompass multiple ecological parameters for wetland ecosystem evaluation. The 24 most suitable stations are operated by Coastal Estuaries Services LLC. Data for the stations are available as hourly records with some gaps.

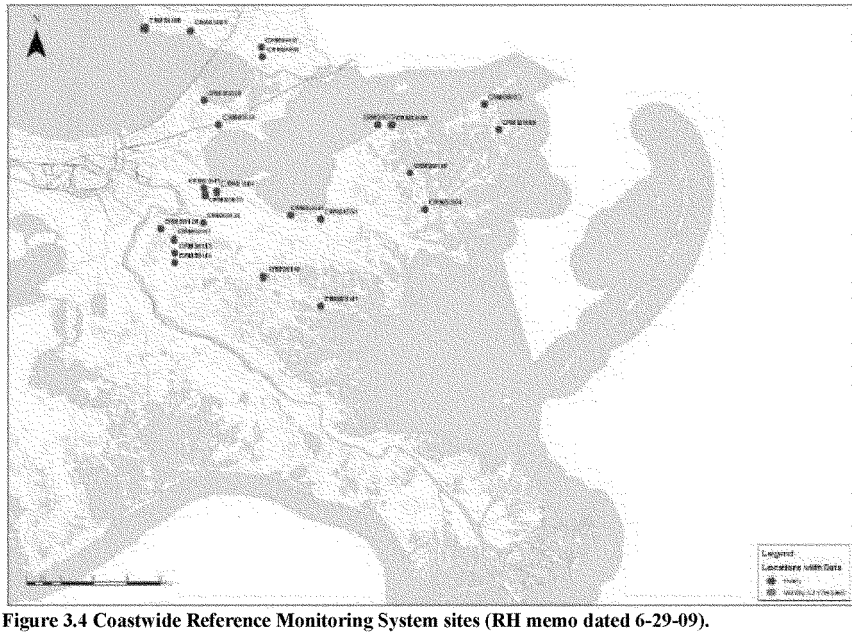


Figure 3.4 Coastwide Reference Monitoring System sites (RH memo dated 6-29-09).

3. *Louisiana Department of Natural Resources (LA DNR).*

Further examination on the location, lengths and quality of records determined that a further 44 stations from the DNR dataset were suitable for potential use in the analysis. These specific salinity stations were selected due to their location and the continuity of data available. The stations are located within an area to the northeast of the Mississippi in about a 40 mile radius of the MRGO.

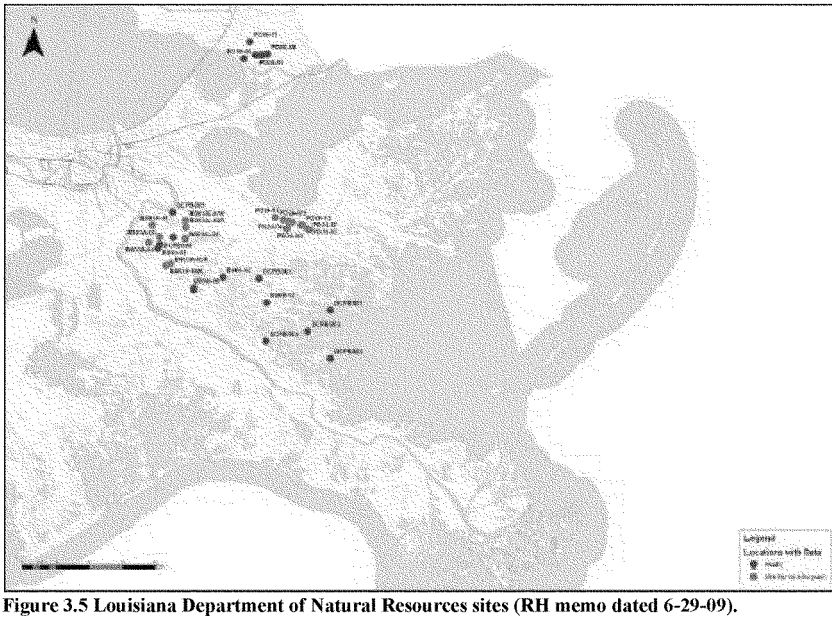


Figure 3.5 Louisiana Department of Natural Resources sites (RH memo dated 6-29-09).

4. Environmental Protection Agency's (EPA) STORET site

Data for the whole of Louisiana was downloaded from the Environmental Protection Agency's (EPA) STORET site. The data is ordered by Parish and only three Parishes have been considered. These are Orleans, St. Bernard and Plaquemines. These three Parishes have 135 sampling locations for salinity, some of which fall outside the area of interest. The data was generally collected in the 1970's and 1980's and has gaps so that it is not a consistent monthly data source.

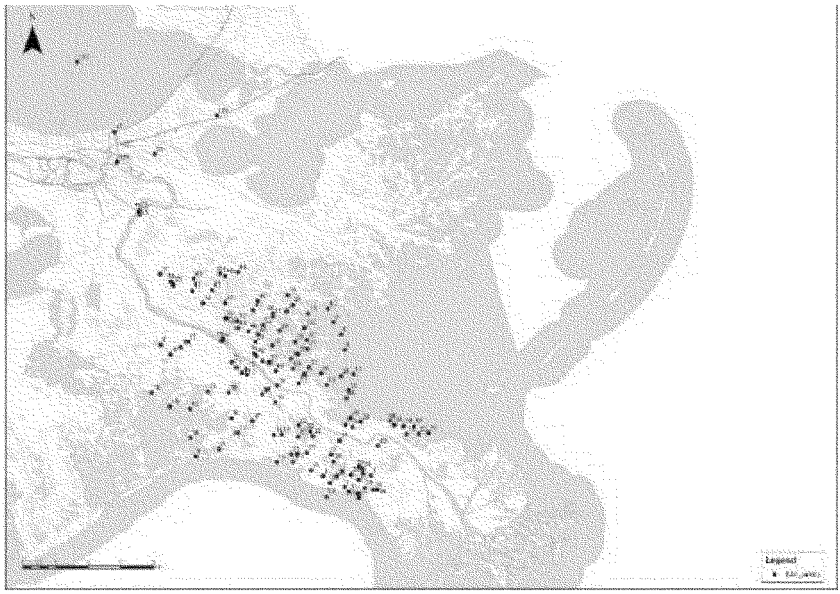


Figure 3.6 EPA STORET data sites (RH memo dated 6-29-09).

APPENDIX B

SEA LEVEL RISE
CENTRAL WETLANDS AND BILOXI MARSH

The topic of Sea Level Rise in southern Louisiana is pertinent and any modeling of salinity and levels within the Biloxi Marsh and the Central Wetlands areas needs to take into consideration the latest thoughts on this process.

Sea Level Rise in southern Louisiana is a combination of eustatic rise (due to global factors), general land settlement and other local factors which have an impact on sea level.

The USACE Circular EC 1165-2-211 Water Resource Policies and Authorities, Incorporating Sea-Level Change Considerations in Civil Works Programs, July 2009, proposes a current eustatic sea level rise of 1.7mm/yr ±0.5mm/yr. The work flow for determining SLR refers to the Gulf of Mexico and Louisiana particularly as being an area that may have a regional sea level rise value different from the regional trend.

To investigate the values of sea level rise in this area two studies have been considered. These are:

- The work carried out for the LACPR technical report in 2007
- Recent analysis of two long term gage data sets by the USACE, New Orleans District.

LACPR

For the LACPR technical report, work was carried out on SLR by Kevin Knuuti of ERDC. His report is attached to the end of this note.

This report divided the coasts of Louisiana into three sections, the Chenier Plain, the Delta Plain and the Pontchartrain Basin. The area of interest for this project falls within both areas 6 and 7 in his figure A.1, which are the St Bernard Delta Plain and the Pontchartrain Basin. These areas overlap in Lake Borgne which makes the selection of specific numbers from the report difficult as area 6 is within the results for the Delta Plain and area 7 in the Pontchartrain Basin, with each of the areas having significantly different rates of relative sea level rise.

The following table provides the range of values suggested for the two different areas:

	Relative Sea-Level Rise Values between 2010 and 2060 (meters/ft)	
Basis for Value	Delta Plain	Pontchartrain Basin
Historic Rate	0.4/1.3'	0.2/0.7'
Future Scenario 1	0.6/2.0'	0.4/1.3'
Future Scenario 2	1.0/3.3'	0.8/2.6'

These rates suggest non eustatic changes (subsidence and other local factors) of around 6mm/year in Delta and 2mm/year in the Pontchartrain Basin (using 2mm/yr for regional eustatic rise). This is a significant change between the two overlapping regions.

This analysis used the historic rates for the low rate, the NRC Curve I for the Future Scenario 1 (or mid range) and the NRC Curve III for the future scenario 2 (or high range).

Comments on the LACPR technical report

Firstly the rates were developed as global numbers for large areas of the Louisiana coastline rather than for the more specific areas being considered at this time. There is no evidence within the report as to which (if any) gages were used within the assessment or whether these results were averaged over spatial areas.

Gage Data Analysis

Data from two gages, Shell Beach and West End, has been analyzed and the results are presented.

Shell Beach

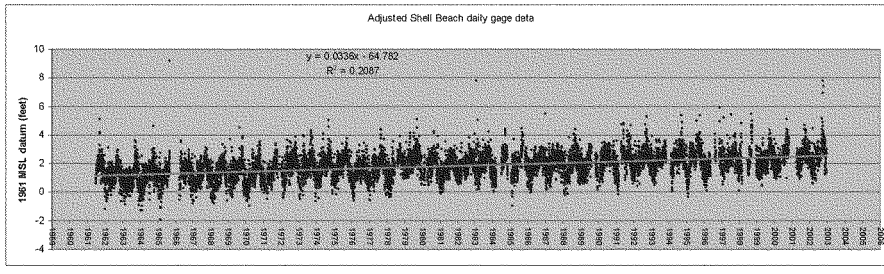
This gage was within Shell Beach on the bayou running through the community. Records were available from 1961 to 2002 when the gage was discontinued. Daily data for this site was readily available although it is thought that hourly data may also be available.

The location of the site is shown in the following figure, together with the location of the current NOAA gage which sits within Lake Borgne.

The analysis generally follows the methodology outlined in the USACE Circular EC1165-2-211 but is based on trends in the daily values rather than MSL values calculated from hourly values. There are 42

years of records which places this within the acceptable range for a single site. The data set is 82% complete over that period.

The datum of the gage appears to have changed in 1978 and so data after July 1978 has been increased by 1' to accommodate this change. The time series from the analysis is shown in the graph below.



There is an apparent trend in the data across the whole period of around 10.2mm/yr. This value include local settlement, local water level changes and global eustatic change i.e. this is the relative sea level rise (RSLR) at this point.

The analysis has then projected this historic rise from 2011 to 2061 (50 years initially to be comparable with the LACPR values), together with using the NRC sea level curves I and III with a eustatic component of 1.7mm/yr to provide intermediate and high estimates of sea level rise into the future. Over this 50 year period the increases are:

- 0.5m/1.7ft for the Historic/low estimate
- 0.6m/2.1ft for the Intermediate estimate
- 1.0m/3.3ft for the High estimate.

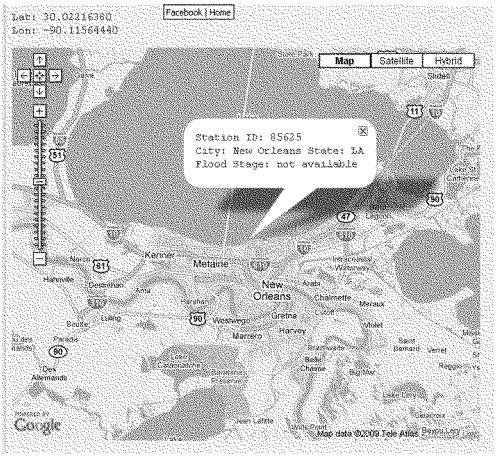
Comments on the Shell Beach Analysis

- The NOAA method for establishing MSL trends uses either annual or monthly MSL's based on analyzing hourly data. The Shell Beach analysis has used trends associated with a single daily value taken at the same time each day. With the length of data available (nearly 13,000 records) it is unlikely that changing to monthly MSL values based on hourly data will change the overall trend within the dataset, but it would help to establish realistic error bands on the trend.
- There is some evidence that subsidence rates may be peaking in the 1970's (possibly as a result of oil and gas extraction within the area). There is a possible suggestion of this within the Shell Beach gage data as the trend before 1978 and after 1978 show a reduction (11.5mm/yr before and 8mm/yr afterwards). However the length of record (≈ 20 years) is realistically too short to draw reasonable conclusions on trends and the USACE Circular advises the use of extreme caution with datasets less than 40 years.

- The use of the global 1.7mm/yr eustatic sea level rise for this region may be incorrect. Analysis of the stable land mass along the western side of Florida has shown a local sea level rise in excess of the 1.7mm/yr (in the range of 2 to 2.4mm/yr) and so the use of a higher number in Louisiana may be appropriate in establishing the intermediate and high values using the NRC curves. However the adoption of say 2.3mm/yr only reduces the 2061 value by 0.15' over the 50 years, and the adoption of these numbers would need further investigation.

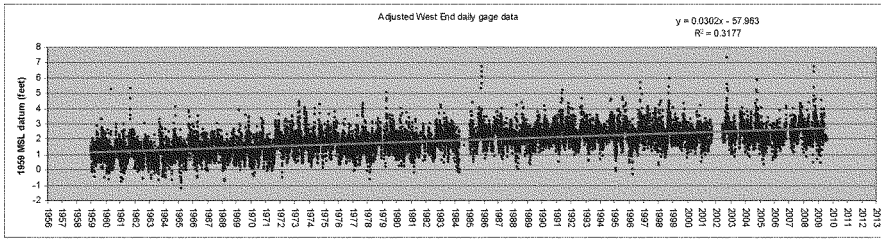
West End

The gage is located in the marina on the lake front in West End. Records were available from 1937 to 2008, but however before 1959 the records were intermittent and not usable for analysis. Daily data for this site was available. The location of the site is shown in the following figure.



The analysis generally follows the methodology outlined in the USACE Circular EC1165-2-211 but is based on trends in the daily values rather than MSL values calculated from hourly values. There are 50 years of records which places this within the acceptable range for a single site. The data set is 91% complete over that period.

The datum of the gage appears to have changed at several points in the period and the data was adjusted so that it all referred to the same datum used in 1959. This resulted in a change of up to +0.81'. The time series from the analysis is shown in the graph below.



There is an apparent trend in the data across the whole period of around 9.2mm/yr. This value includes local settlement, local water level changes and global eustatic change i.e. this is the relative sea level rise (RSLR) at this point.

The analysis has then projected this historic rise from 2011 to 2061 (50 years initially to be comparable with the LACPR values), together with using the NRC sea level curves I and III with a eustatic component of 1.7mm/yr to provide intermediate and high estimates of sea level rise into the future. Over this 50 year period the increases are:

- 0.5m/1.5ft for the Historic/low estimate
- 0.6m/2.1ft for the Intermediate estimate
- 1.0m/3.3ft for the High estimate.

The comments on the West End gage are the same as those for Shell Beach

Comment on Analysis

Both of the two gages resulted in very similar total values of SLR over 50 years which are comparable with the Delta Plain numbers from LACPR

Source	LACPR (Delta) 2010-2060	Shell Beach 2011-2061	West End 2011-2061
Low (Historic)	0.4m/1.3'	0.5m/1.7'	0.5m/1.5'
Intermediate	0.6m/2.0'	0.6m/2.1'	0.6m/2.1'
High	1.0m/3.3'	1.0m/3.3'	1.0m/3.3'

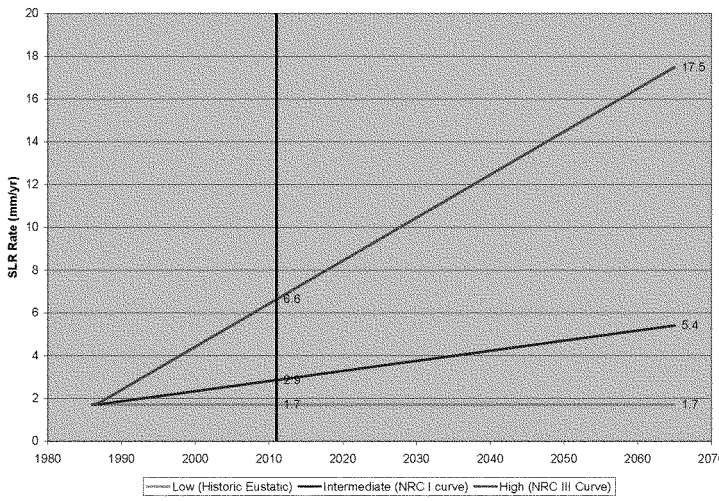
(Note variations in conversions due to rounding errors)

There is no justification at this stage for adopting lower rates of local water level change due to potential slackening of subsidence. The length of record available for analysis is insufficient to draw conclusion and significant trends, and the error in the trend increases with a reduction in record length.

There is also no justification or data to adjust the rate of eustatic SLR used in establishing the higher rates of rise in this area. Further studies may challenge the 1.7mm/yr eustatic rise for this area, but a small change in this value will have little impact on the values in 50 years.

Consideration should be given to the error in the trend. The USACE circular 1165-2-211 suggests an error band of around ±0.5mm/yr for a data set of 40 years and around ±0.4mm/yr for 50 years of data. These would equate to ±25mm in 50 years for Shell Beach and ±20mm in 50 years for West End (i.e. around 1' additional) which is insignificant in comparison with the total increases (<5% on the low case).

One further comment should be made with regard to the accelerated growth curves. These curves start from 1986 with an estimated eustatic rise of 1.7mm/yr and then increase this rate over time. By 2011, the the intermediate rate is 2.9mm/yr and the high rate 6.6mm/yr. This is illustrated in the graph below - this shows the rates of annual eustatic sea level rise in the three scenarios from 1986 to 2065. The thick line represents 2011.



There is no evidence to suggest that either this increased rate has or has not occurred over the past few years, and until further analysis is undertaken over a reasonable time period the methodology used to establish the growth curves should be taken as providing an indication of how sea level rise may accelerate over time.

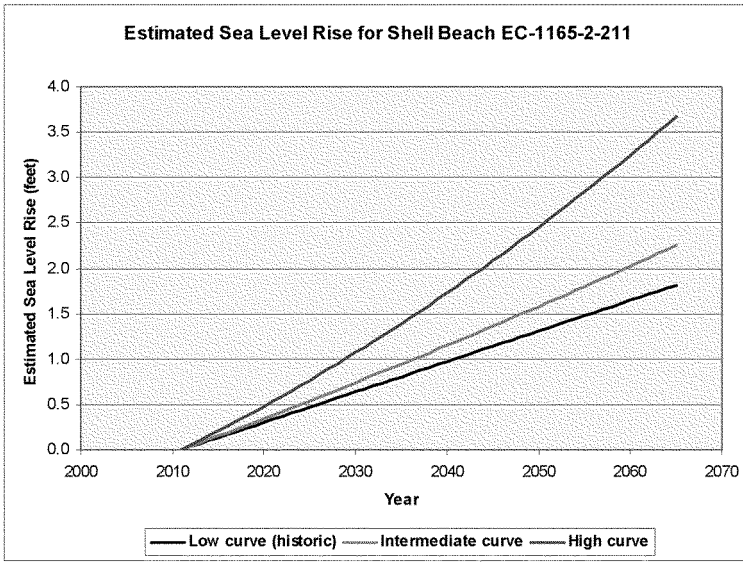
Conclusions

As there is little to choose between the three data sets we would propose using the results from Shell Beach as being the site nearest to the area of interest, and which follows a defined methodology in line with EC-11652-211.

Considering a longer project period than 50 years i.e. from 2011 to 2065 gives the following figures:

Low rate (based on historic trend of 10.24mm/yr)	1.8ft (0.55m)
Med rate (based on NRC Curve I and 1.7mm/yr baseline eustatic)	2.2ft (0.69m)
High rate (based on NRC Curve III and 1.7mm/yr baseline eustatic)	3.7ft (1.12m)

A plot of the sea level rise over the period is shown below.



LACPR Extract - LACPR Final Report Vol II, Hydraulics and Hydrology Appendix, Annex A, June 2009

Author: Kevin Knuuti, ERDC-CHL

Variations and trends in the relationship between local mean sea level (LMSL) and land elevations are important considerations in the planning and design of structures in areas that are currently tidally influenced or that could become tidally influenced in the future. In areas where the LMSL is rising relative to land elevation, the relative sea-level rise (RSLR) is often divided into a global increase in water mass (eustatic rise), a rise in local water level due to density changes in the water (steric rise), and a drop in local land elevation (subsidence). Throughout the 20th century, the global average SLR due to eustatic and steric effects has been approximately 1.8 mm/year (Meehl, 2007). Examination of tide gauges on geologically stable platforms in the northern Gulf of Mexico indicates a regional average SLR of approximately 1.8-2.0 mm/year during that same time period. Throughout coastal Louisiana, rates of subsidence exceed the rate of SLR by varying amounts. The resulting rates of RSLR throughout coastal Louisiana are significantly higher than the global average and regional average SLR rates.

Though the causes of climate change and future projections of climate change are somewhat controversial, it is well accepted that RSL has been rising across coastal Louisiana and will continue to do so in the future. Because of the difficulty associated with quantifying the rates of SLR that will occur in different areas of Louisiana, a sensitivity analysis is performed to determine how different project designs would respond to a range of SLR rates. For this sensitivity analysis, an extrapolation of the historic rates of RSLR is used as the low level for future sea-level rise and accelerated rates of rise based on National Research Council (NRC, 1987) and Intergovernmental Panel on Climate Change(IPCC) (Meehl, 2007) projections are used for higher rates of rise. Historic rates of RSLR vary across Louisiana and also vary depending on the methods used to estimate those rates. The two most commonly cited methods of estimating historic RSLR rates in Louisiana are radiometric dating of organic deposits (mostly peat) and analysis of long-term tide-gauge data. Because the RSLR rates determined from tide gauge data are based on more recent (20th century) data and because these rates are generally greater than the rates determined from radiometric dating, tide gauge RSLR rates are used for the low rate of RSLR in the sensitivity analysis.

Both the National Ocean Service and the U.S. Army Corps of Engineers have maintained long-term water-level gauges that can be used to calculate historic RSLR rates across coastal Louisiana. Because of the distance between these gauges, and the engineering difficulty associated with using numerous historic RSLR rates for analysis, coastal Louisiana was divided into different geomorphic regions for RSLR analysis. Within each geomorphic region, subsidence rates were thought to be relatively uniform due to relatively homogeneous geologic conditions. The geomorphic regions considered were based on the historic shifting of the Mississippi River's main stem and the associated delta lobes the river created, as shown in figure A.1 and as described by Penland (1990). Based on similarities in historic RSLR rates, alternative screening further grouped the regions into three primary geomorphic regions: the Chenier Plain (region 1 in figure A.1), the Delta Plain (regions 2-6 in figure A.1), and the Pontchartrain Basin (region 7 in figure A.1).

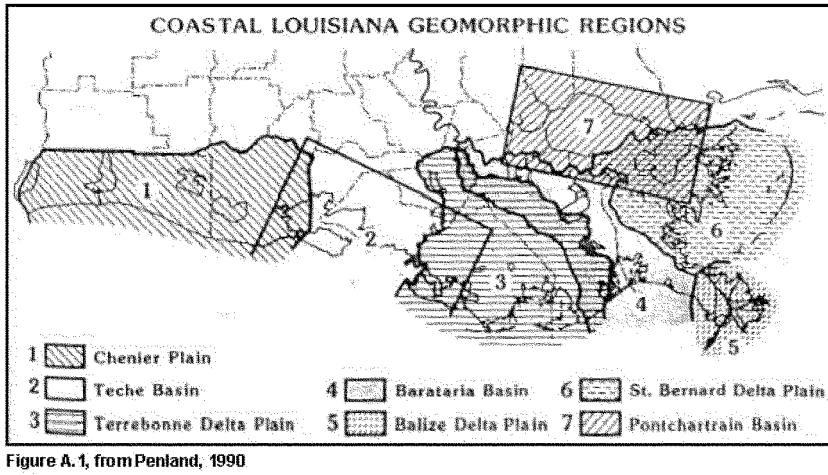


Figure A.1, from Penland, 1990

Future rates of RSLR were determined by considering both the 1987 NRC global mean SLR projections and the 2007 IPCC global mean SLR projections, along with estimates for local and regional subsidence rates across coastal Louisiana. While the 2007 IPCC projections are considered the most current and rigorous effort to estimate future global mean SLR rates there has been some criticism that these projections do not adequately consider the potential for extreme scenarios such as massive ice loss and melting from Antarctica. The 2007 IPCC mean central value estimate for global mean SLR by 2100 is 0.343 meters and the upper limit value is 0.59 meters. Due to the uncertainties associated with the IPCC estimate methods, a conservative value of 0.5 meters of rise by 2100 is used for rigorous sensitivity analysis, with the acceleration.

$$E(t_2) - E(t_1) = 0.0012(t_2 - t_1) + b(t_2^2 - t_1^2)$$

(see Knuuti, 2002, for description of variables and derivation of equation).

To account for possible extreme scenarios of global mean SLR and the associated RSLR across Louisiana, the sensitivity analysis also considered the "Curve III" value from the 1987 NRC report, which estimates a global mean SLR of 1.5 meters by 2100.

Estimates of local and regional subsidence rates were calculated by subtracting the regional historic SLR rate (2.0 mm/year) from the local and regional RSLR rates described earlier. These subsidence rates were combined with the future projections described in the previous two paragraphs to determine local and regional projections for future rates of RSLR. Table A.1 summarizes the RSLR values developed for the sensitivity analysis scenarios.

Table A.1: Relative Sea-Level Rise Values, 50-year project life

	Relative Sea-Level Rise Values between 2010 and 2060 (meters)		
Basis for value	Chenier Plain	Delta Plain	Pontchartrain Basin
Historic rate	0.2	0.4	0.2
Future scenario 1	0.4	0.6	0.4
Future scenario 2	0.8	1.0	0.8

References:

National Research Council (NRC), 1987. Responding to Changes in Sea Level: Engineering Implications.

Corps of Engineers Policy, as described in ER 1105-2-100 (dated 22 April 2000), Knuuti, K. (2002).

"Planning for Sea-Level Rise: U.S. Army Corps of Engineers Policy" in Solutions to Coastal Disasters '02. ASCE, Alexandria, VA.

Meehl, G. (Intergovernmental Panel on Climate Change), 2007. The Scientific Basis.

APPENDIX C

DESCRIPTION OF THE UNO MASS BALANCE MODEL

DESCRIPTION OF THE UNO MASS BALANCE MODEL

The UNO Mass Balance Model for hydrology, hydraulic, salinity and water quality that was applied in this study was adapted from the model developed by McCorquodale et al. (2007b).

The hydrodynamic module of the 1-D model uses a similar link-cell structure and connectivity matrix to that used in the EPA EXTRAN model (the hydrodynamic part of the U.S. EPA Storm Water Management Model (SWMM) 5.0) for urban hydraulics. The main difference is that the UNO model considers the effect of salinity on the pressure gradient. The procedures in the EPA WASP model were adapted for the mass balance modeling of salinity, suspended solids and nutrients (http://www.epa.gov/athens/wwqtsc/WASP.pdf).

The study area is divided into storage elements (cells) and conveyance channels (links) between the cells. The stage in each cell is computed by the continuity equation (Eq. 1). The advective flow in the model is determined by the differential pressure gradient between the cells subtending the connecting links (Eq. 2). Wetland areas are incorporated into the model by assigning a hydraulically connected area (drainage area to each cell). The atmospheric open water area and the runoff contribution from the adjacent wetlands are also considered (Eq. 1).

$$\frac{d\eta_j}{dt} = n_j' = \left(\frac{\sum Q_{ji,trib,div} + P_j - ET_j}{As_j} \right) + \frac{Run_j}{As_j} \qquad \text{(Eq. 1)}$$

$$Q_i = A_i \left\{ \frac{2g\left|(\eta_j + \frac{d_i S_j}{1000}) - (\eta_{j+1} + \frac{d_i S_{j+1}}{1000})\right|}{\left(\sum k_{im} + 2gn_i^{\,2} \frac{L_i}{R_j^{\frac{2}{3}}} \right)} \right\}^{\frac{1}{2}} sign[(\eta_j + \frac{d_i S_j}{1000}) - (\eta_{j+1} + \frac{d_i S_{j+1}}{1000})]$$

(Eq. 2)

$$Run_j = A_{dj} \{P_j - k_{ow} \times ET_j - (1 - k_{ow}) k_{crop} \times ET_j\} \geq 0 \qquad \text{(Eq. 3)}$$

where j = cell reference number; i = link reference number; η_j = stage in each cell; $Q_{ji,trib,div}$ = inflow to each storage cell (j) from links (i) and/or tributaries (trib) and/or diversions (div); P_j =

precipitation rate on each cell; d_i = water depth in link (i); ET_j = evapotranspiration rate on each cell; As_j = surface area of each storage cell; Run_j = runoff contribution for each cell; A_i = cross-sectional area of each link; k_{im} = eddy loss coefficients in each link (internal energy losses due to generation of turbulence); n_i = Manning's roughness coefficient for each link; L_i = length of each link; R_i = hydraulic radius of each link; the function *sign* assigns a negative or positive value to 1 depending on the value in the brackets; A_{dj} = hydraulically connected area for each cell; k_{ow}= fraction of open water in A_{dj}; and k_{crop} = crop factor (0.1 to 1).

The mass balance equations for salinity and suspended solids are given in Eqs. 4 and 5, respectively.

$$\frac{dCS_j}{dt} + \frac{CS_j \eta_j'}{y_j} = \frac{\sum CS_{i,trib} Q_{i,trib}}{y_j As_j} - k_{dis}\left(\frac{A_i}{L_i}\right)\left(\frac{CS_j - CS_{j,nb}}{y_j As_j}\right) \qquad \text{(Eq. 4)}$$

$$\frac{dCSS_j}{dt} + \frac{CSS_j \eta_j'}{y_j} = \frac{\sum CSS_{i,trib,div} Q_{i,trib,div}}{y_j A_j} - \frac{k_{set} Vs CSS_j}{y_j} + \frac{k_{rs} k_{rsc} d_{ref} Vw^2 - k_{ls} CSS_j y_j}{2 y_j^2 T_{res}} - k_{dis}\left(\frac{A_i}{L_i}\right)\left(\frac{CSS_j - CSS_{j,nb}}{y_j As_j}\right) + G_s \qquad \text{(Eq. 5)}$$

where CS_j = salinity concentration in each cell; $CS_{i,trib}$ = salinity concentration from each link and tributary; y_j = depth in each storage cell; k_{dis} = dispersion coefficient; A_i = area of each link; L_i = length of each link; $CS_{j,nb}$ = salinity concentration in neighboring cells; η_j' = rate of rise of stage in each cell; CSS_j = suspended sediment concentration in each cell; $CSS_{i,trib,div}$ = suspended sediment concentration from each link, tributary and diversion; k_{set} =settling velocity calibration factor; Vs = settling velocity; k_{rs} = wind resuspension coefficient; k_{rsc} = wind resuspension calibration factor; d_{ref} = reference depth; Vw = wind speed; k_{ls} = suspended sediments boundary calibration factor; T_{res} = residence time; $CSS_{j,nb}$ = suspended sediment concentration in neighboring cells; and G_s = area based internal source generation rate such as shell fish production with units of mass per unit volume per unit time. The sedimentation general parameters were: the reference depth (d_{ref}) = 4.0 m; settling velocity (Vs) = 8 m/d (Miller et al.,

2005); and the area based internal source generation rate (G_s) is about 30 g/m^3/year (USACE, 1984).

All numerical integrations were made using the Euler method with a time step on the order of 60 seconds. A hybrid upwinding and central differencing numerical integration solution scheme was used to solve the advective transport of salinity, suspended sediment and chemical constituents. A central difference/upwinding calibration factor was used to determine the weighting between each solution method where 1 = pure upwinding and 0.5 = central differencing. A pure central difference scheme produced oscillations that were unrealistic while pure upwinding resulted in so much numerical dispersion that the model became insensitive to realistic eddy dispersivities. Based on a sensitivity study it was found that a weighting factor of 0.5009 introduced sufficient upwinding to prevent instability but still retain most of the second order accuracy of the central differencing method without introducing excessive numerical dispersion. Since the weighting factor is very close to 0.5, the model can be considered to be a central difference scheme and as such it is second order accurate. The control volume approach ensures conservation of mass, such that any quantity leaving through a face of one cell is the same as that entering the adjoining cell. The scheme was applied to internal links and seaward open boundaries but not to the inflow boundaries. The diffusive fluxes were computed using central differencing.

APPENDIX D

UNO MASS BALANCE MODEL GEOMETRY DETAILS

The constants k_m, k_{en} and k_{ex} represent the minor loss coefficient due to structures, the entrance loss coefficient and the exit loss coefficient in each link respectively. The constant E represents a dispersion factor.

This appendix includes a table of cell input attributes and the calibration factors. Graphic representations of the cell-link for the alternatives are included.

Table of Cell Attributes

Cell No.	Cell Name	Surface Area (As_j in km^2)	Depth (m)	Hydraulically Connected Area (A_{dj} in km^2)	Percent Open Water	Initial Salinity (CS_j in ppt)	Fetch (km)
1	LB N	325	2.8	50	15	0	18
2	LB S	340	2.7	50	15	0	18
3	LP E	200	2.6	150	15	0	14
4	LP SE	350	3.8	10	10	0	19
5	LP NE	350	4	15	20	0	19
6	LP NW	350	3.5	15	20	0	19
7	LM	350	3.5	25	20	0	19
8	MRGO BM	55	6.5	50	20	0	1
9	MRGO N	50	6.5	50	20	0	1
10	LP SW	350	3.2	2.5	20	0	19
11	Caern E	190	1	520	15	0	14
12	Caern BS	525	1.7	195	50	0	23
13	BM N	85	1.1	55	45	0	9
14	B. St. L	575	3.5	5	50	0	24
15	BS nr MR	640	2	50	15	0	25
16	SE of BM	1120	1.5	50	15	0	33
17	NE of BM	1340	2	50	15	0	37
18	Biloxi R	700	2.6	2.5	75	0	26
19	Off Bara	2500	8	520	40	0	50
20	Off P a Loutre	3015	15	50	15	0	55
21	Off HOP E	2880	20	550	20	0	54
22	Off Pasc R	3850	20	50	15	0	62
23	Off Delta S	3075	100	50	15	0	55
24	Deep Gulf	2900	100	50	15	0	54
25	Off Mobile R	2990	100	50	15	0	55
26	Mobile R	1030	4	50	15	0	32
27	Pascag R	800	3.1	50	25	0	28
28	MRGO S	500	4.2	10	50	0	22
29	Off Bara	3000	100	1	50	0	55
30	Above HOP E	400	1	500	20	0	20
31	MR Delta W	1200	5	1220	20	0	35
32	Deep Gulf	3000	50	1	50	0	55
33	E MR Delta	420	1	400	10	0	20
34	Bara B	68.9	3.4	140.9	33	0	8
35	Bara B	94.9	1.3	16.3	85	0	10
36	Bara B	102.1	1.9	18.4	85	0	10
37	Bara B	46.7	1.4	3	94	0	7

Cell No.	Cell Name	Surface Area (As_j in km^2)	Depth (m)	Hydraulically Connected Area (A_{dj} in km^2)	Percent Open Water	Initial Salinity (CS_j in ppt)	Fetch (km)
38	BARA Est	118.1	1	16.7	88	0	5
39	BARA Est	222.7	1.4	144	20	0	7
40	BARA Est	174.8	0.8	91.8	66	0	6
41	BARA Est	133.2	1.6	43	76	0	6
42	BARA Est	30	1.2	18.8	61	0	5
43	BARA Est	65.8	0.9	85.1	44	0	8
44	BARA Est	86.2	1.7	38.7	69	0	9
45	BARA Est	57.6	1.5	4.4	93	0	8
46	BARA Est	88.4	1.5	42.8	67	0	9
47	BARA Est	39.5	0.8	101.4	28	0	6
48	BARA Est	211.1	1.4	254.3	45	0	8
49	BARA Est	11.7	2	9.3	56	0	3
50	BARA Est	15.7	1.1	10.7	60	0	4
51	BARA Est	40.9	1.2	76.1	35	0	6
52	BARA Est	10.25	1.3	13	16	0	3
53	BARA Est	16	1.3	23.2	41	0	4
54	BARA Est	6.8	2	65.7	9	0	3
55	BARA Est	65.6	1.8	91.7	42	0	8
56	BARA Est	37.1	1.1	63.1	37	0	6
57	BARA Est	52.6	0.7	85.7	38	0	7
58	BARA Est	120	1.8	160	10	0	8
59	BARA Est	68.5	1.8	56.4	10	0	8
60	BARA Est	10.31	4	27.5	10	0	3
61	BARA Est	11.2	4	101	10	0	3
62	BARA Est	7.3	0.5	128	10	0	3
63	BARA Est	10.8	0.7	246.6	10	0	3
64	BARA Est	17.6	0.7	342.3	10	0	4
65	BARA Est	5.1	4	46.2	10	0	2
66	BARA Est	9.4	4	84.5	10	0	3
67	BARA Est	71.7	2	1212	10	0	8
68	BARA Est	7.9	1.3	43.7	10	0	3
69	BARA Est	7.8	4	70	10	0	3
70	Terreb Est	1400	1	500	20.9	0	30
71	Terreb Est	200	2	4220	10.9	0	7
72	BARA Est	1200	6	1220	1	0	20
73	BM LB	124	1	373	15	0	2
74	BM BS	240	1	260	40	0	5
75	CWA	20	1.5	175	15	0	4

Table of Cell Attributes

Cell No.	Cell Name	Surface Area (As_j in km^2)	Depth (m)	Hydraulically Connected Area (A_{dj} in km^2)	Percent Open Water	Initial Salinity (CS_j in ppt)	Fetch (km)
76	B St L	50	2.5	20	25	0	7
77	Biloxi R	50	2	50	25	0	7
78	BM E	110	1.5	160	50	0	5
79	INTER Caern	250	1	300	30	0	5

Table of Cell Attributes

Calibration Values for Historic

Link No.	From Cell	To Cell	Depth (m)	Length (m)	Width (m)	Manning's n	K_m	K_{en}	K_{ex}	E
1	1	14	5.5	3000	15000	0.016	0.007	0.25	1	9
2	3	1	10.5	10500	985	0.024	0.075	0.5	2	2500
3	2	1	4.0	15000	15000	0.021	0.007	0.1	1	50
4	3	2	8	7850	360	0.025	0.075	0.5	2	30
5	8	28	6.5	60420	320	0.023	0	0.5	1	100
6	9	8	6.5	20000	300	0.023	0	0.5	1	100
7	9	2	4.05	12000	150	0.03	0	0.5	2	55
8	4	9	8.5	15000	150	0.025	0.1	0.5	19	350
9	5	3	3	20000	20000	0.023	0	0.025	0.25	155
10	5	4	4.3	40000	40000	0.02	0	0.02	0.25	195
11	6	5	3.9	40000	20000	0.02	0	0.5	1	46
12	7	6	8.1	8800	395	0.024	0	0.5	1	200
13	8	2	3	2000	50	0.03	0	0.5	1	2
14	10	6	3.7	20000	20000	0.025	0	0.02	0.25	56
15	10	4	3.9	40009	20000	0.025	0	0.02	0.25	56
16	1	13	2.1	14500	1000	0.04	0	0.02	1.25	651
17	14	18	5	10000	20000	0.015	0	0.02	0.25	56
18	18	27	5	15000	20000	0.02	0	0.02	0.25	26
19	27	26	5	20000	20000	0.032	0	0.02	0.25	16
20	26	25	5	5000	4000	0.032	0	0.02	0.25	116
21	2	73	1	5000	650	0.075	0	0.02	0.25	271
22	14	13	1	5000	400	0.08	0	0.02	0.25	201
23	14	17	6	3000	7500	0.02	0	0.08	0.25	150
24	78	17	2	3500	5000	0.058	0	0.12	0.25	200
25	17	22	11.	10000	10000	0.018	0	0.02	0.25	201
26	27	22	5	5000	10000	0.023	0	0.02	0.25	16
27	22	25	19	30000	55000	0.02	0	0.02	0.25	151
28	74	16	1	4000	500	0.045	0	0.038	0.25	20
29	16	17	4.6	20000	15000	0.022	0	0.02	0.25	251
30	16	21	11.5	3000	18000	0.02	0	0.02	0.25	101
31	21	22	8	20000	15000	0.02	0	0.02	0.25	251
32	21	24	21	30000	60000	0.02	0	0.02	0.25	501
33	24	25	11	30000	20000	0.02	0	0.02	0.25	501
34	28	20	5	20000	4000	0.02	0	0.02	0.25	16
35	28	16	5	20000	10000	0.02	0	0.02	0.25	500
36	15	28	5	20000	10000	0.018	0	0.02	0.25	500
37	28	74	2	20000	10000	0.08	0	0.02	0.25	200
38	20	21	8	20000	15000	0.018	0	0.02	0.25	506
39	20	23	21	30000	50000	0.018	0	0.02	0.25	501
40	23	24	15	30000	20000	0.02	0	0.02	0.25	501

Calibration Values for Historic

Link No.	From Cell	To Cell	Depth (m)	Length (m)	Width (m)	Manning's n	K_m	K_{en}	K_{ex}	E
41	11	79	1	10000	6400	0.04	0	0.02	0.25	126
42	12	15	2.7	20000	25000	0.022	0	0.02	0.25	501
43	15	20	4	10000	5000	0.032	0	0.02	0.25	501
44	20	31	6	10000	5000	0.032	0	0.02	0.25	501
45	23	32	25	45000	25000	0.032	0	0.02	0.25	151
46	19	29	16	20000	20000	0.03	0	0.02	0.25	151
47	73	74	1	5000	1000	0.1	0	0.12	0.25	200
48	18	17	2	15000	15000	0.023	0	0.02	0.25	151
49	30	15	2	8000	2000	0.023	0	0.032	0.25	251
50	33	20	3	10000	20000	0.023	0	0.02	0.25	201
51	12	30	5	20000	300	0.02	0	0.02	0.25	351
52	32	29	5	20000	20000	0.032	0	0.02	0.25	1501
53	31	19	5	20000	20000	0.032	0	0.02	0.25	1501
54	31	32	4	20000	45000	0.033	0	0.02	0.25	201
55	25	101	30	30000	20000	0.028	0	0.02	0.25	1001
56	24	102	30	30000	20000	0.03	0	0.02	0.25	1001
57	23	103	30	30000	20000	0.03	0	0.02	0.25	1001
58	29	104	28	30000	20000	0.03	0	0.02	0.25	1501
59	32	105	27	30000	20000	0.03	0	0.02	0.25	1501
60	9	2	1.5	15000	50	0.041	0	0.12	1	175
61	34	19	2	5000	100	0.035	0	0.12	1	51
62	35	19	4	2000	800	0.025	0	0.12	1	51
63	36	19	18	1000	700	0.025	0	0.12	1	51
64	37	19	6	2000	2300	0.035	0	0.12	1	51
65	38	19	8.5	2000	1900	0.025	0	0.12	1	51
66	35	19	7	2000	870	0.035	0	0.12	1	51
67	36	31	6	2000	500	0.05	0	0.12	1	51
68	37	31	6	2000	500	0.05	0	0.12	1	51
69	38	31	6	2000	500	0.05	0	0.12	1	51
70	34	35	1.5	10638	15723	0.025	0	0.12	0.5	60
71	35	36	2	9222	11877	0.025	0	0.12	0.5	84
72	37	36	2	9366	8884	0.025	0	0.12	0.5	87
73	38	37	2	9157	9189	0.025	0	0.12	0.5	83
74	39	38	2	15047	13679	0.025	0	0.12	0.5	201
75	39	40	2	21372	12022	0.025	0	0.12	0.5	327
76	70	72	2	54374	8280	0.025	0	0.12	0.5	1288
77	71	70	1.5	38280	643	0.025	0	0.12	0.5	524
78	40	41	1	15659	3218	0.025	0	0.12	0.5	157
79	41	42	1	10573	9350	0.025	0	0.12	0.5	106
80	43	34	1	16238	11072	0.025	0	0.12	0.5	162
81	43	35	1	10815	6936	0.025	0	0.12	0.5	108
82	44	36	1	11169	10911	0.025	0	0.12	0.5	112

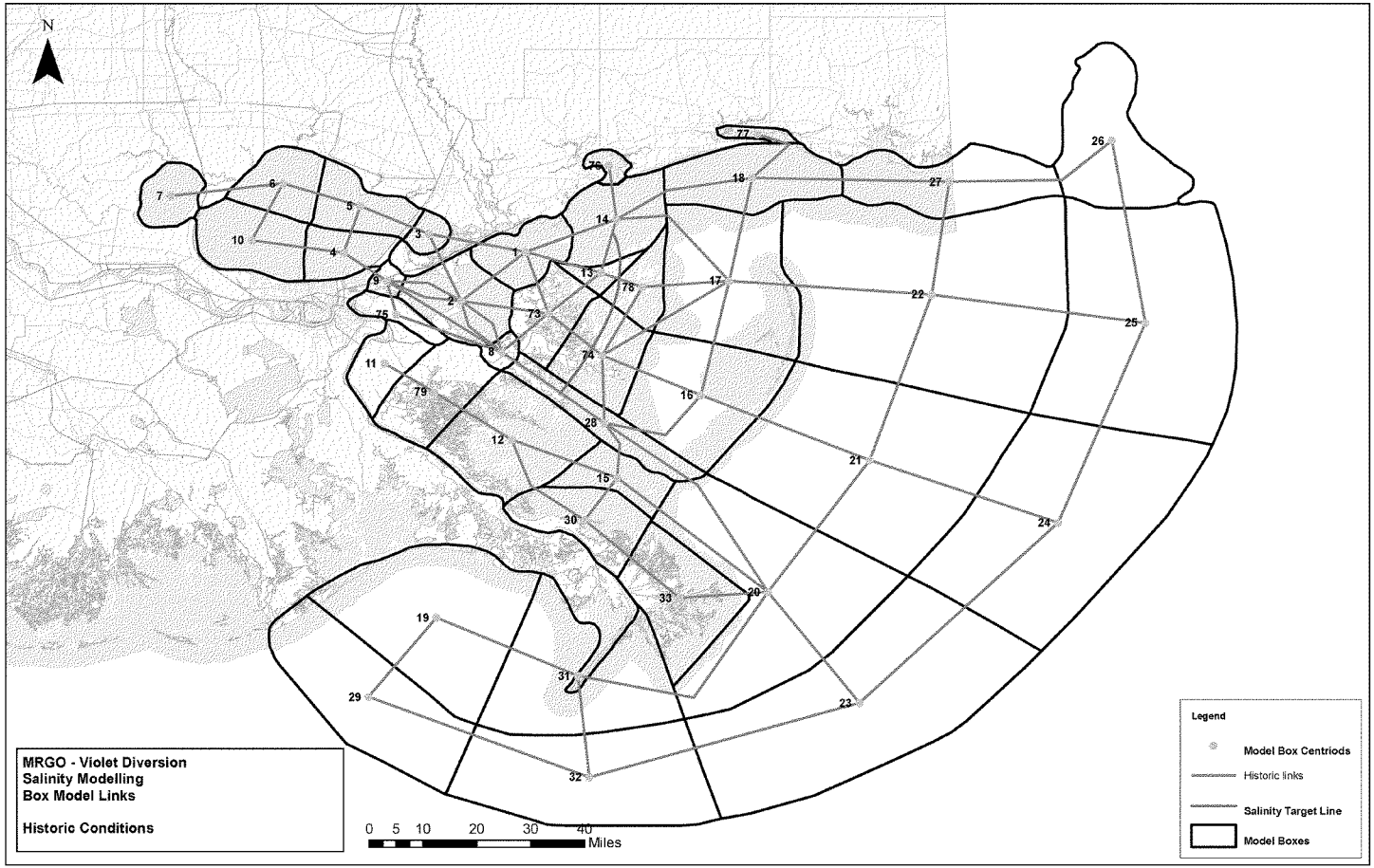
Calibration Values for Historic

Link No.	From Cell	To Cell	Depth (m)	Length (m)	Width (m)	Manning's n	K_m	K_{en}	K_{ex}	E
83	45	37	1	10026	5279	0.025	0	0.12	0.5	100
84	46	38	1	11426	10364	0.025	0	0.12	0.5	114
85	47	39	1	16093	81	0.025	0	0.12	0.5	160
86	43	44	1	12907	11346	0.025	0	0.12	0.5	129
87	45	44	1	8723	10219	0.025	0	0.12	0.5	87
88	46	45	1	7242	8691	0.025	0	0.12	0.5	72
89	47	46	1	7725	241	0.025	0	0.12	0.5	77
90	48	44	1	4522	3347	0.025	0	0.12	0.5	245
91	49	45	1	5279	1400	0.025	0	0.12	0.5	53
92	50	45	1	2140	81	0.025	0	0.12	0.5	21
93	51	46	1	3444	1448	0.025	0	0.12	0.5	34
94	51	47	1	9061	1062	0.025	0	0.12	0.5	91
95	48	49	1	12778	2044	0.025	0	0.12	0.5	128
96	54	48	1	11475	193	0.025	0	0.12	0.5	115
97	55	48	1	4345	1432	0.025	0	0.12	0.5	44
98	52	49	1	7886	290	0.025	0	0.12	0.5	79
99	53	50	1	7081	708	0.025	0	0.12	0.5	71
100	56	52	1	11459	258	0.025	0	0.12	0.5	115
101	52	53	1	4828	161	0.025	0	0.12	0.5	48
102	53	51	1	1883	274	0.025	0	0.12	0.5	19
103	48	52	1	3267	451	0.025	0	0.12	0.5	33
104	55	56	1	5150	322	0.025	0	0.12	0.5	52
105	56	57	0.2	8964	3380	0.07	0	0.12	0.5	18
106	57	51	0.5	2865	193	0.035	0	0.12	0.5	14
107	57	53	0.5	4989	402	0.05	0	0.12	0.5	25
108	59	55	3	3685	402	0.03	0	0.12	0.5	111
109	58	54	5.5	22128	161	0.025	0	0.12	0.5	114
110	60	55	3.7	7129	2913	0.04	0	0.12	0.5	261
111	61	60	2	4571	81	0.04	0	0.12	0.5	91
112	61	56	1	6759	338	0.04	0	0.12	0.5	68
113	61	57	1	4587	483	0.06	0	0.12	0.5	46
114	65	59	5.5	10252	161	0.025	0	0.12	0.5	163
115	65	61	2	3074	32	0.035	0	0.12	0.5	62
116	66	61	1	2639	16	0.1	0	0.12	0.5	26
117	69	65	3.5	9930	137	0.03	0	0.12	0.5	148
118	64	59	4	3541	644	0.025	0	0.12	0.5	142
119	64	58	4	2816	644	0.025	0	0.12	0.5	113
120	63	58	2	19650	241	0.04	0	0.12	0.5	393
121	62	63	2.1	5343	48	0.024	0	0.12	0.5	53
122	67	63	2	7178	1143	0.024	0	0.12	0.5	144
123	68	64	2	2044	171	0.023	0	0.12	0.5	120
124	58	59	2	12392	10621	0.025	0	0.12	0.5	248

Calibration Values for Historic

Link No.	From Cell	To Cell	Depth (m)	Length (m)	Width (m)	Manning's n	K_m	K_{en}	K_{ex}	E
125	66	61	4.9	21050	160	0.03	0	0.12	0.5	1027
126	51	50	1	6759	804	0.08	0	0.12	0.5	68
127	59	49	1	6759	1448	0.08	0	0.12	0.5	68
128	72	29	10	20000	10000	0.023	0	0.025	0.25	851
129	72	19	8	20000	15000	0.023	0	0.02	0.25	851
130	72	106	8	20000	12000	0.025	0	0.02	0.25	851
131	74	17	1	5000	100	0.1	0	0.12	0.25	13
132	1	73	1.2	5000	1000	0.05	0	0.12	0.25	235
133	73	13	1.1	5000	1000	0.078	0	0.12	0.25	500
134	74	78	1.1	5000	1000	0.078	0	0.12	0.25	485
135	8	73	1.2	10000	100	0.05	0	0.12	0.25	115
136	8	2	2.3	1000	750	0.023	0	0.12	1.25	135
137	76	14	2.6	4000	2000	0.023	0	0.12	0.25	55
138	77	18	2.3	4000	1000	0.023	0	0.12	0.25	35
139	13	78	1.8	5000	6000	0.035	0	0.02	0.25	141
140	79	12	1.2	10000	6400	0.042	0	0.02	0.25	531
141	75	9	2	15000	50	0.03	0	0.12	10	135
142	75	8	2.5	9500	75	0.03	0	0.5	15	55

Calibration Values for Historic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MRGO - Violet Diversion
Salinity Modelling
Box Model Links
Historic Conditions
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Miles
Legend
Model Box Centriods
Historic links
Salinity Target Line
Model Boxes

CALIBRATION VALUES FOR FWOP

Link No.	From Cell	To Cell	Depth (m)	Length (m)	Width (m)	Manning's n	K_m	K_{en}	K_{ex}	E
1	1	14	5.5	3000	15000	0.016	0.007	0.25	1	9
2	3	1	10.5	10500	985	0.024	0.075	0.5	2	2500
3	2	1	4.0	15000	15000	0.021	0.007	0.1	1	50
4	3	2	8	7850	360	0.025	0.075	0.5	1.95	30
5	8	28	6.5	60420	320	CLOSED	0	0.5	1	1
6	9	8	6.5	20000	300	CLOSED	0	0.5	1	1
7	9	2	4.0	12000	150	0.03	0	0.5	10	55
8	4	9	8.5	15000	155	0.025	0.1	0.5	19	350
9	5	3	3	20000	20000	0.023	0	0.025	0.25	155
10	5	4	4.3	40000	40000	0.02	0	0.02	0.25	195
11	6	5	3.9	40000	20000	0.02	0	0.5	1	46
12	7	6	8.1	8800	395	0.024	0	0.5	1	200
13	75	2	3	10500	300	0.03	0	0.5	1	100
14	10	6	3.7	20000	20000	0.025	0	0.02	0.25	56
15	10	4	3.9	40009	20000	0.025	0	0.02	0.25	56
16	1	13	2.1	14500	1000	0.04	0	0.02	1.25	651
17	14	18	5	10000	20000	0.015	0	0.02	0.25	56
18	18	27	5	15000	20000	0.02	0	0.02	0.25	26
19	27	26	5	20000	20000	0.032	0	0.02	0.25	16
20	26	25	5	5000	4000	0.032	0	0.02	0.25	116
21	2	73	1	5000	650	0.075	0	0.02	0.25	271
22	14	13	1	5000	400	0.08	0	0.02	0.25	201
23	14	17	6	3000	7500	0.02	0	0.08	0.25	150
24	78	17	2	3500	5000	0.058	0	0.12	0.25	200
25	17	22	11.	10000	10000	0.018	0	0.02	0.25	201
26	27	22	5	5000	10000	0.023	0	0.02	0.25	16
27	22	25	19	30000	55000	0.02	0	0.02	0.25	151
28	74	16	1	4000	500	0.045	0	0.038	0.25	20
29	16	17	4.6	20000	15000	0.022	0	0.02	0.25	251
30	16	21	11.	3000	18000	0.02	0	0.02	0.25	101
31	21	22	8	20000	15000	0.02	0	0.02	0.25	251
32	21	24	21	30000	60000	0.02	0	0.02	0.25	501
33	24	25	11	30000	20000	0.02	0	0.02	0.25	501
34	28	20	5	20000	4000	0.02	0	0.02	0.25	16
35	28	16	5	20000	10000	0.02	0	0.02	0.25	500
36	15	28	5	20000	10000	0.018	0	0.02	0.25	500
37	28	74	2	20000	10000	0.08	0	0.02	0.25	200
38	20	21	8	20000	15000	0.018	0	0.02	0.25	506
39	20	23	21	30000	50000	0.018	0	0.02	0.25	501

FWOP – LAKE BORGNE OPEN

40	23	24	15	30000	20000	0.02	0	0.02	0.25	501
41	11	79	1	10000	6400	0.04	0	0.02	0.25	126
42	12	15	2.7	20000	25000	0.022	0	0.02	0.25	501
43	15	20	4	10000	5000	0.032	0	0.02	0.25	501
44	20	31	6	10000	5000	0.032	0	0.02	0.25	501
45	23	32	25	45000	25000	0.032	0	0.02	0.25	151
46	19	29	16	20000	20000	0.03	0	0.02	0.25	151
47	73	74	1	5000	1000	0.1	0	0.12	0.25	200
48	18	17	2	15000	15000	0.023	0	0.02	0.25	151
49	30	15	2	8000	2000	0.023	0	0.032	0.25	251
50	33	20	3	10000	20000	0.023	0	0.02	0.25	201
51	12	30	5	20000	300	0.02	0	0.02	0.25	351
52	32	29	5	20000	20000	0.032	0	0.02	0.25	1501
53	31	19	5	20000	20000	0.032	0	0.02	0.25	1501
54	31	32	4	20000	45000	0.033	0	0.02	0.25	201
55	25	101	30	30000	20000	0.028	0	0.02	0.25	1001
56	24	102	30	30000	20000	0.03	0	0.02	0.25	1001
57	23	103	30	30000	20000	0.03	0	0.02	0.25	1001
58	29	104	28	30000	20000	0.03	0	0.02	0.25	1501
59	32	105	27	30000	20000	0.03	0	0.02	0.25	1501
60	9	2	1.5	15000	50	0.041	0	0.12	20	175
61	34	19	2	5000	100	0.035	0	0.12	1	51
62	35	19	4	2000	800	0.025	0	0.12	1	51
63	36	19	18	1000	700	0.025	0	0.12	1	51
64	37	19	6	2000	2300	0.035	0	0.12	1	51
65	38	19	8.5	2000	1900	0.025	0	0.12	1	51
66	35	19	7	2000	870	0.035	0	0.12	1	51
67	36	31	6	2000	500	0.05	0	0.12	1	51
68	37	31	6	2000	500	0.05	0	0.12	1	51
69	38	31	6	2000	500	0.05	0	0.12	1	51
70	34	35	1.5	10638	15723	0.025	0	0.12	0.5	60
71	35	36	2	9222	11877	0.025	0	0.12	0.5	84
72	37	36	2	9366	8884	0.025	0	0.12	0.5	87
73	38	37	2	9157	9189	0.025	0	0.12	0.5	83
74	39	38	2	15047	13679	0.025	0	0.12	0.5	201
75	39	40	2	21372	12022	0.025	0	0.12	0.5	327
76	70	72	2	54374	8280	0.025	0	0.12	0.5	1288
77	71	70	1.5	38280	643	0.025	0	0.12	0.5	524
78	40	41	1	15659	3218	0.025	0	0.12	0.5	157
79	41	42	1	10573	9350	0.025	0	0.12	0.5	106
80	43	34	1	16238	11072	0.025	0	0.12	0.5	162
81	43	35	1	10815	6936	0.025	0	0.12	0.5	108
82	44	36	1	11169	10911	0.025	0	0.12	0.5	112

FWOP – LAKE BORGNE OPEN

83	45	37	1	10026	5279	0.025	0	0.12	0.5	100
84	46	38	1	11426	10364	0.025	0	0.12	0.5	114
85	47	39	1	16093	81	0.025	0	0.12	0.5	160
86	43	44	1	12907	11346	0.025	0	0.12	0.5	129
87	45	44	1	8723	10219	0.025	0	0.12	0.5	87
88	46	45	1	7242	8691	0.025	0	0.12	0.5	72
89	47	46	1	7725	241	0.025	0	0.12	0.5	77
90	48	44	1	4522	3347	0.025	0	0.12	0.5	245
91	49	45	1	5279	1400	0.025	0	0.12	0.5	53
92	50	45	1	2140	81	0.025	0	0.12	0.5	21
93	51	46	1	3444	1448	0.025	0	0.12	0.5	34
94	51	47	1	9061	1062	0.025	0	0.12	0.5	91
95	48	49	1	12778	2044	0.025	0	0.12	0.5	128
96	54	48	1	11475	193	0.025	0	0.12	0.5	115
97	55	48	1	4345	1432	0.025	0	0.12	0.5	44
98	52	49	1	7886	290	0.025	0	0.12	0.5	79
99	53	50	1	7081	708	0.025	0	0.12	0.5	71
100	56	52	1	11459	258	0.025	0	0.12	0.5	115
101	52	53	1	4828	161	0.025	0	0.12	0.5	48
102	53	51	1	1883	274	0.025	0	0.12	0.5	19
103	48	52	1	3267	451	0.025	0	0.12	0.5	33
104	55	56	1	5150	322	0.025	0	0.12	0.5	52
105	56	57	0.2	8964	3380	0.07	0	0.12	0.5	18
106	57	51	0.5	2865	193	0.035	0	0.12	0.5	14
107	57	53	0.5	4989	402	0.05	0	0.12	0.5	25
108	59	55	3	3685	402	0.03	0	0.12	0.5	111
109	58	54	5.5	22128	161	0.025	0	0.12	0.5	114
110	60	55	3.7	7129	2913	0.04	0	0.12	0.5	261
111	61	60	2	4571	81	0.04	0	0.12	0.5	91
112	61	56	1	6759	338	0.04	0	0.12	0.5	68
113	61	57	1	4587	483	0.06	0	0.12	0.5	46
114	65	59	5.5	10252	161	0.025	0	0.12	0.5	163
115	65	61	2	3074	32	0.035	0	0.12	0.5	62
116	66	61	1	2639	16	0.1	0	0.12	0.5	26
117	69	65	3.5	9930	137	0.03	0	0.12	0.5	148
118	64	59	4	3541	644	0.025	0	0.12	0.5	142
119	64	58	4	2816	644	0.025	0	0.12	0.5	113
120	63	58	2	19650	241	0.04	0	0.12	0.5	393
121	62	63	2.1	5343	48	0.024	0	0.12	0.5	53
122	67	63	2	7178	1143	0.024	0	0.12	0.5	144
123	68	64	2	2044	171	0.023	0	0.12	0.5	120
124	58	59	2	12392	10621	0.025	0	0.12	0.5	248
125	66	61	4.9	21050	160	0.03	0	0.12	0.5	1027

FWOP – LAKE BORGNE OPEN

126	51	50	1	6759	804	0.08	0	0.12	0.5	68
127	59	49	1	6759	1448	0.08	0	0.12	0.5	68
128	72	29	10	20000	10000	0.023	0	0.025	0.25	851
129	72	19	8	20000	15000	0.023	0	0.02	0.25	851
130	72	106	8	20000	12000	0.025	0	0.02	0.25	851
131	74	17	1	5000	100	0.1	0	0.12	0.25	13
132	1	73	1.2	5000	1000	0.05	0	0.12	0.25	235
133	73	13	1.1	5000	1000	0.078	0	0.12	0.25	500
134	74	78	1.1	5000	1000	0.078	0	0.12	0.25	485
135	8	73	1.2	15000	100	0.05	0	0.12	0.25	115
136	8	2	2.3	1000	750	0.023	0	0.12	1.25	135
137	76	14	2.6	4000	2000	0.023	0	0.12	0.25	55
138	77	18	2.3	4000	1000	0.023	0	0.12	0.25	35
139	13	78	1.8	5000	6000	0.035	0	0.02	0.25	141
140	79	12	1.2	10000	6400	0.042	0	0.02	0.25	531
141	75	9	2	15000	50	0.03	0	0.12	10	135
142	75	8	2.5	10000	50	0.03	0	0.5	10	155
143	30	33	1.1	30000	5000	0.05	0	0.5	1	100
144	15	28	3.0	3000	78	0.05	0	0.5	1	100
145	75	8	4.1	10000	170	CLOSED	0	0.5	1	155

FWOP – LAKE BORGNE OPEN

CALIBRATION VALUES FOR ALTERNATIVE 1

Link No.	From Cell	To Cell	Depth (m)	Length (m)	Width (m)	Manning's n	K_m	K_{en}	K_{ex}	E
1	1	14	5.5	3000	15000	0.016	0.007	0.25	1	9
2	3	1	10.5	10500	985	0.024	0.075	0.5	2	2500
3	2	1	4.0	15000	15000	0.021	0.007	0.1	1	50
4	3	2	8	7850	360	0.025	0.075	0.5	1.95	30
5	8	28	6.5	60420	320	CLOSED	0	0.5	1	1
6	9	8	6.5	20000	300	CLOSED	0	0.5	1	1
7	9	2	4.05	12000	150	0.03	0	0.5	10	55
8	4	9	8.5	15000	150	0.025	0.1	0.5	19	350
9	5	3	3	20000	20000	0.023	0	0.025	0.25	155
10	5	4	4.3	40000	40000	0.02	0	0.02	0.25	195
11	6	5	3.9	40000	20000	0.02	0	0.5	1	46
12	7	6	8.1	8800	395	0.024	0	0.5	1	200
13	8	2	3	2000	50	0.03	0	0.5	1	2
14	10	6	3.7	20000	20000	0.025	0	0.02	0.25	56
15	10	4	3.9	40009	20000	0.025	0	0.02	0.25	56
16	1	13	2.1	14500	1000	0.04	0	0.02	1.25	651
17	14	18	5	10000	20000	0.015	0	0.02	0.25	56
18	18	27	5	15000	20000	0.02	0	0.02	0.25	26
19	27	26	5	20000	20000	0.032	0	0.02	0.25	16
20	26	25	5	5000	4000	0.032	0	0.02	0.25	116
21	2	73	1	5000	650	0.075	0	0.02	0.25	271
22	14	13	1	5000	400	0.08	0	0.02	0.25	201
23	14	17	6	3000	7500	0.02	0	0.08	0.25	150
24	78	17	2	3500	5000	0.058	0	0.12	0.25	200
25	17	22	11.	10000	10000	0.018	0	0.02	0.25	201
26	27	22	5	5000	10000	0.023	0	0.02	0.25	16
27	22	25	19	30000	55000	0.02	0	0.02	0.25	151
28	74	16	1	4000	500	0.045	0	0.038	0.25	20
29	16	17	4.6	20000	15000	0.022	0	0.02	0.25	251
30	16	21	11.	3000	18000	0.02	0	0.02	0.25	101
31	21	22	8	20000	15000	0.02	0	0.02	0.25	251
32	21	24	21	30000	60000	0.02	0	0.02	0.25	501
33	24	25	11	30000	20000	0.02	0	0.02	0.25	501
34	28	20	5	20000	4000	0.02	0	0.02	0.25	16
35	28	16	5	20000	10000	0.02	0	0.02	0.25	500
36	15	28	5	20000	10000	0.018	0	0.02	0.25	500
37	28	74	2	20000	10000	0.08	0	0.02	0.25	200
38	20	21	8	20000	15000	0.018	0	0.02	0.25	506
39	20	23	21	30000	50000	0.018	0	0.02	0.25	501
40	23	24	15	30000	20000	0.02	0	0.02	0.25	501
41	11	79	1	10000	6400	0.04	0	0.02	0.25	126

Alternative 1 (Lake Borgne Open)

42	12	15	2.7	20000	25000	0.022	0	0.02	0.25	501
43	15	20	4	10000	5000	0.032	0	0.02	0.25	501
44	20	31	6	10000	5000	0.032	0	0.02	0.25	501
45	23	32	25	45000	25000	0.032	0	0.02	0.25	151
46	19	29	16	20000	20000	0.03	0	0.02	0.25	151
47	73	74	1	5000	1000	0.1	0	0.12	0.25	200
48	18	17	2	15000	15000	0.023	0	0.02	0.25	151
49	30	15	2	8000	2000	0.023	0	0.032	0.25	251
50	33	20	3	10000	20000	0.023	0	0.02	0.25	201
51	12	30	5	20000	300	0.02	0	0.02	0.25	351
52	32	29	5	20000	20000	0.032	0	0.02	0.25	1501
53	31	19	5	20000	20000	0.032	0	0.02	0.25	1501
54	31	32	4	20000	45000	0.033	0	0.02	0.25	201
55	25	101	30	30000	20000	0.028	0	0.02	0.25	1001
56	24	102	30	30000	20000	0.03	0	0.02	0.25	1001
57	23	103	30	30000	20000	0.03	0	0.02	0.25	1001
58	29	104	28	30000	20000	0.03	0	0.02	0.25	1501
59	32	105	27	30000	20000	0.03	0	0.02	0.25	1501
60	9	2	1.5	15000	50	0.041	0	0.12	20	175
61	34	19	2	5000	100	0.035	0	0.12	1	51
62	35	19	4	2000	800	0.025	0	0.12	1	51
63	36	19	18	1000	700	0.025	0	0.12	1	51
64	37	19	6	2000	2300	0.035	0	0.12	1	51
65	38	19	8.5	2000	1900	0.025	0	0.12	1	51
66	35	19	7	2000	870	0.035	0	0.12	1	51
67	36	31	6	2000	500	0.05	0	0.12	1	51
68	37	31	6	2000	500	0.05	0	0.12	1	51
69	38	31	6	2000	500	0.05	0	0.12	1	51
70	34	35	1.5	10638	15723	0.025	0	0.12	0.5	60
71	35	36	2	9222	11877	0.025	0	0.12	0.5	84
72	37	36	2	9366	8884	0.025	0	0.12	0.5	87
73	38	37	2	9157	9189	0.025	0	0.12	0.5	83
74	39	38	2	15047	13679	0.025	0	0.12	0.5	201
75	39	40	2	21372	12022	0.025	0	0.12	0.5	327
76	70	72	2	54374	8280	0.025	0	0.12	0.5	1288
77	71	70	1.5	38280	643	0.025	0	0.12	0.5	524
78	40	41	1	15659	3218	0.025	0	0.12	0.5	157
79	41	42	1	10573	9350	0.025	0	0.12	0.5	106
80	43	34	1	16238	11072	0.025	0	0.12	0.5	162
81	43	35	1	10815	6936	0.025	0	0.12	0.5	108
82	44	36	1	11169	10911	0.025	0	0.12	0.5	112
83	45	37	1	10026	5279	0.025	0	0.12	0.5	100
84	46	38	1	11426	10364	0.025	0	0.12	0.5	114

Alternative 1 (Lake Borgne Open)

85	47	39	1	16093	81	0.025	0	0.12	0.5	160
86	43	44	1	12907	11346	0.025	0	0.12	0.5	129
87	45	44	1	8723	10219	0.025	0	0.12	0.5	87
88	46	45	1	7242	8691	0.025	0	0.12	0.5	72
89	47	46	1	7725	241	0.025	0	0.12	0.5	77
90	48	44	1	4522	3347	0.025	0	0.12	0.5	245
91	49	45	1	5279	1400	0.025	0	0.12	0.5	53
92	50	45	1	2140	81	0.025	0	0.12	0.5	21
93	51	46	1	3444	1448	0.025	0	0.12	0.5	34
94	51	47	1	9061	1062	0.025	0	0.12	0.5	91
95	48	49	1	12778	2044	0.025	0	0.12	0.5	128
96	54	48	1	11475	193	0.025	0	0.12	0.5	115
97	55	48	1	4345	1432	0.025	0	0.12	0.5	44
98	52	49	1	7886	290	0.025	0	0.12	0.5	79
99	53	50	1	7081	708	0.025	0	0.12	0.5	71
100	56	52	1	11459	258	0.025	0	0.12	0.5	115
101	52	53	1	4828	161	0.025	0	0.12	0.5	48
102	53	51	1	1883	274	0.025	0	0.12	0.5	19
103	48	52	1	3267	451	0.025	0	0.12	0.5	33
104	55	56	1	5150	322	0.025	0	0.12	0.5	52
105	56	57	0.2	8964	3380	0.07	0	0.12	0.5	18
106	57	51	0.5	2865	193	0.035	0	0.12	0.5	14
107	57	53	0.5	4989	402	0.05	0	0.12	0.5	25
108	59	55	3	3685	402	0.03	0	0.12	0.5	111
109	58	54	5.5	22128	161	0.025	0	0.12	0.5	114
110	60	55	3.7	7129	2913	0.04	0	0.12	0.5	261
111	61	60	2	4571	81	0.04	0	0.12	0.5	91
112	61	56	1	6759	338	0.04	0	0.12	0.5	68
113	61	57	1	4587	483	0.06	0	0.12	0.5	46
114	65	59	5.5	10252	161	0.025	0	0.12	0.5	163
115	65	61	2	3074	32	0.035	0	0.12	0.5	62
116	66	61	1	2639	16	0.1	0	0.12	0.5	26
117	69	65	3.5	9930	137	0.03	0	0.12	0.5	148
118	64	59	4	3541	644	0.025	0	0.12	0.5	142
119	64	58	4	2816	644	0.025	0	0.12	0.5	113
120	63	58	2	19650	241	0.04	0	0.12	0.5	393
121	62	63	2.1	5343	48	0.024	0	0.12	0.5	53
122	67	63	2	7178	1143	0.024	0	0.12	0.5	144
123	68	64	2	2044	171	0.023	0	0.12	0.5	120
124	58	59	2	12392	10621	0.025	0	0.12	0.5	248
125	66	61	4.9	21050	160	0.03	0	0.12	0.5	1027
126	51	50	1	6759	804	0.08	0	0.12	0.5	68
127	59	49	1	6759	1448	0.08	0	0.12	0.5	68

Alternative 1 (Lake Borgne Open)

128	72	29	10	20000	10000	0.023	0	0.025	0.25	851
129	72	19	8	20000	15000	0.023	0	0.02	0.25	851
130	72	106	8	20000	12000	0.025	0	0.02	0.25	851
131	74	17	1	5000	100	0.1	0	0.12	0.25	13
132	1	73	1.2	5000	1000	0.05	0	0.12	0.25	235
133	73	13	1.1	5000	1000	0.078	0	0.12	0.25	500
134	74	78	1.1	5000	1000	0.078	0	0.12	0.25	485
135	8	73	1.2	15000	100	0.05	0	0.12	0.25	115
136	8	2	2.3	1000	750	0.023	0	0.12	1.25	135
137	76	14	2.6	4000	2000	0.023	0	0.12	0.25	55
138	77	18	2.3	4000	1000	0.023	0	0.12	0.25	35
139	13	78	1.8	5000	6000	0.035	0	0.02	0.25	141
140	79	12	1.2	10000	6400	0.042	0	0.02	0.25	531
141	75	9	4	10000	50	0.03	0	0.5	10	135
142	75	8	2.5	10000	50	0.03	0	0.5	10	155
143	30	33	1.1	30000	5000	0.05	0	0.5	1	100
144	15	28	3.0	3000	78	0.05	0	0.5	1	100
145	75	8	4.1	10000	170	0.03	0	0.5	1	155

Alternative 1 (Lake Borgne Open)

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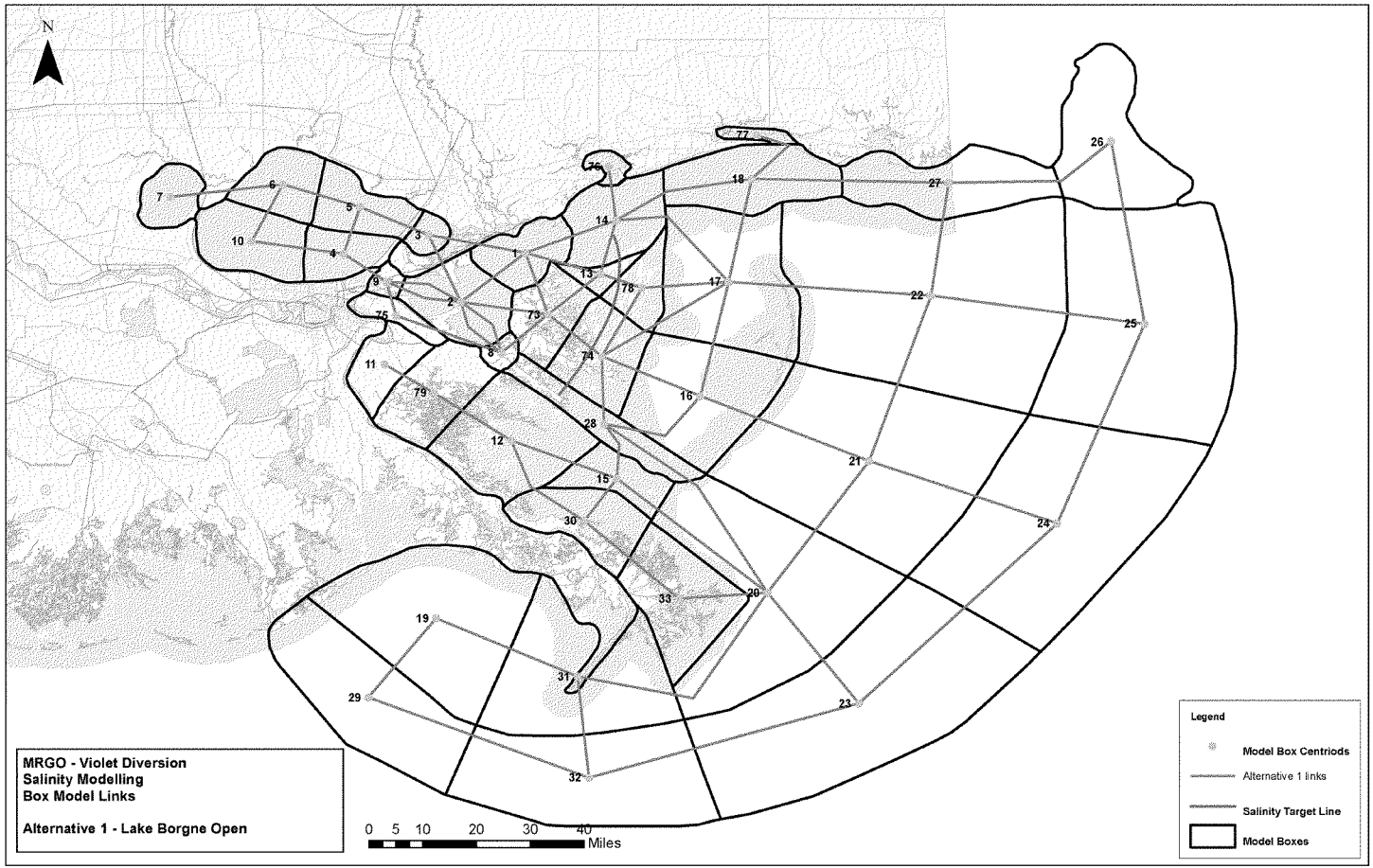
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MRGO - Violet Diversion
Salinity Modelling
Box Model Links
Alternative 1 - Lake Borgne Open
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Miles
Legend
Model Box Centriods
Alternative 1 links
Salinity Target Line
Model Boxes

CALIBRATION VALUES FOR ALTERNATIVE 2

Link No.	From Cell	To Cell	Depth (m)	Length (m)	Width (m)	Manning's n	K_m	K_{en}	K_{ex} E	
1	1	14	5.5	3000	15000	0.016	0.007	0.25	1	9
2	3	1	10.5	10500	985	0.024	0.075	0.5	2	2500
3	2	1	4.0	15000	15000	0.021	0.007	0.1	1	50
4	3	2	8	7850	360	0.025	0.075	0.5	2	30
5	8	28	6.5	60420	320	CLOSED	0	0.5	1	1
6	9	8	6.5	20000	300	CLOSED	0	0.5	1	1
7	9	2	4.05	12000	150	0.03	0	0.5	10	55
8	4	9	8.5	15000	150	0.025	0.1	0.5	19	350
9	5	3	3	20000	20000	0.023	0	0.025	0.25	155
10	5	4	4.3	40000	40000	0.02	0	0.02	0.25	195
11	6	5	3.9	40000	20000	0.02	0	0.5	1	46
12	7	6	8.1	8800	395	0.024	0	0.5	1	200
13	8	2	3	2000	50	0.03	0	0.5	1	2
14	10	6	3.7	20000	20000	0.025	0	0.02	0.25	56
15	10	4	3.9	40009	20000	0.025	0	0.02	0.25	56
16	1	13	2.1	14500	1000	0.04	0	0.02	1.25	651
17	14	18	5	10000	20000	0.015	0	0.02	0.25	56
18	18	27	5	15000	20000	0.02	0	0.02	0.25	26
19	27	26	5	20000	20000	0.032	0	0.02	0.25	16
20	26	25	5	5000	4000	0.032	0	0.02	0.25	116
21	2	73	1	5000	650	0.075	0	0.02	0.25	271
22	14	13	1	5000	400	0.08	0	0.02	0.25	201
23	14	17	6	3000	7500	0.02	0	0.08	0.25	150
24	78	17	2	3500	5000	0.058	0	0.12	0.25	200
25	17	22	11.	10000	10000	0.018	0	0.02	0.25	201
26	27	22	5	5000	10000	0.023	0	0.02	0.25	16
27	22	25	19	30000	55000	0.02	0	0.02	0.25	151
28	74	16	1	4000	500	0.045	0	0.038	0.25	20
29	16	17	4.6	20000	15000	0.022	0	0.02	0.25	251
30	16	21	11.5	3000	18000	0.02	0	0.02	0.25	101
31	21	22	8	20000	15000	0.02	0	0.02	0.25	251
32	21	24	21	30000	60000	0.02	0	0.02	0.25	501
33	24	25	11	30000	20000	0.02	0	0.02	0.25	501
34	28	20	5	20000	4000	0.02	0	0.02	0.25	16
35	28	16	5	20000	10000	0.02	0	0.02	0.25	500
36	15	28	5	20000	10000	0.018	0	0.02	0.25	500
37	28	74	2	20000	10000	0.08	0	0.02	0.25	200
38	20	21	8	20000	15000	0.018	0	0.02	0.25	506
39	20	23	21	30000	50000	0.018	0	0.02	0.25	501
40	23	24	15	30000	20000	0.02	0	0.02	0.25	501
41	11	79	1	10000	6400	0.04	0	0.02	0.25	126

ALTERNATIVE 2 (LAKE BORGNE CLOSED)

42	12	15	2.7	20000	25000	0.022	0	0.02	0.25	501
43	15	20	4	10000	5000	0.032	0	0.02	0.25	501
44	20	31	6	10000	5000	0.032	0	0.02	0.25	501
45	23	32	25	45000	25000	0.032	0	0.02	0.25	151
46	19	29	16	20000	20000	0.03	0	0.02	0.25	151
47	73	74	1	5000	1000	0.1	0	0.12	0.25	200
48	18	17	2	15000	15000	0.023	0	0.02	0.25	151
49	30	15	2	8000	2000	0.023	0	0.032	0.25	251
50	33	20	3	10000	20000	0.023	0	0.02	0.25	201
51	12	30	5	20000	300	0.02	0	0.02	0.25	351
52	32	29	5	20000	20000	0.032	0	0.02	0.25	1501
53	31	19	5	20000	20000	0.032	0	0.02	0.25	1501
54	31	32	4	20000	45000	0.033	0	0.02	0.25	201
55	25	101	30	30000	20000	0.028	0	0.02	0.25	1001
56	24	102	30	30000	20000	0.03	0	0.02	0.25	1001
57	23	103	30	30000	20000	0.03	0	0.02	0.25	1001
58	29	104	28	30000	20000	0.03	0	0.02	0.25	1501
59	32	105	27	30000	20000	0.03	0	0.02	0.25	1501
60	9	2	1.5	15000	50	0.041	0	0.12	20	175
61	34	19	2	5000	100	0.035	0	0.12	1	51
62	35	19	4	2000	800	0.025	0	0.12	1	51
63	36	19	18	1000	700	0.025	0	0.12	1	51
64	37	19	6	2000	2300	0.035	0	0.12	1	51
65	38	19	8.5	2000	1900	0.025	0	0.12	1	51
66	35	19	7	2000	870	0.035	0	0.12	1	51
67	36	31	6	2000	500	0.05	0	0.12	1	51
68	37	31	6	2000	500	0.05	0	0.12	1	51
69	38	31	6	2000	500	0.05	0	0.12	1	51
70	34	35	1.5	10638	15723	0.025	0	0.12	0.5	60
71	35	36	2	9222	11877	0.025	0	0.12	0.5	84
72	37	36	2	9366	8884	0.025	0	0.12	0.5	87
73	38	37	2	9157	9189	0.025	0	0.12	0.5	83
74	39	38	2	15047	13679	0.025	0	0.12	0.5	201
75	39	40	2	21372	12022	0.025	0	0.12	0.5	327
76	70	72	2	54374	8280	0.025	0	0.12	0.5	1288
77	71	70	1.5	38280	643	0.025	0	0.12	0.5	524
78	40	41	1	15659	3218	0.025	0	0.12	0.5	157
79	41	42	1	10573	9350	0.025	0	0.12	0.5	106
80	43	34	1	16238	11072	0.025	0	0.12	0.5	162
81	43	35	1	10815	6936	0.025	0	0.12	0.5	108
82	44	36	1	11169	10911	0.025	0	0.12	0.5	112
83	45	37	1	10026	5279	0.025	0	0.12	0.5	100
84	46	38	1	11426	10364	0.025	0	0.12	0.5	114

ALTERNATIVE 2 (LAKE BORGNE CLOSED)

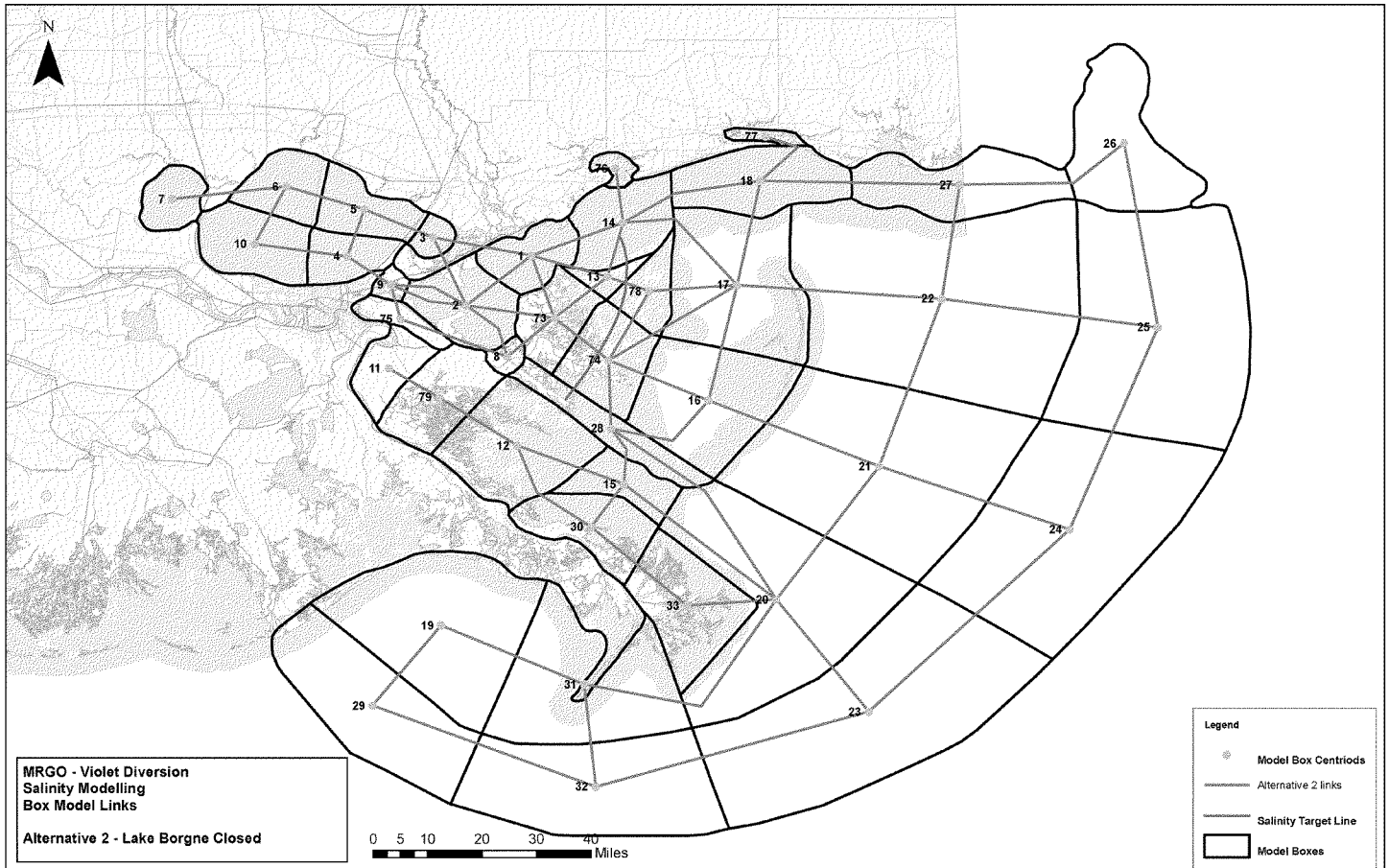
85	47	39	1	16093	81	0.025	0	0.12	0.5	160
86	43	44	1	12907	11346	0.025	0	0.12	0.5	129
87	45	44	1	8723	10219	0.025	0	0.12	0.5	87
88	46	45	1	7242	8691	0.025	0	0.12	0.5	72
89	47	46	1	7725	241	0.025	0	0.12	0.5	77
90	48	44	1	4522	3347	0.025	0	0.12	0.5	245
91	49	45	1	5279	1400	0.025	0	0.12	0.5	53
92	50	45	1	2140	81	0.025	0	0.12	0.5	21
93	51	46	1	3444	1448	0.025	0	0.12	0.5	34
94	51	47	1	9061	1062	0.025	0	0.12	0.5	91
95	48	49	1	12778	2044	0.025	0	0.12	0.5	128
96	54	48	1	11475	193	0.025	0	0.12	0.5	115
97	55	48	1	4345	1432	0.025	0	0.12	0.5	44
98	52	49	1	7886	290	0.025	0	0.12	0.5	79
99	53	50	1	7081	708	0.025	0	0.12	0.5	71
100	56	52	1	11459	258	0.025	0	0.12	0.5	115
101	52	53	1	4828	161	0.025	0	0.12	0.5	48
102	53	51	1	1883	274	0.025	0	0.12	0.5	19
103	48	52	1	3267	451	0.025	0	0.12	0.5	33
104	55	56	1	5150	322	0.025	0	0.12	0.5	52
105	56	57	0.2	8964	3380	0.07	0	0.12	0.5	18
106	57	51	0.5	2865	193	0.035	0	0.12	0.5	14
107	57	53	0.5	4989	402	0.05	0	0.12	0.5	25
108	59	55	3	3685	402	0.03	0	0.12	0.5	111
109	58	54	5.5	22128	161	0.025	0	0.12	0.5	114
110	60	55	3.7	7129	2913	0.04	0	0.12	0.5	261
111	61	60	2	4571	81	0.04	0	0.12	0.5	91
112	61	56	1	6759	338	0.04	0	0.12	0.5	68
113	61	57	1	4587	483	0.06	0	0.12	0.5	46
114	65	59	5.5	10252	161	0.025	0	0.12	0.5	163
115	65	61	2	3074	32	0.035	0	0.12	0.5	62
116	66	61	1	2639	16	0.1	0	0.12	0.5	26
117	69	65	3.5	9930	137	0.03	0	0.12	0.5	148
118	64	59	4	3541	644	0.025	0	0.12	0.5	142
119	64	58	4	2816	644	0.025	0	0.12	0.5	113
120	63	58	2	19650	241	0.04	0	0.12	0.5	393
121	62	63	2.1	5343	48	0.024	0	0.12	0.5	53
122	67	63	2	7178	1143	0.024	0	0.12	0.5	144
123	68	64	2	2044	171	0.023	0	0.12	0.5	120
124	58	59	2	12392	10621	0.025	0	0.12	0.5	248
125	66	61	4.9	21050	160	0.03	0	0.12	0.5	1027
126	51	50	1	6759	804	0.08	0	0.12	0.5	68
127	59	49	1	6759	1448	0.08	0	0.12	0.5	68

ALTERNATIVE 2 (LAKE BORGNE CLOSED)

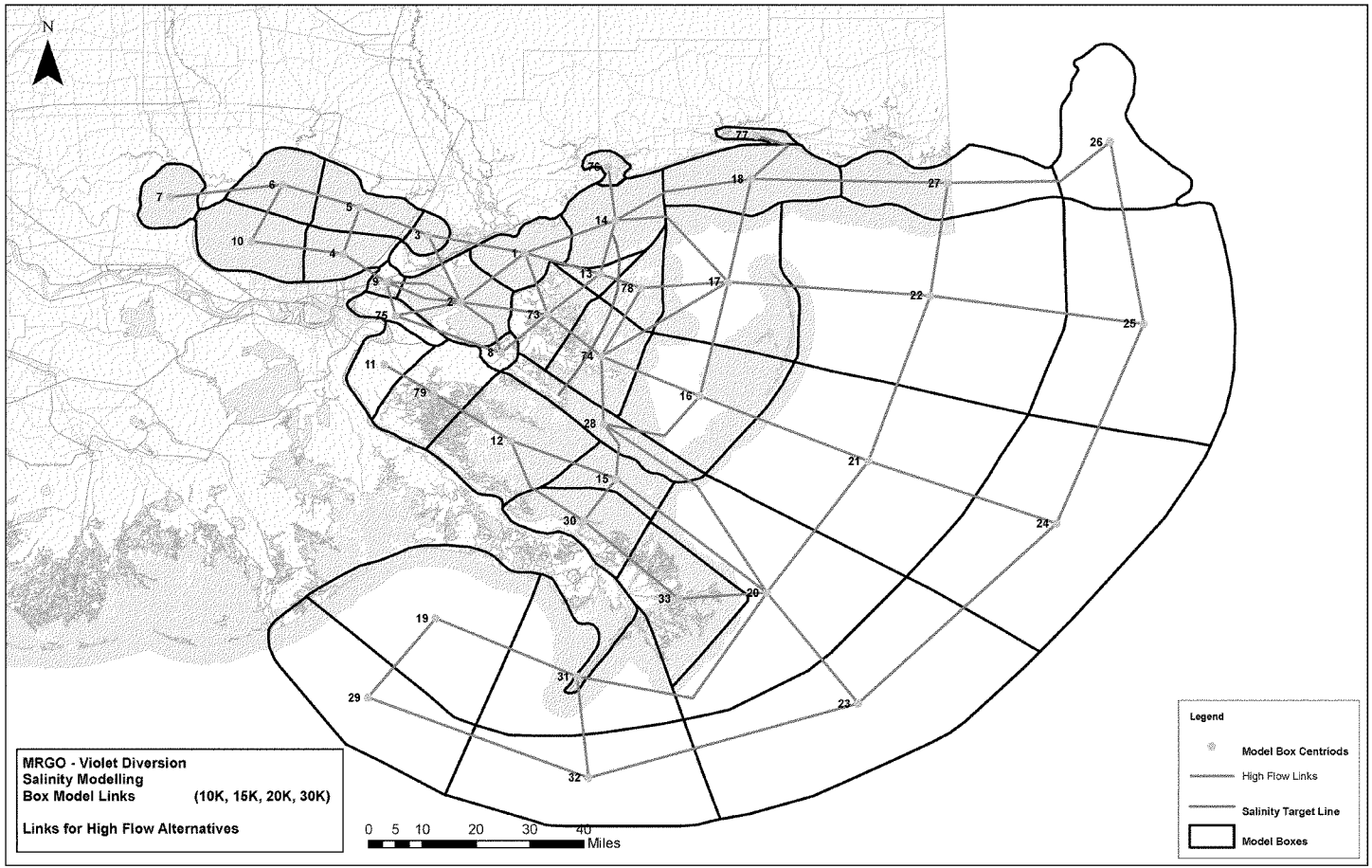
128	72	29	10	20000	10000	0.023	0	0.025	0.25	851
129	72	19	8	20000	15000	0.023	0	0.02	0.25	851
130	72	106	8	20000	12000	0.025	0	0.02	0.25	851
131	74	17	1	5000	100	0.1	0	0.12	0.25	13
132	1	73	1.2	5000	1000	0.05	0	0.12	0.25	235
133	73	13	1.1	5000	1000	0.078	0	0.12	0.25	500
134	74	78	1.1	5000	1000	0.078	0	0.12	0.25	485
135	8	73	1.2	10000	100	0.05	0	0.12	0.25	115
136	8	2	2.3	1000	750	CLOSED	0	0.12	1.25	1
137	76	14	2.6	4000	2000	0.023	0	0.12	0.25	55
138	77	18	2.3	4000	1000	0.023	0	0.12	0.25	35
139	13	78	1.8	5000	6000	0.035	0	0.02	0.25	141
140	79	12	1.2	10000	6400	0.042	0	0.02	0.25	531
141	75	9	4	10000	50	0.03	0	0.5	10	135
142	75	8	2.5	10000	50	0.03	0	0.5	10	155
143	30	33	1.1	30000	5000	0.05	0	0.5	1	100
144	15	28	3.0	3000	78	0.05	0	0.5	1	100
145	75	8	4.1	10000	170	0.03	0	0.5	1	155

ALTERNATIVE 2 (LAKE BORGNE CLOSED)

02 04 10


N
MRGO - Violet Diversion
Salinity Modelling
Box Model Links
Alternative 2 - Lake Borgne Closed
0 5 10 20 30 40
Miles
Legend
Model Box Centriods
Alternative 2 links
Salinity Target Line
Model Boxes

02 04 10


N
MRGO - Violet Diversion
Salinity Modelling
Box Model Links (10K, 15K, 20K, 30K)
Links for High Flow Alternatives
0 5 10 20 30 40
Miles
Legend
Model Box Centriods
High Flow Links
Salinity Target Line
Model Boxes

APPENDIX E

UNO MASS BALANCE MODEL RESULTS TABLES AND FIGURES

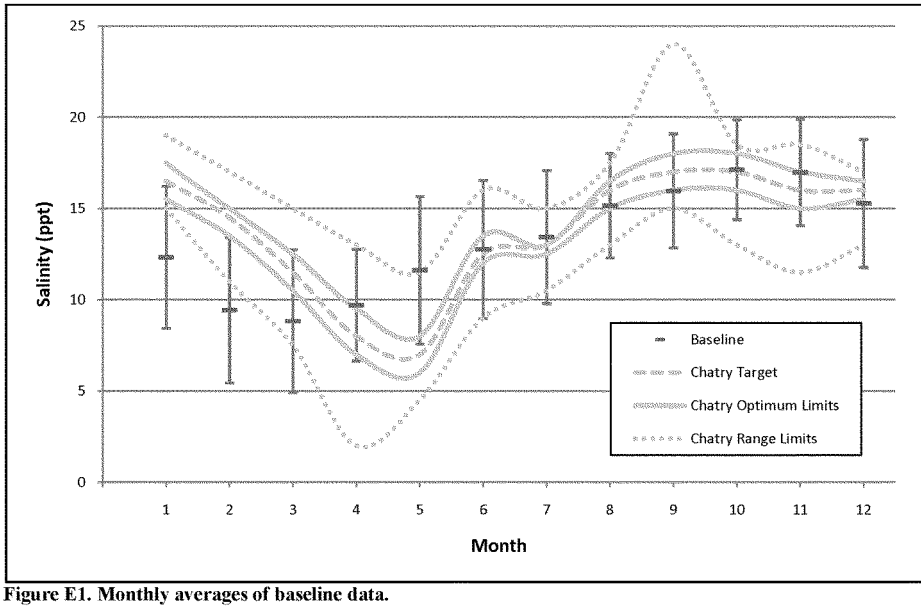


Figure E1. Monthly averages of baseline data.

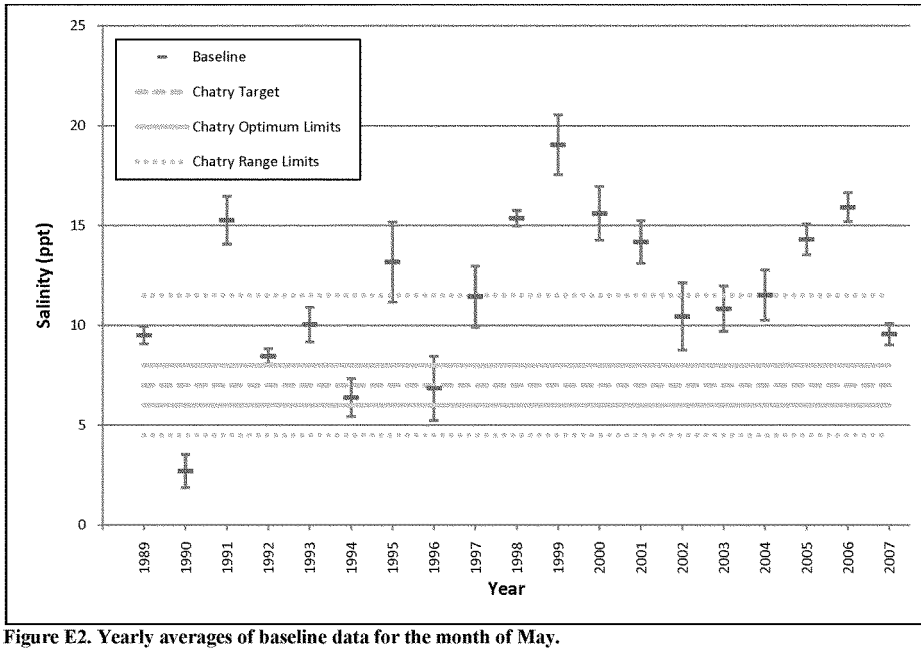


Figure E2. Yearly averages of baseline data for the month of May.

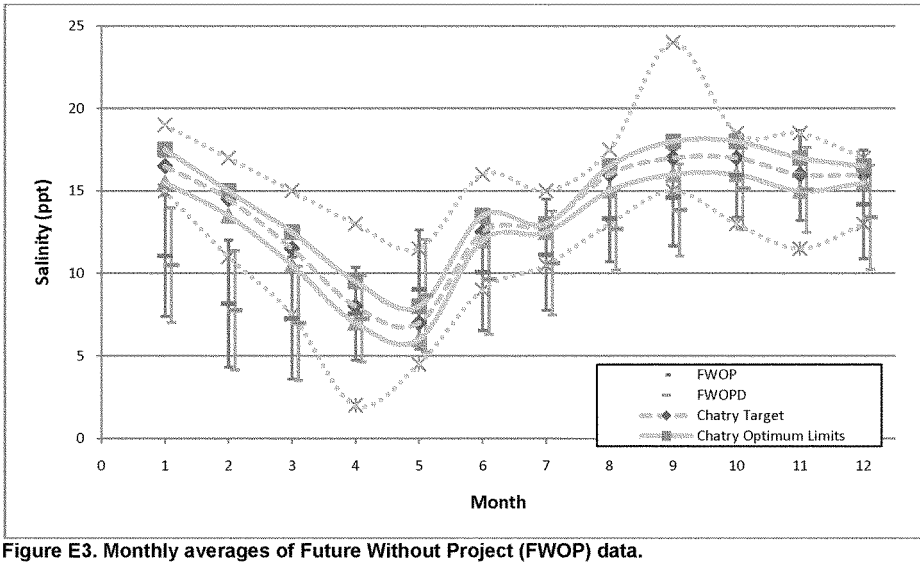


Figure E3. Monthly averages of Future Without Project (FWOP) data.

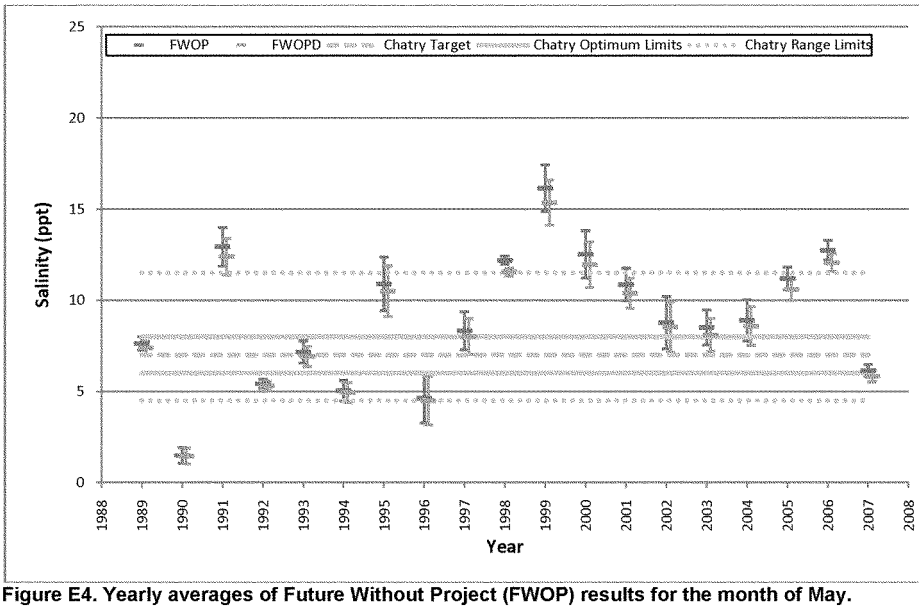


Figure E4. Yearly averages of Future Without Project (FWOP) results for the month of May.

03-10-2010

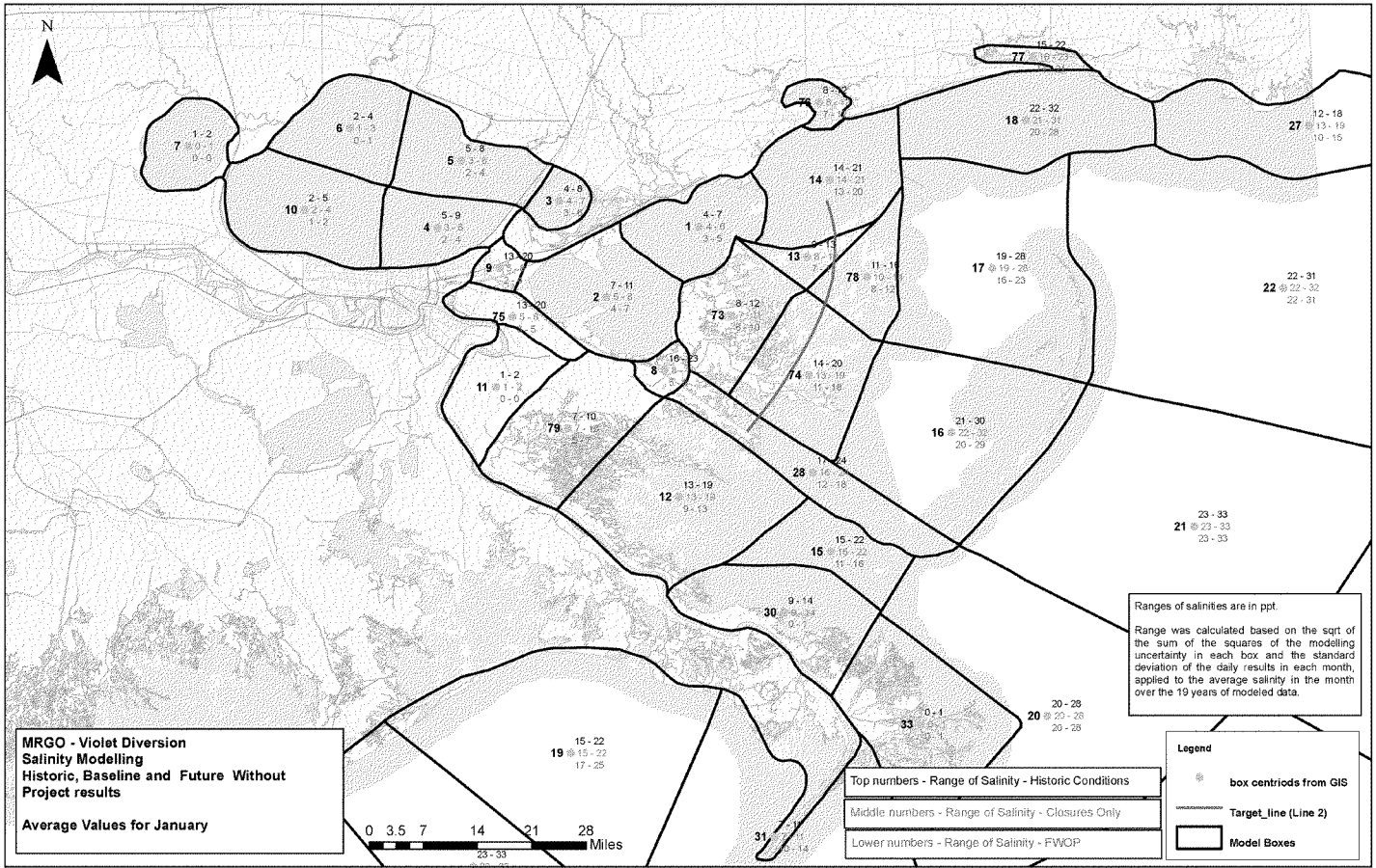


Figure E4. Results Values for Historic, Baseline, and FWOP for January.

03-10-2010

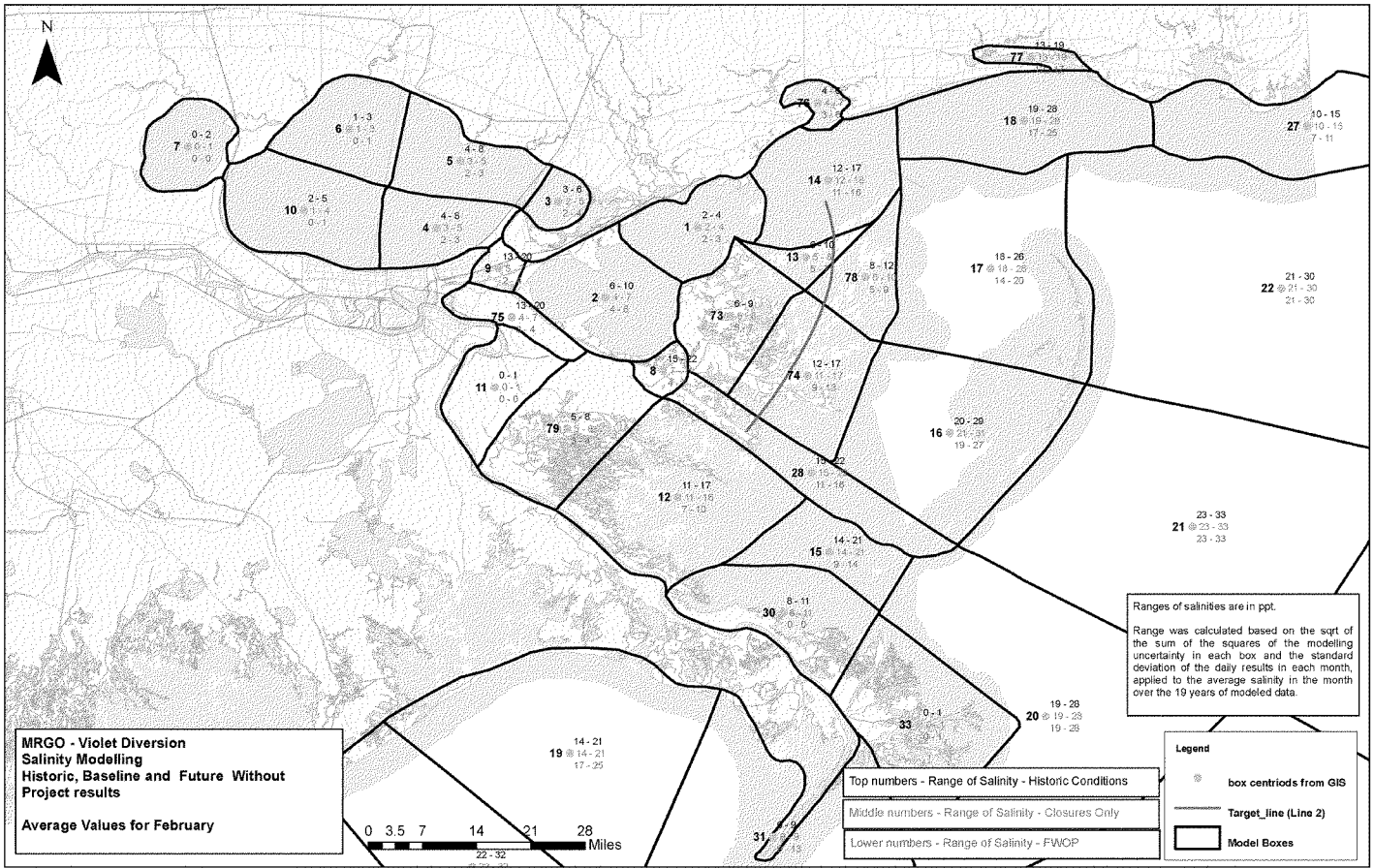


Figure E5. Results Values for Historic, Baseline, and FWOP for February.

03-10-2010

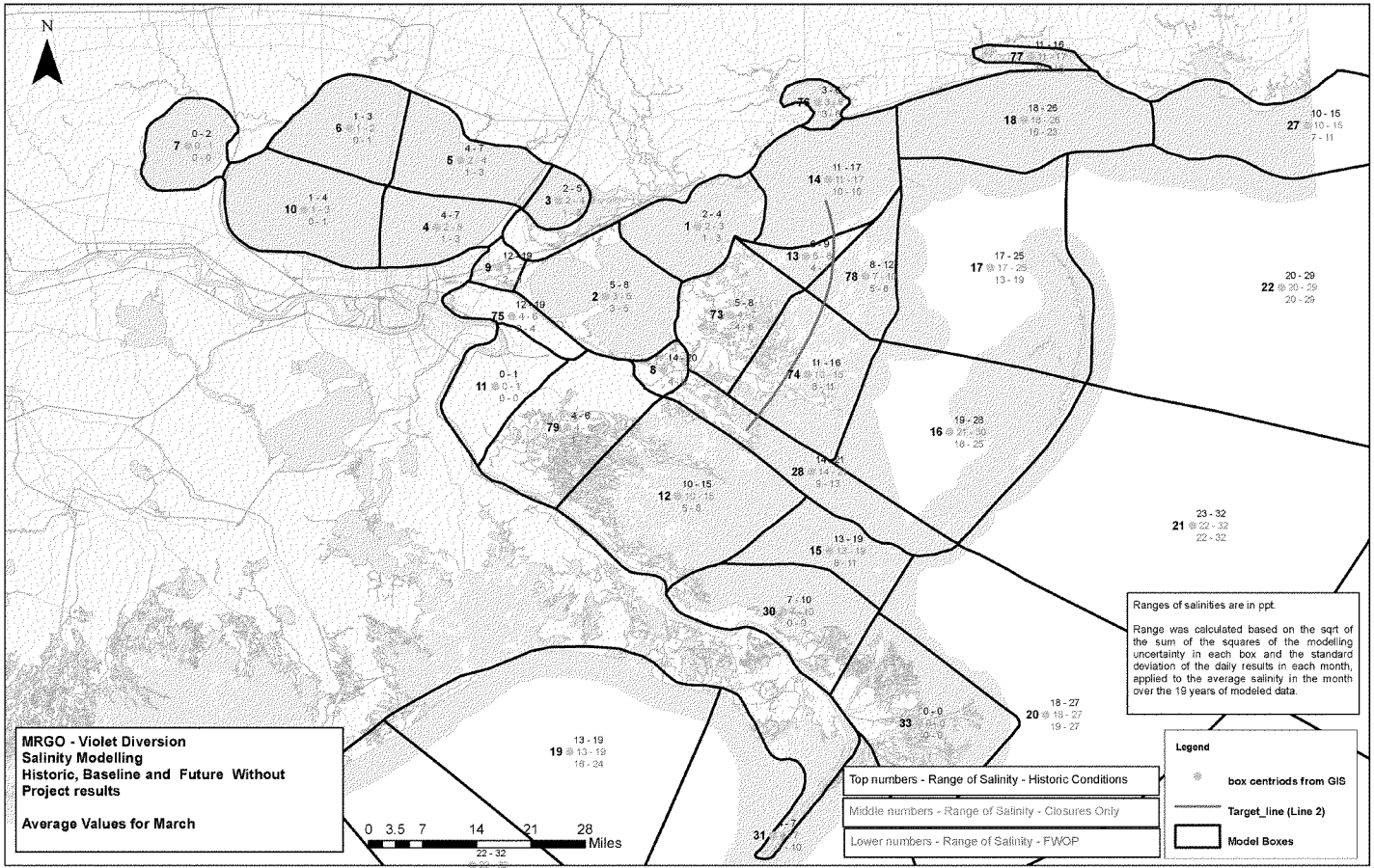


Figure E6. Results Values for Historic, Baseline, and FWOP for March

03-10-2010

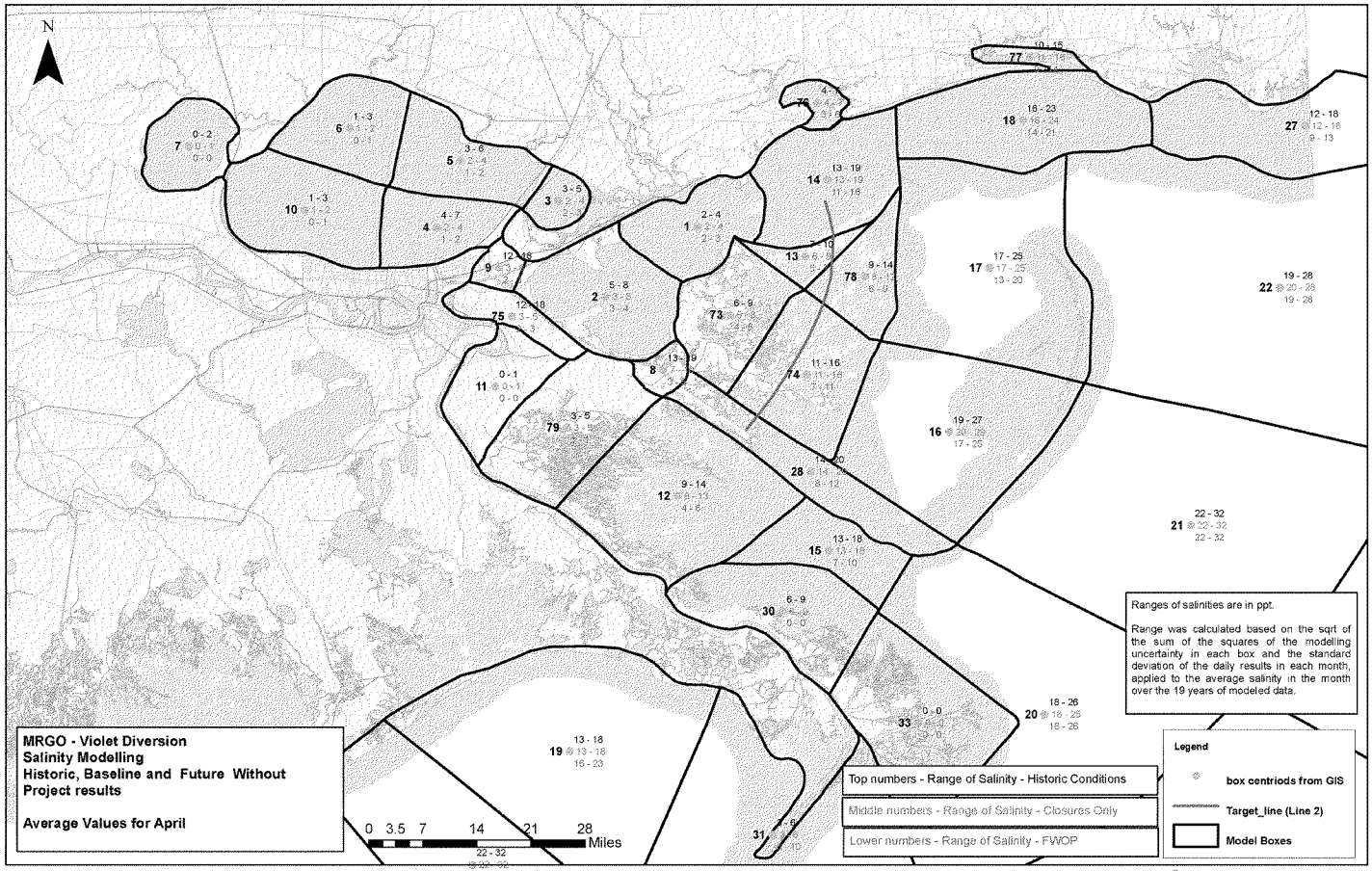


Figure E7. Results Values for Historic, Baseline, and FWOP for April

03-10-2010

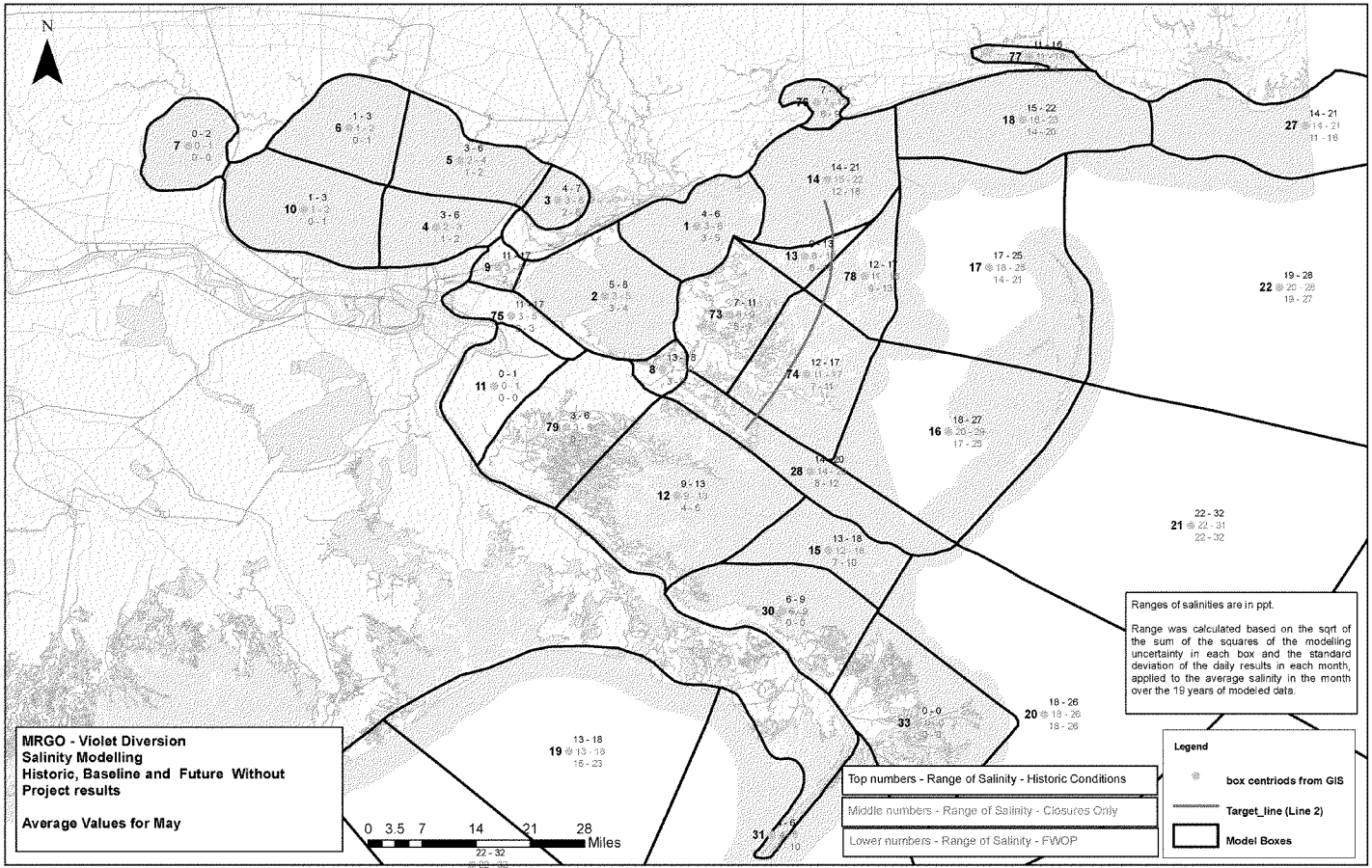


Figure E8. Results Values for Historic, Baseline, and FWOP for May.

03-10-2010

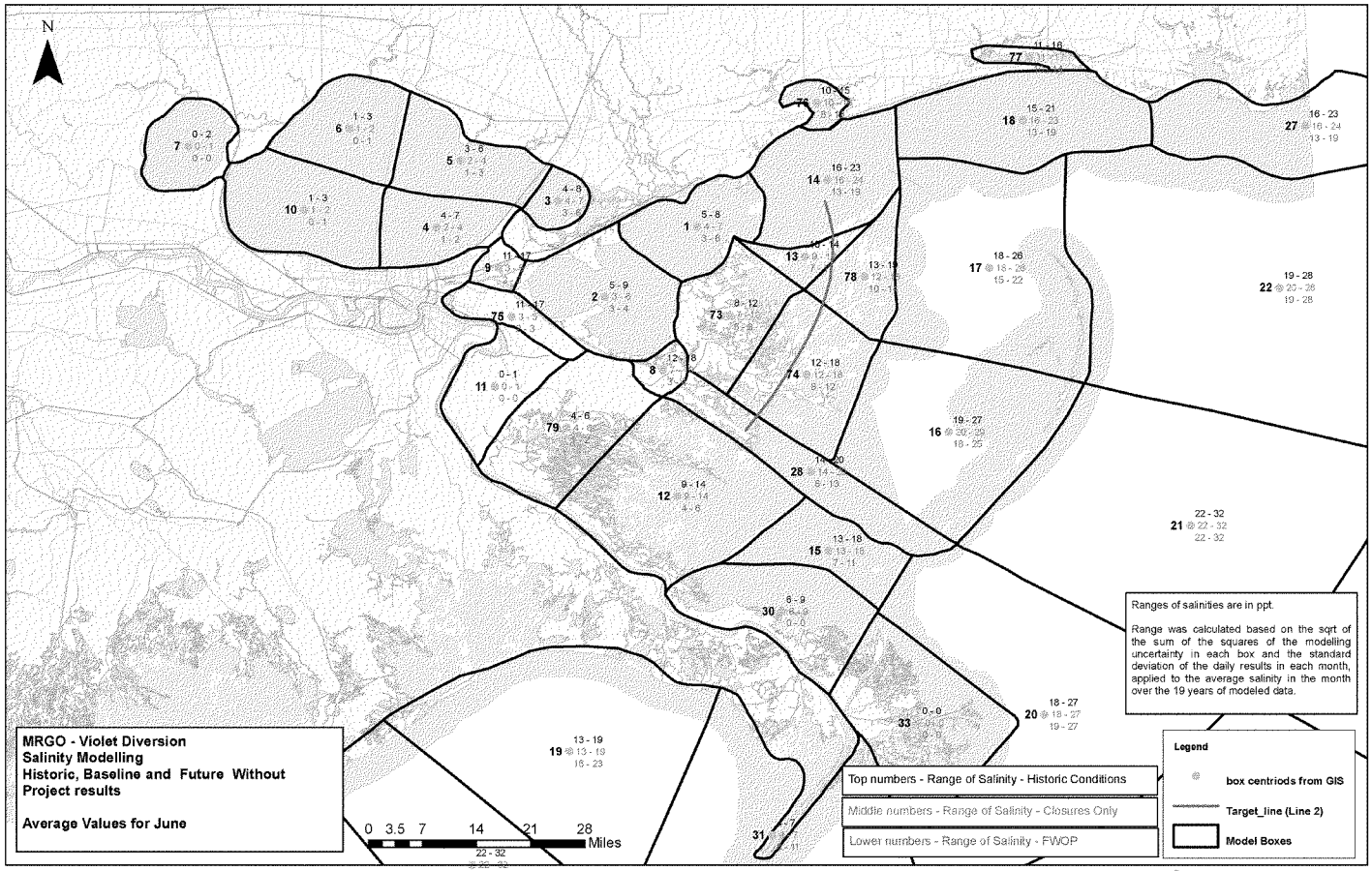


Figure E9. Results Values for Historic, Baseline, and FWOP for June.

03-10-2010

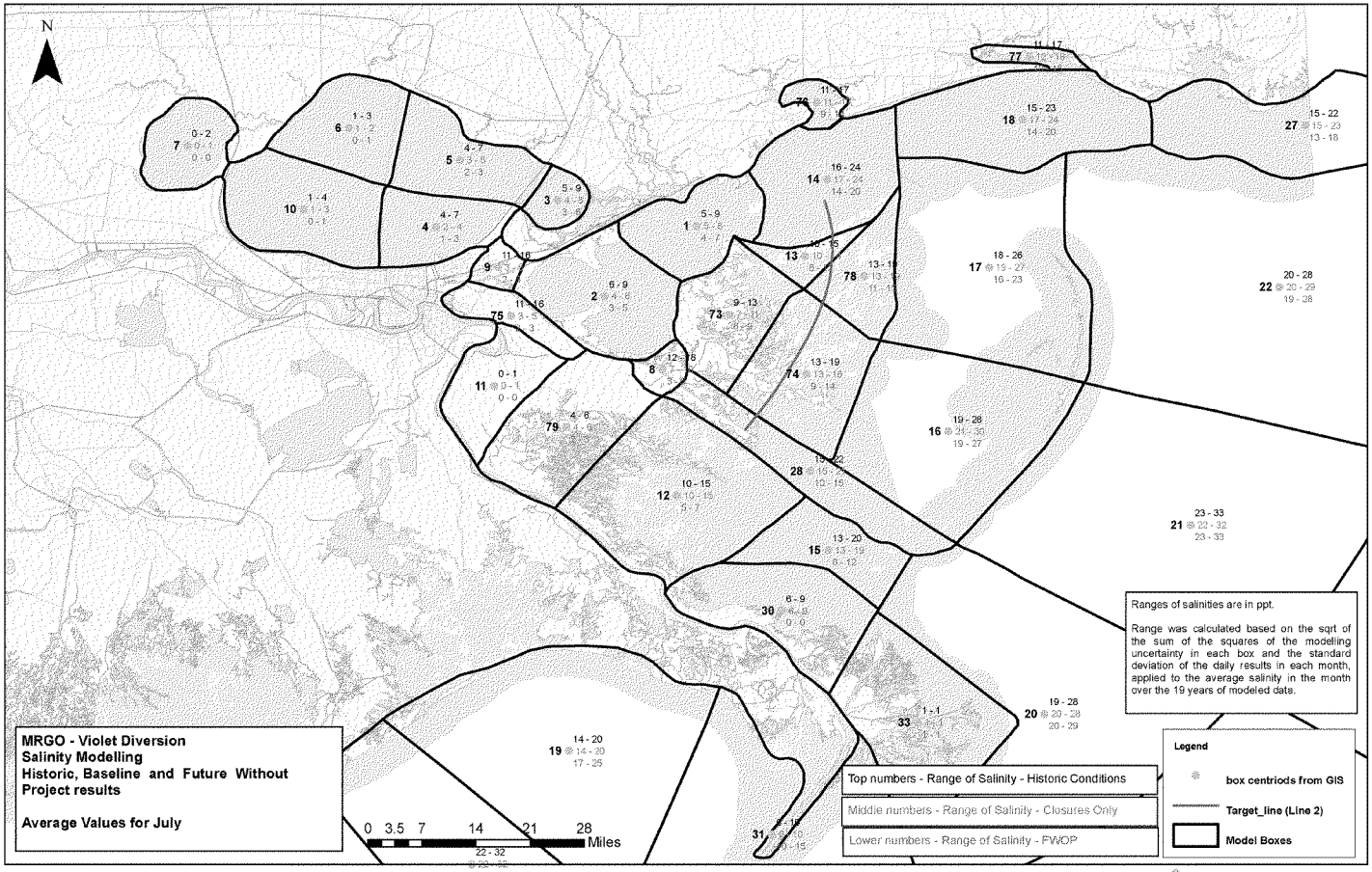


Figure E10. Results Values for Historic, Baseline, and FWOP for July.

03-10-2010

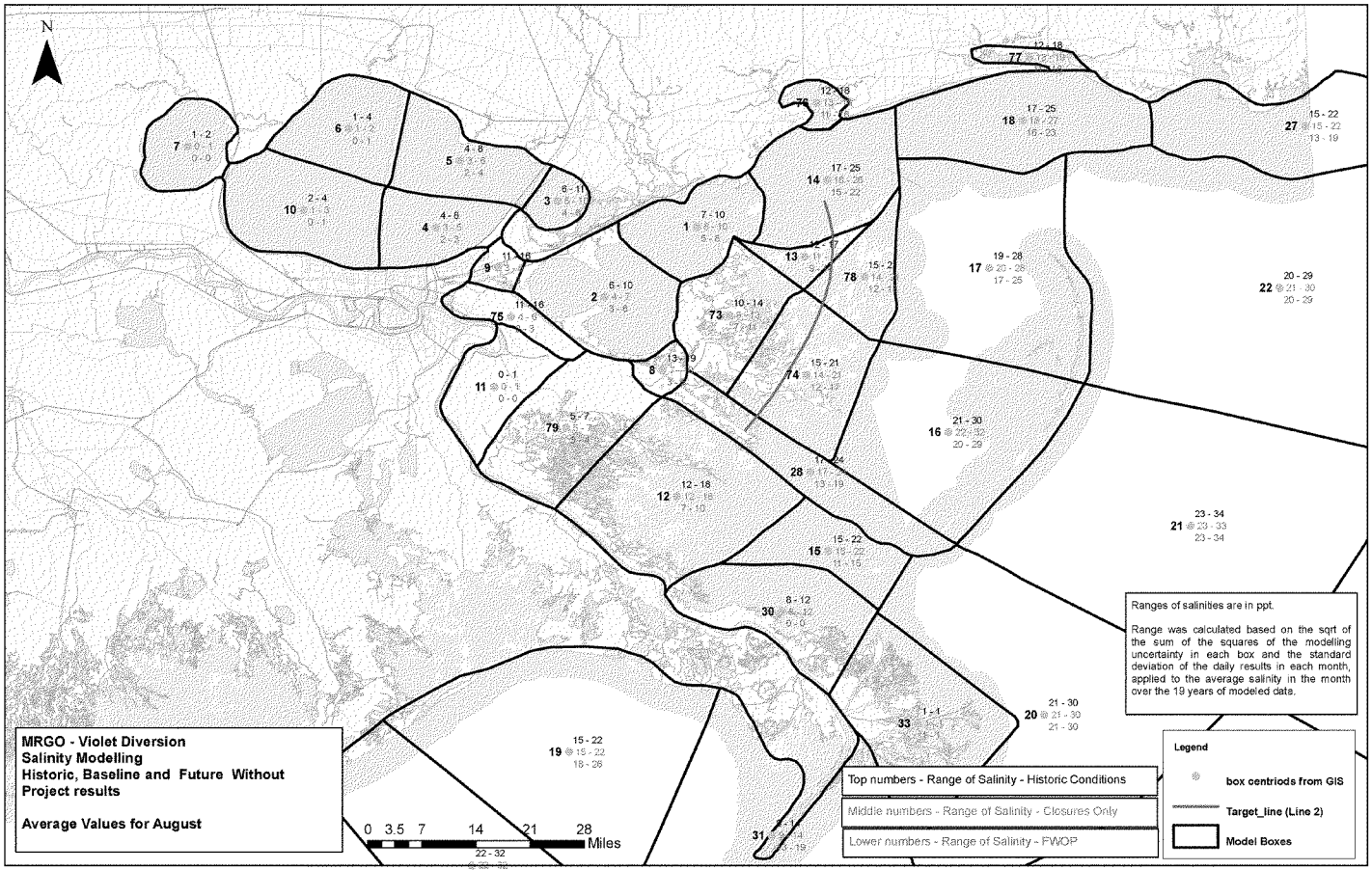


Figure E11. Results Values for Historic, Baseline, and FWOP for August

03-10-2010

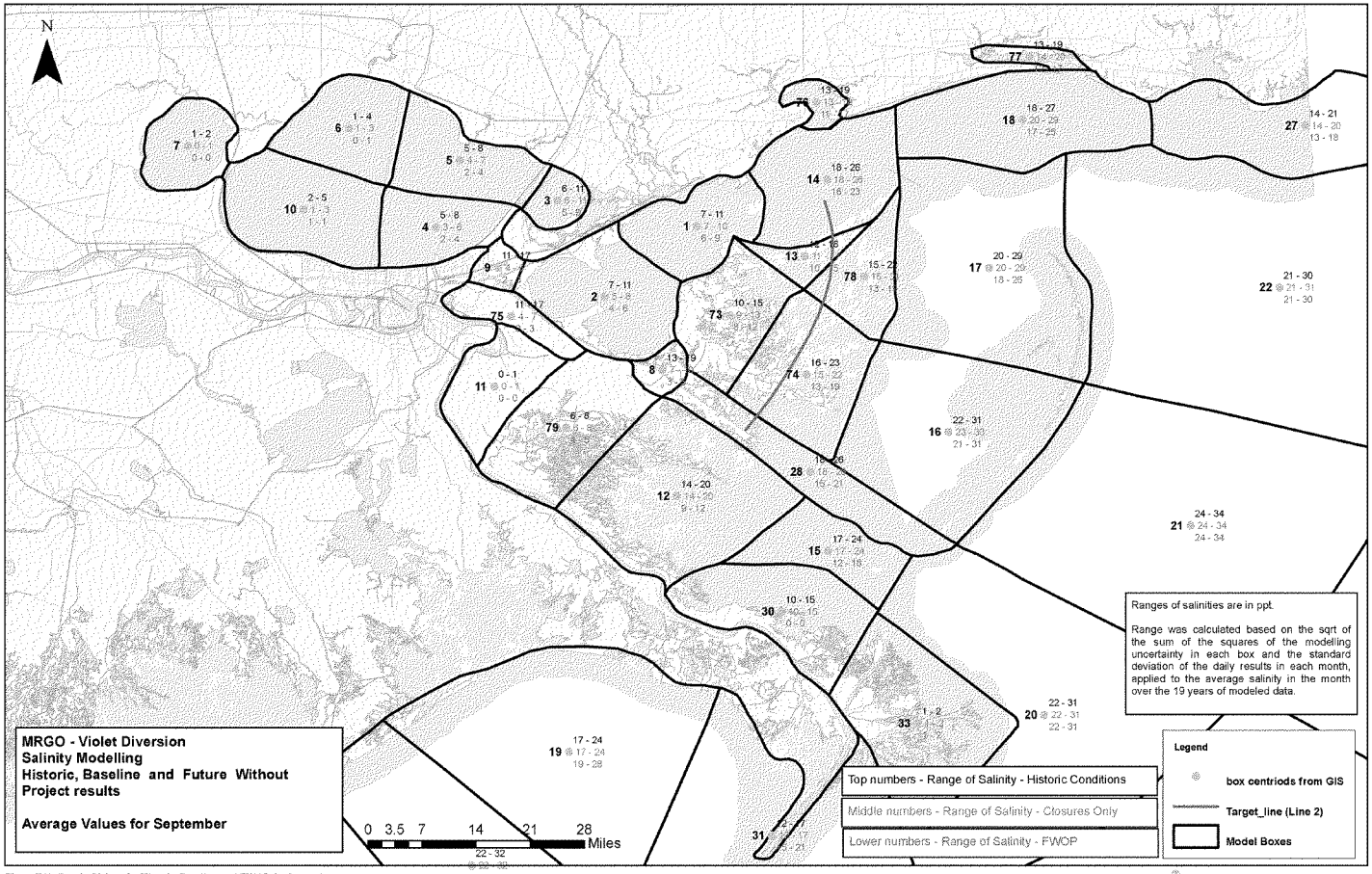


Figure E12. Results Values for Historic, Baseline, and FWOP for September.

03-10-2010

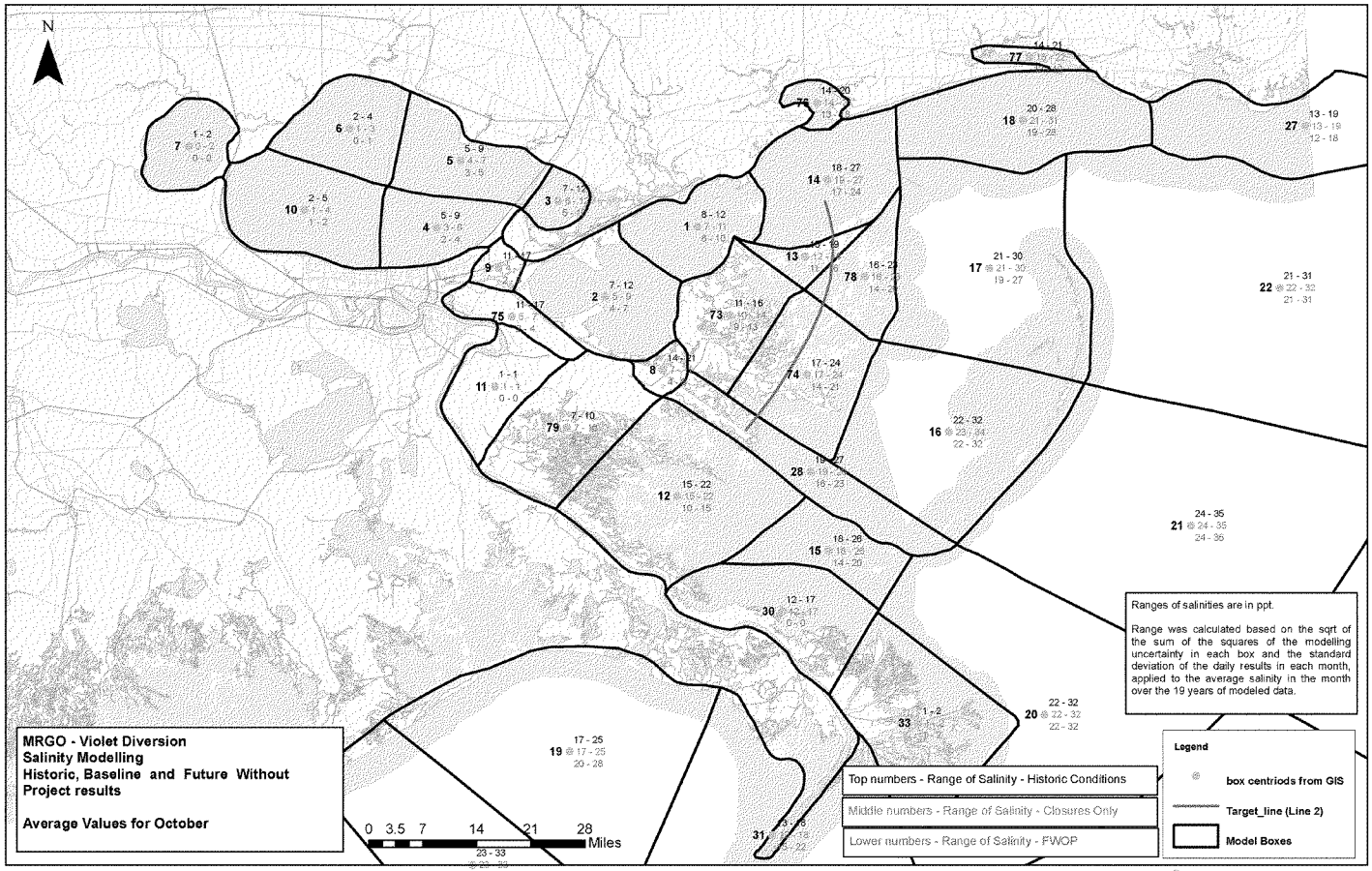


Figure E13. Results Values for Historic, Baseline, and FWOP for October.

03-10-2010

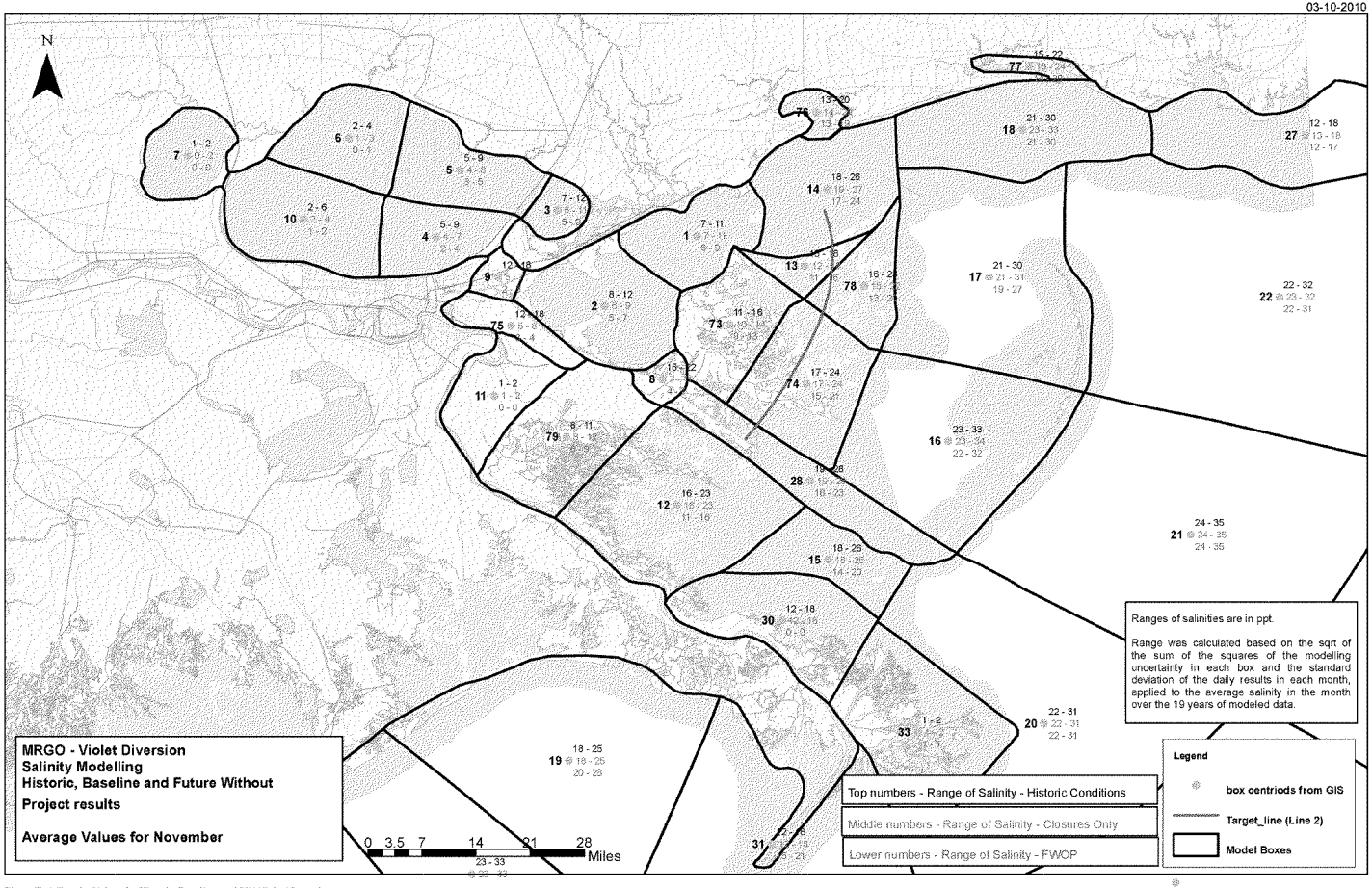


Figure E14. Results Values for Historic, Baseline, and FWOP for November.

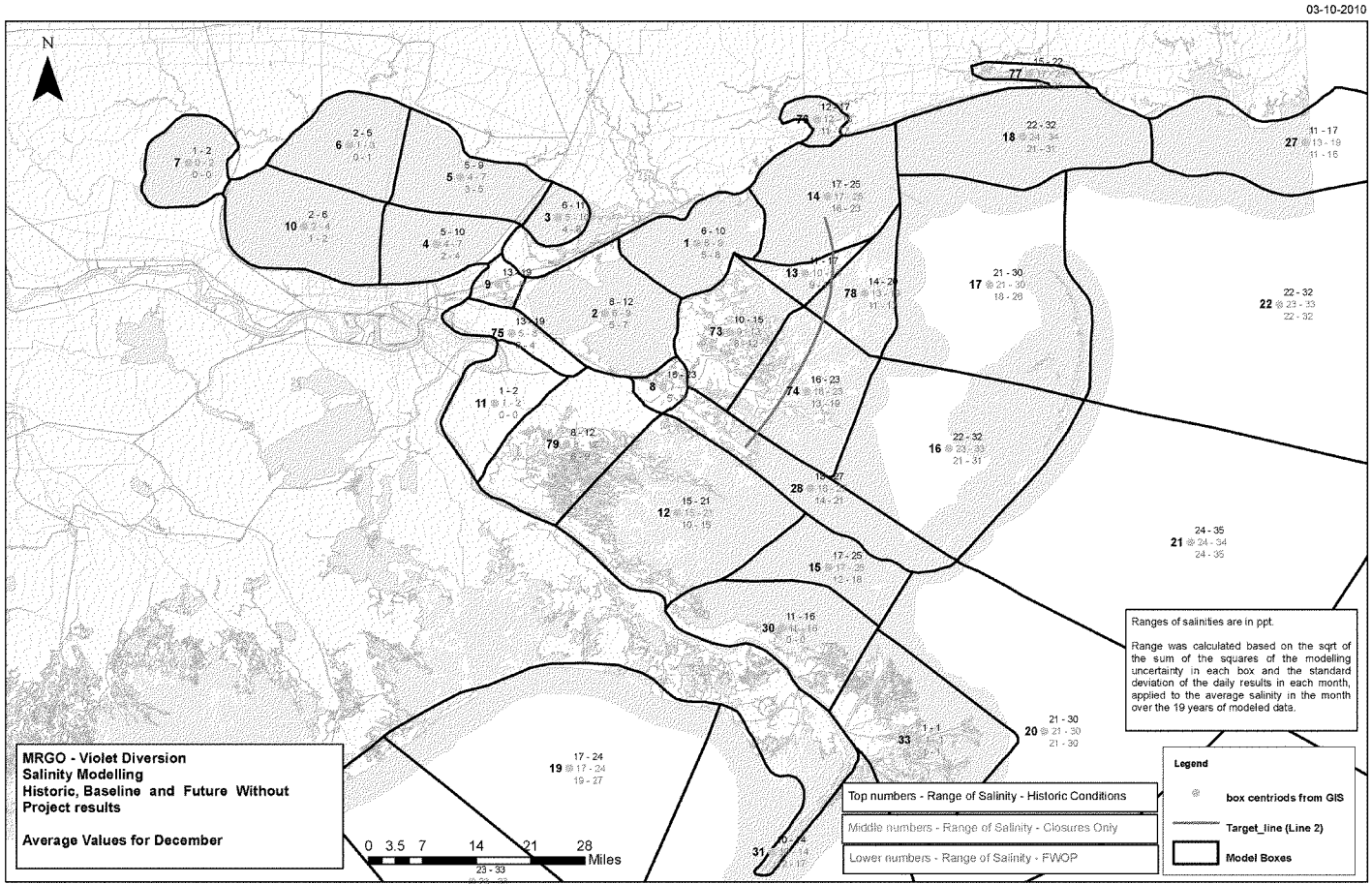


Figure E15. Results Values for Historic, Baseline, and FWOP for December

Table E1. FWP 1,000 cfs with Lake Borgn Open Condition Model Results – 1A1.

	Model Results		Model Uncertainty	
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	Below Chatry Target
January	10.73	3.27	2.07	99.8%
February	8.05	3.51	1.66	100.0%
March	7.32	3.36	1.53	99.9%
April	7.66	2.46	1.49	85.3%
May	9.07	3.40	1.81	26.7%
June	10.03	3.27	1.95	94.4%
July	11.04	3.10	2.11	84.7%
August	13.09	2.37	2.42	91.2%
September	14.24	2.74	2.64	91.7%
October	15.50	2.32	2.84	77.3%
November	15.35	2.45	2.82	70.9%
December	13.61	2.93	2.54	84.2%

Table E2. FWP 1,000/7000 cfs with Lake Borgne Open Condition Model Results – 7A1.

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	10.65	3.23	2.06	99.8%
February	8.00	3.47	1.65	100.0%
March	7.28	3.32	1.52	99.9%
April	7.54	2.38	1.46	87.4%
May	8.76	3.22	1.74	31.7%
June	9.75	3.08	1.89	96.2%
July	10.85	2.97	2.07	87.1%
August	12.90	2.28	2.38	92.6%
September	14.06	2.66	2.60	92.9%
October	15.62	2.26	2.81	79.4%
November	15.18	2.41	2.79	73.0%
December	13.48	2.88	2.52	85.4%

Table E3. FWP 10,000 cfs with Lake Borgne Open Condition Model Results – 10A3.

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	9.25	2.59	1.77	100.0%
February	7.06	2.80	1.43	100.0%
March	6.51	2.73	1.33	100.0%
April	6.86	2.02	1.32	95.8%
May	8.07	2.87	1.60	46.2%
June	8.85	2.63	1.70	99.1%
July	9.67	2.40	1.83	96.8%
August	11.37	1.77	2.09	98.8%
September	12.27	2.15	2.26	99.0%
October	13.26	1.75	2.42	95.7%
November	13.00	1.89	2.38	94.1%
December	11.51	2.23	2.13	98.0%

Table E4. FWP 15,000 cfs Condition Model Results – 15A3.

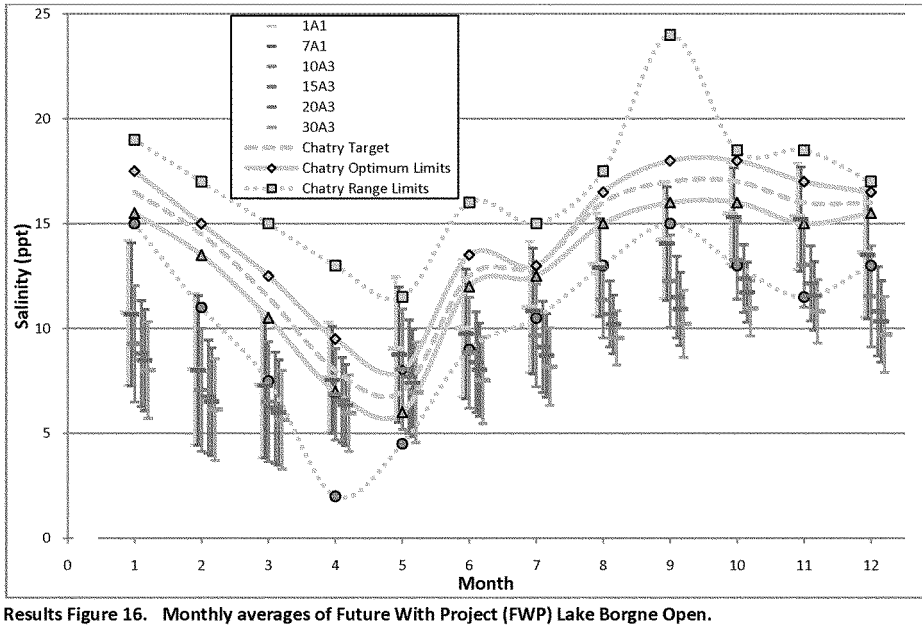
	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	8.78	2.34	1.67	100.0%
February	6.75	2.56	1.35	100.0%
March	6.23	2.50	1.26	100.0%
April	6.58	1.88	1.26	97.7%
May	7.72	2.68	1.52	55.2%
June	8.39	2.37	1.61	99.7%
July	9.13	2.12	1.71	98.7%
August	10.69	1.51	1.96	99.6%
September	11.50	1.88	2.11	99.7%
October	12.39	1.50	2.26	98.4%
November	12.13	1.68	2.22	97.8%
December	10.80	1.96	1.99	99.3%

Table E5. FWP 20,000 cfs Condition Model Results –20A3.

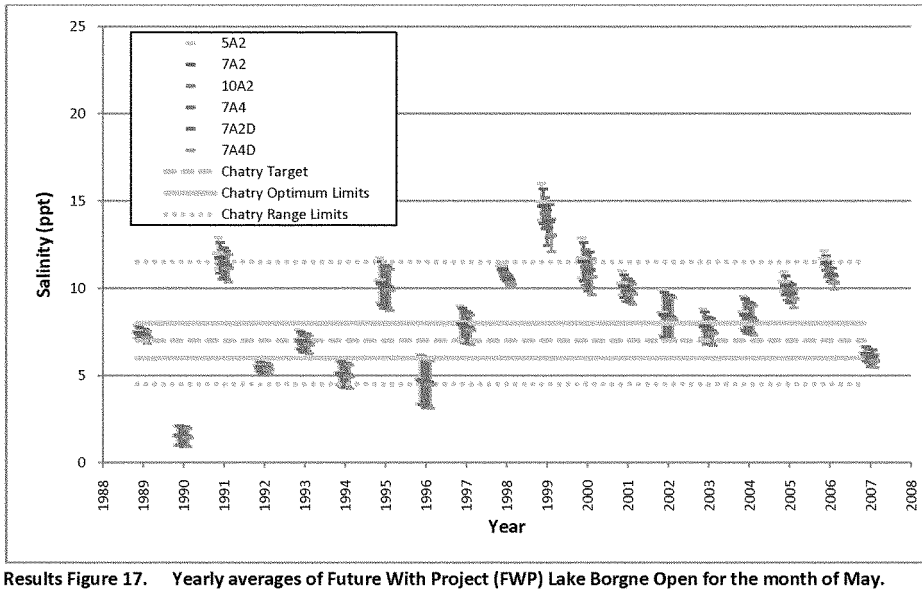
	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	8.47	2.22	1.61	100.0%
February	6.51	2.43	1.30	100.0%
March	6.00	2.35	1.21	100.0%
April	6.34	1.79	1.21	98.7%
May	7.42	2.55	1.46	63.3%
June	8.02	2.19	1.53	99.9%
July	8.73	1.92	1.63	99.4%
August	10.20	1.32	1.86	99.8%
September	10.94	1.67	2.01	99.9%
October	11.74	1.31	2.13	99.4%
November	11.53	1.54	2.11	99.0%
December	10.32	1.77	1.90	99.7%

Table E6. FWP 30,000 cfs Condition Model Results – 30A3.

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Error (ppt)	Sigma (ppt)	
Jan	8.47	2.22	1.61	100.0%
Feb	6.51	2.43	1.30	100.0%
Mar	6.00	2.35	1.21	100.0%
Apr	6.34	1.79	1.21	98.7%
May	7.42	2.55	1.46	63.3%
Jun	8.02	2.19	1.53	99.9%
Jul	8.73	1.92	1.63	99.4%
Aug	10.20	1.32	1.86	99.8%
Sep	10.94	1.67	2.01	99.9%
Oct	11.74	1.31	2.13	99.4%
Nov	11.53	1.54	2.11	99.0%
Dec	10.32	1.77	1.90	99.7%



Results Figure 16. Monthly averages of Future With Project (FWP) Lake Borgne Open.



Results Figure 17. Yearly averages of Future With Project (FWP) Lake Borgne Open for the month of May.

Table E7. FWP 1,000/5,000 cfs with Lake Borgne Closed Condition Model Results – 5A2.

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	10.58	3.22	2.04	99.8%
February	7.95	3.45	1.63	100.0%
March	7.22	3.30	1.51	99.9%
April	7.44	2.37	1.45	88.9%
May	8.66	3.21	1.72	33.7%
June	9.70	3.11	1.89	96.4%
July	10.80	2.99	2.06	87.6%
August	12.84	2.30	2.37	93.0%
September	13.98	2.67	2.59	93.4%
October	15.23	2.66	2.79	80.4%
November	15.08	2.41	2.77	74.3%
December	13.39	2.88	2.50	86.4%

Table E8. FWP 1,000/7,000 cfs with Lake Borgne Closed Condition Model Results – 7A2.

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	10.59	3.21	2.04	99.8%
February	7.94	3.44	1.63	100.0%
March	7.22	3.30	1.50	99.9%
April	7.37	2.35	1.43	89.9%
May	8.50	3.14	1.69	36.7%
June	9.60	3.04	1.86	96.9%
July	10.75	2.95	2.05	88.3%
August	12.80	2.27	2.36	93.3%
September	13.94	2.65	2.58	93.6%
October	15.20	2.52	2.78	80.7%
November	15.05	2.40	2.76	74.6%
December	13.37	2.87	2.49	86.6%

Table E9. FWP 7,000 cfs all year with Lake Borgne Closed Condition Model Results – 7A4.

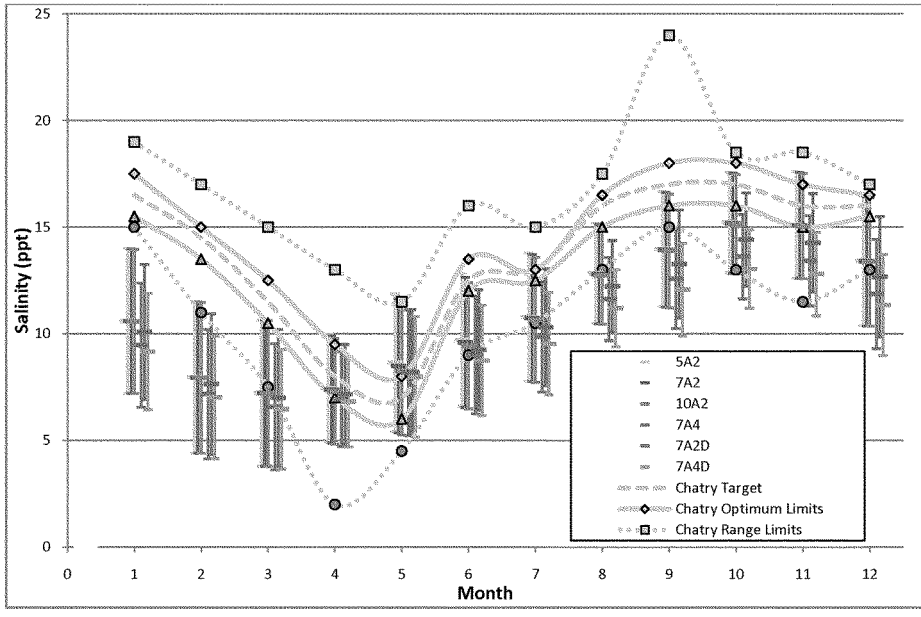
	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	9.45	2.74	1.81	100.0%
February	7.16	2.92	1.45	100.0%
March	6.58	2.82	1.35	100.0%
April	6.93	2.07	1.33	95.2%
May	8.19	2.94	1.62	43.6%
June	9.00	2.74	1.74	98.8%
July	9.87	2.55	1.87	95.7%
August	11.63	1.90	2.14	98.2%
September	12.58	2.28	2.32	98.5%
October	13.62	1.87	2.49	93.9%
November	13.39	2.02	2.45	91.6%
December	11.84	2.39	2.20	96.9%

Table E10. FWP 1,000/7,000 cfs with Lake Borgne Closed and Lake Maurepas Diversions at 4,500 cfs Condition Model Results – 7A2D.

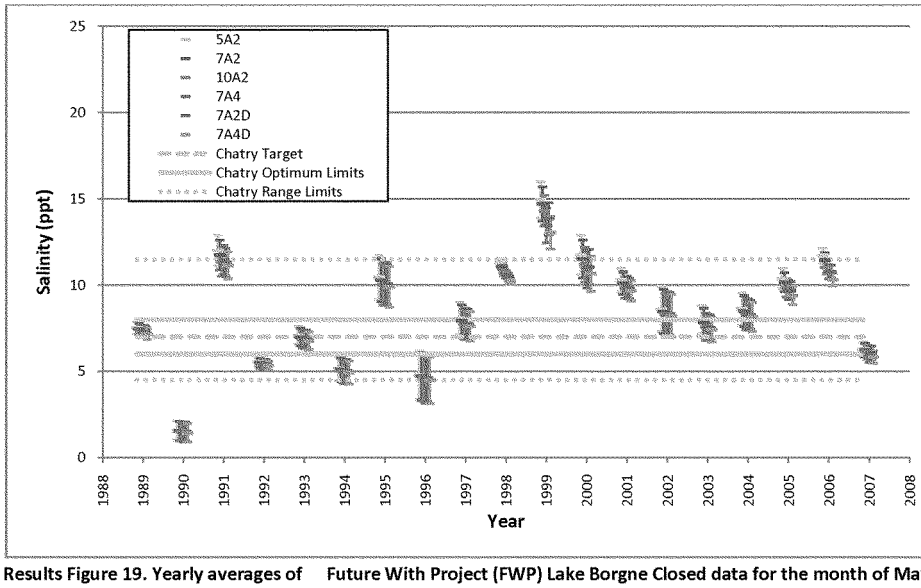
	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	10.06	2.98	1.94	99.9%
February	7.64	3.20	1.56	100.0%
March	7.00	3.07	1.44	99.9%
April	7.15	2.17	1.38	92.9%
May	8.21	2.94	1.62	43.0%
June	9.24	2.81	1.78	98.2%
July	10.32	2.71	1.96	92.5%
August	12.23	2.09	2.25	96.3%
September	13.27	2.49	2.46	96.6%
October	14.43	2.10	2.64	88.2%
November	14.24	2.22	2.61	84.1%
December	12.65	2.66	2.36	92.6%

Table E11. FWP 7,000 cfs all year with Lake Borgne Closed and Lake Maurepas Diversions at 4,500 cfs Condition Model Results – 7A4D.

	Model Results		Model Uncertainty	Below Chatry Target
	Mean (ppt)	Std Dev (ppt)	Sigma (ppt)	
January	9.15	2.56	1.75	100.0%
February	7.01	2.75	1.41	100.0%
March	6.47	2.66	1.31	100.0%
April	6.81	1.97	1.31	96.2%
May	8.00	2.82	1.58	48.1%
June	8.74	2.57	1.68	99.3%
July	9.55	2.35	1.80	97.3%
August	11.20	1.75	2.06	99.0%
September	12.07	2.13	2.23	99.2%
October	13.04	1.73	2.38	96.6%
November	12.77	1.86	2.34	95.3%
December	11.32	2.21	2.10	98.4%



Results Figure 18. Monthly averages of Future With Project (FWP) Lake Borgne Closed.



Results Figure 19. Yearly averages of Future With Project (FWP) Lake Borgne Closed data for the month of May.

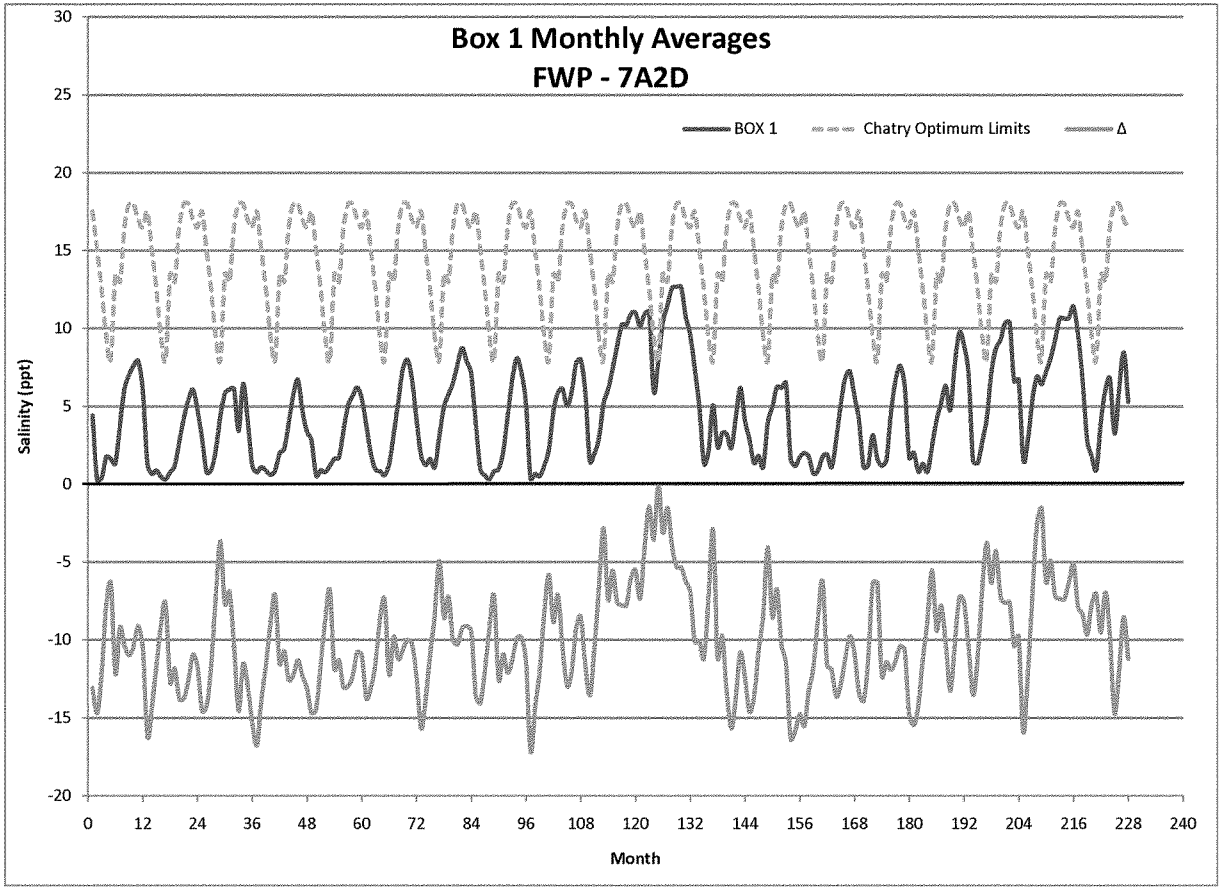


Figure E20. Time Series of Box 1 for Future With Project (FWP) Scenario 7A2D.

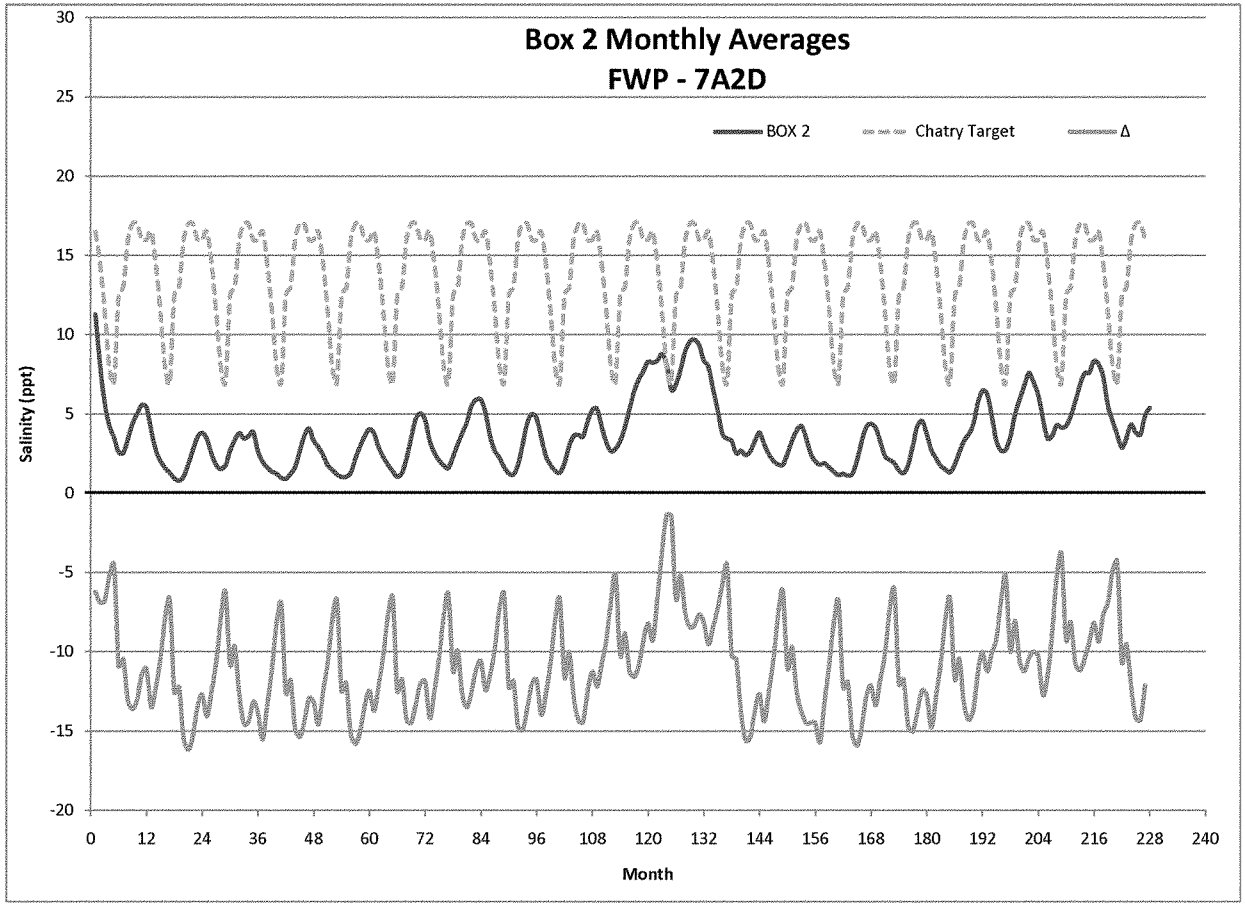


Figure E21. Time Series of Box 2 for Future With Project (FWP) Scenario 7A2D.

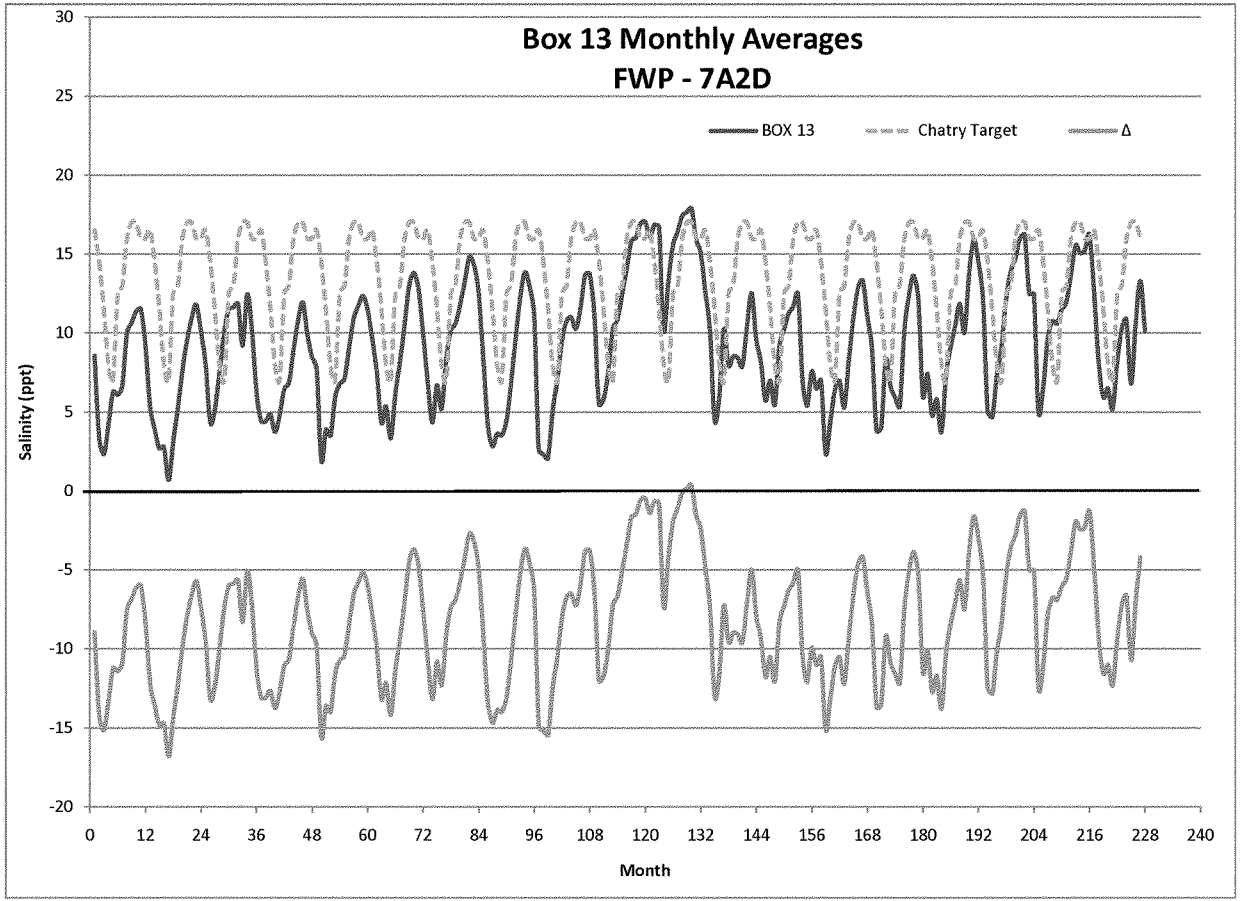


Figure E22. Time Series of Box 13 for Future With Project (FWP) Scenario 7A2D.

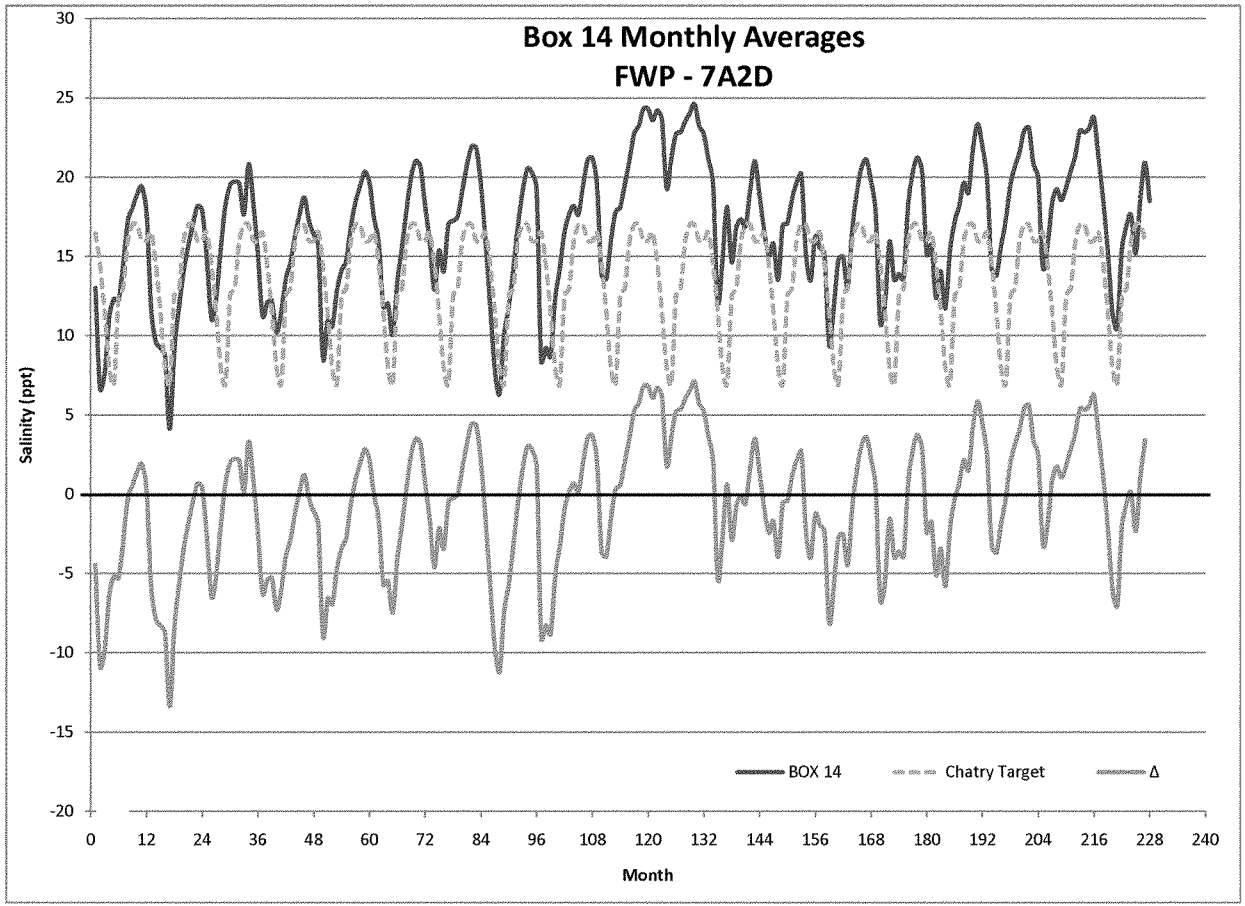


Figure E23. Time Series of Box 14 for Future With Project (FWP) Scenario 7A2D.

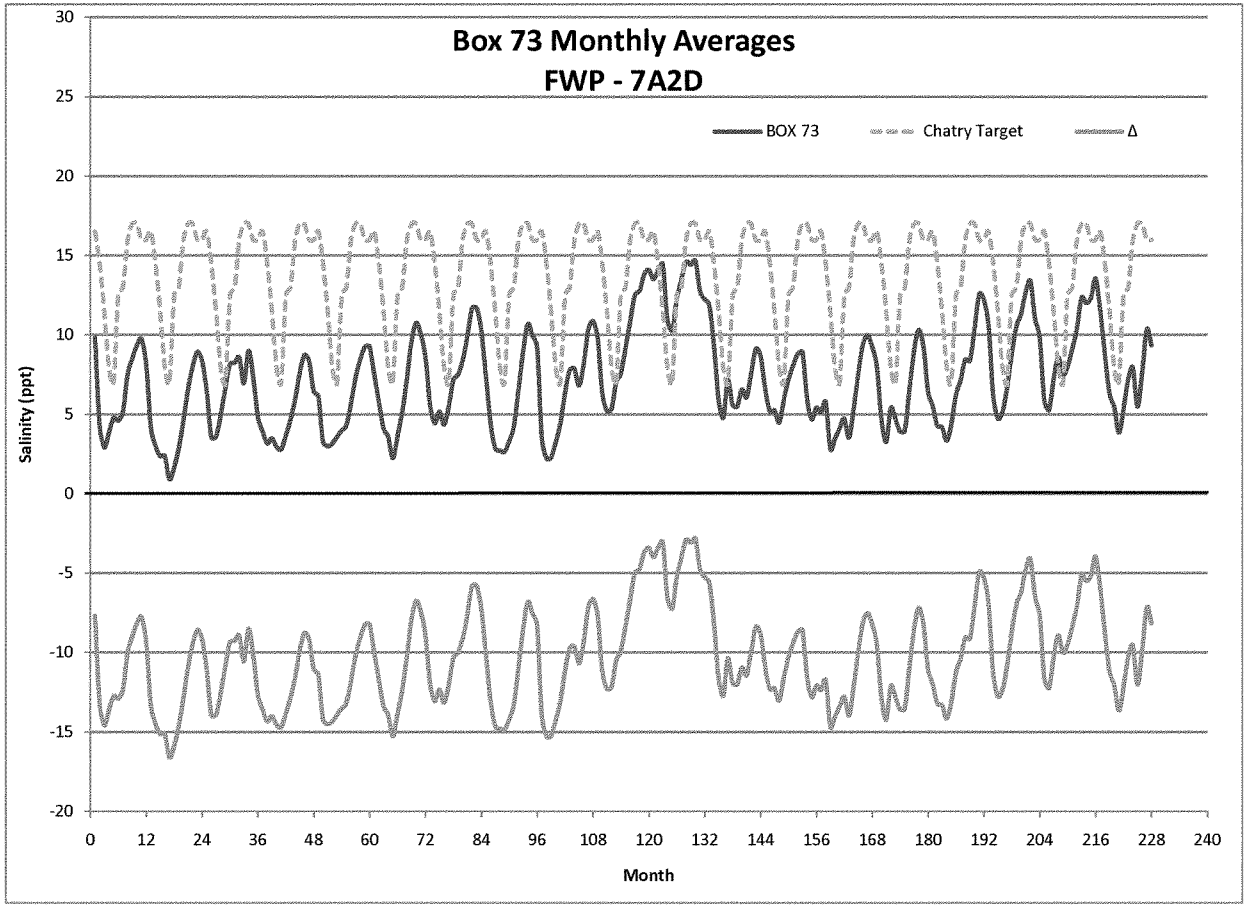


Figure E24. Time Series of Box 73 for Future With Project (FWP) Scenario 7A2D.

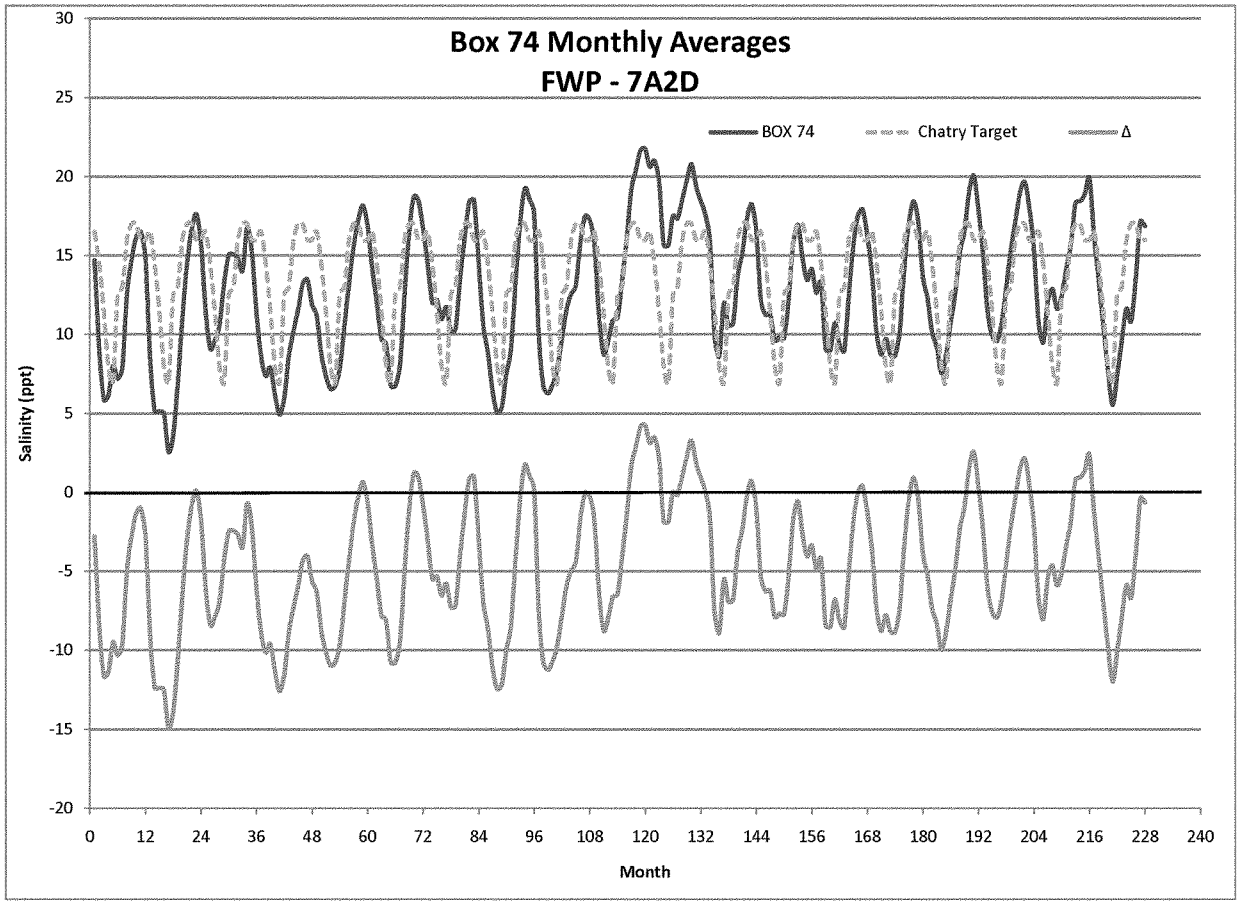


Figure E25. Time Series of Box 74 for Future With Project (FWP) Scenario 7A2D.

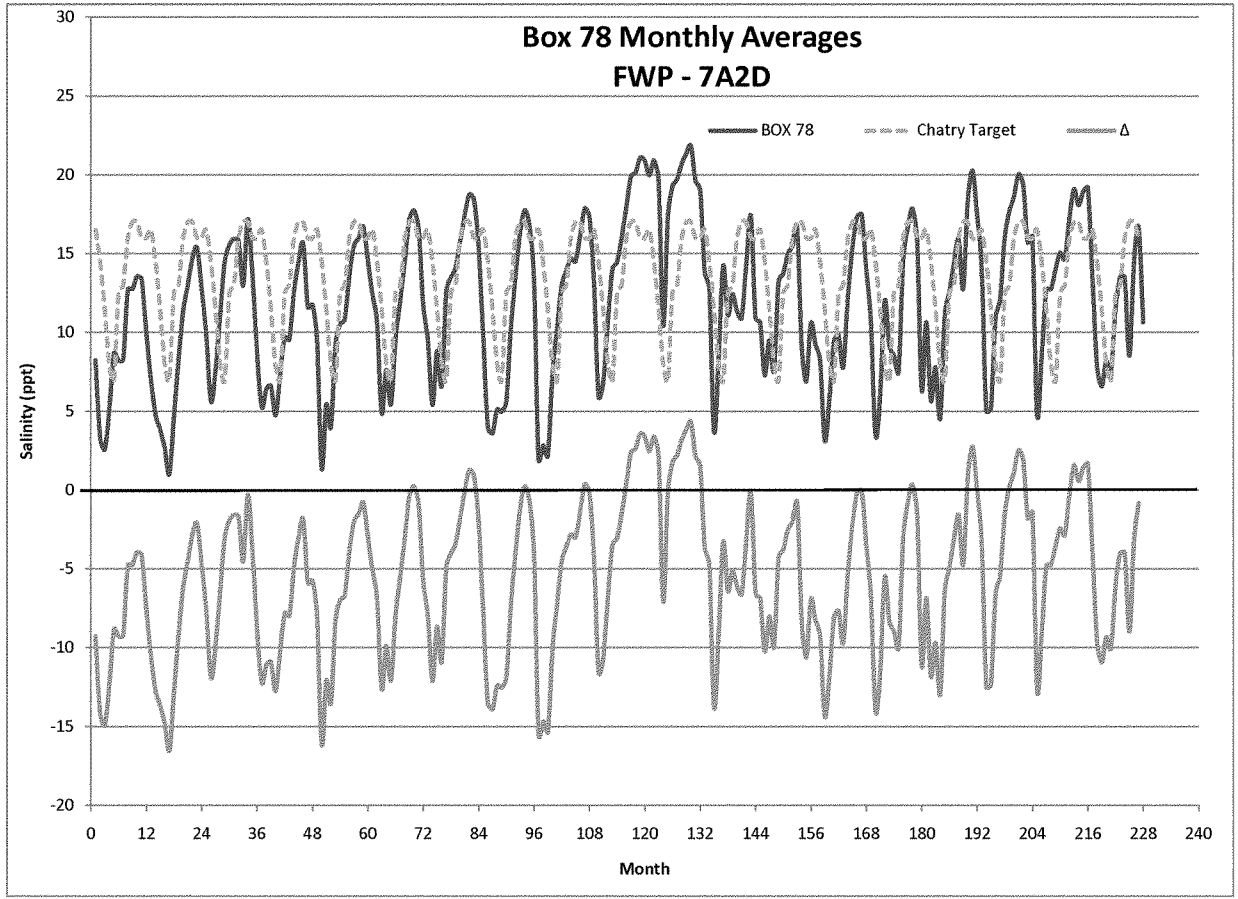


Figure E26. Time Series of Box 78 for Future With Project (FWP) Scenario 7A2D.

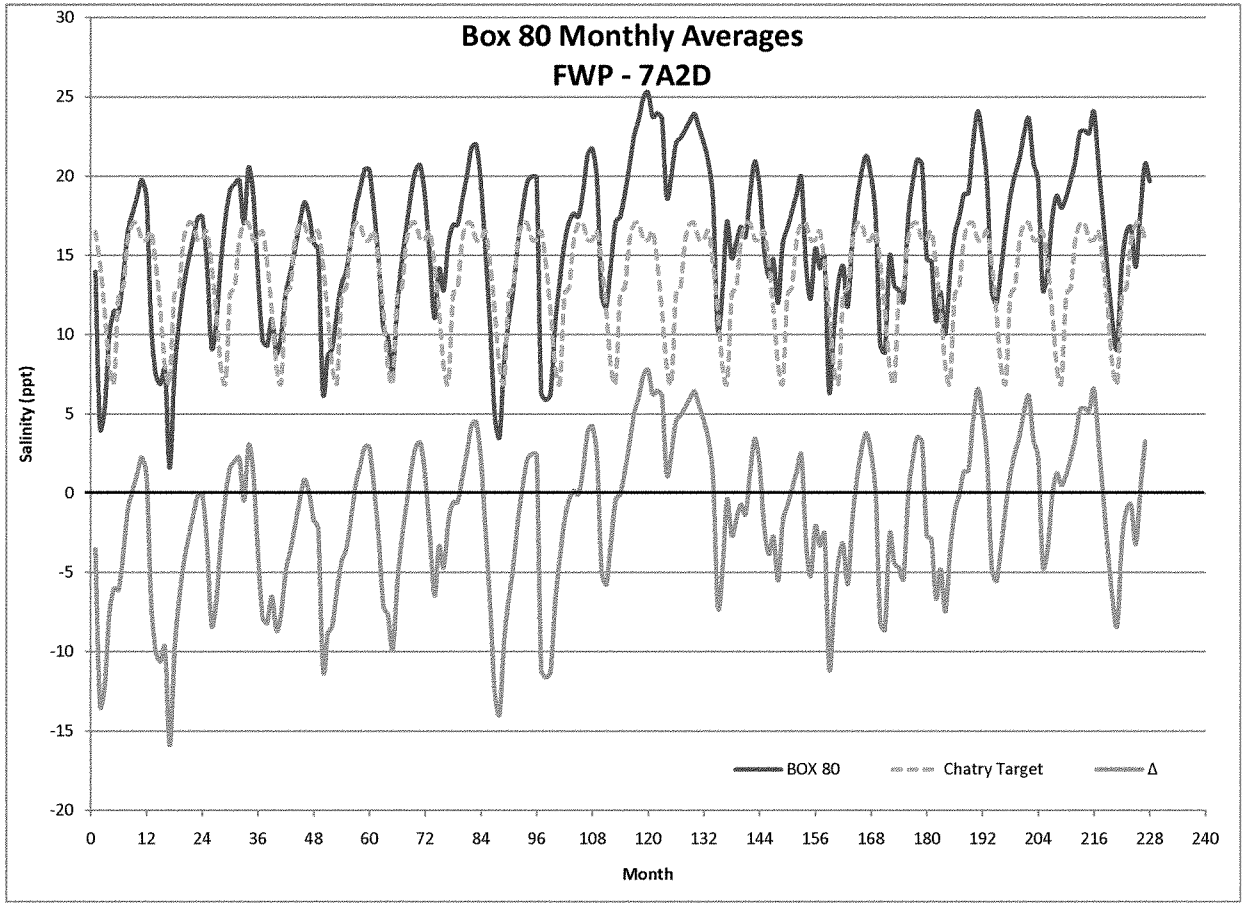


Figure E27. Time Series of Box 80 for Future With Project (FWP) Scenario 7A2D.

03-10-2010

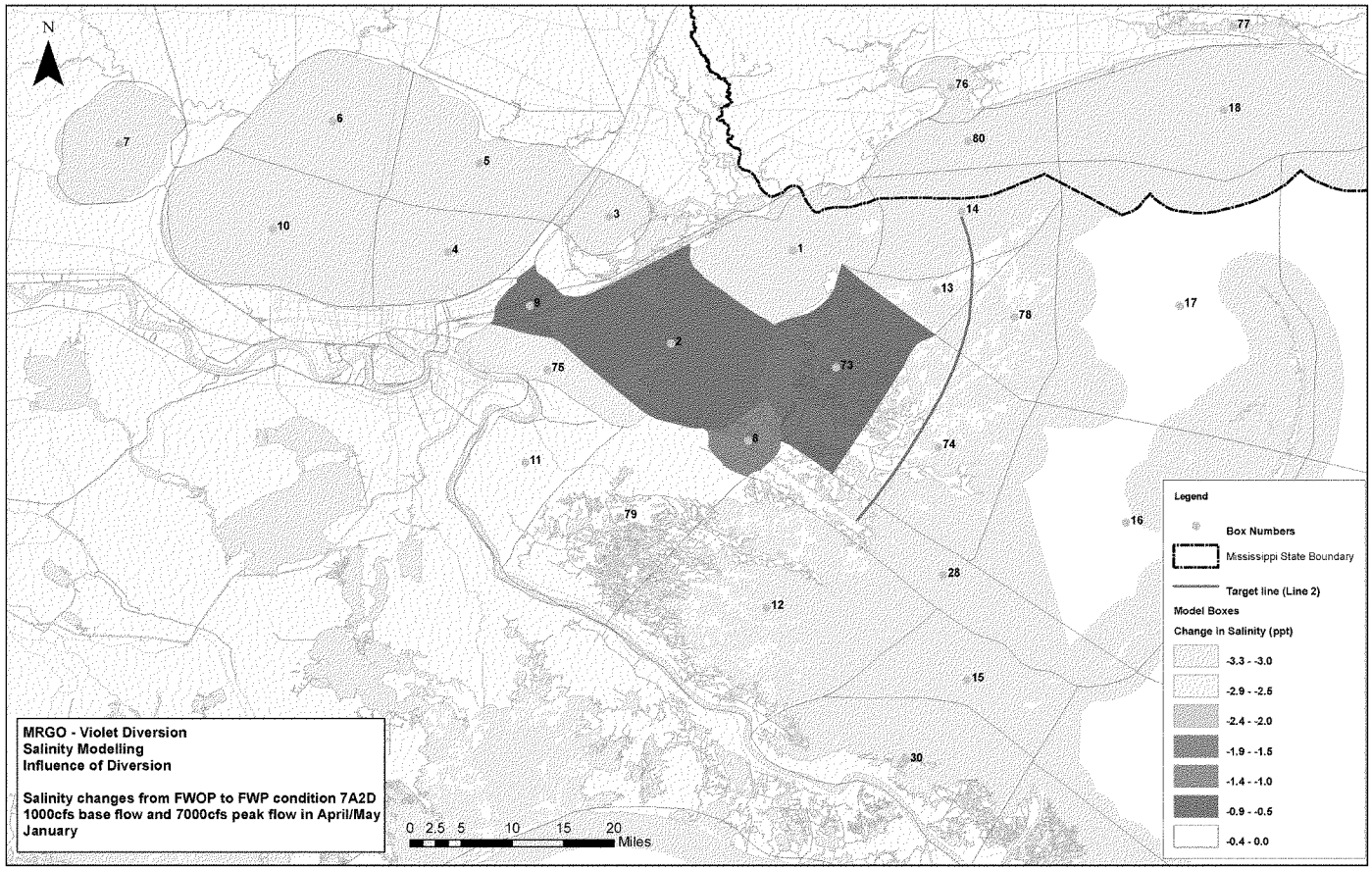


Figure E28. Influence Map showing change from FWOP to 7A2D in January.

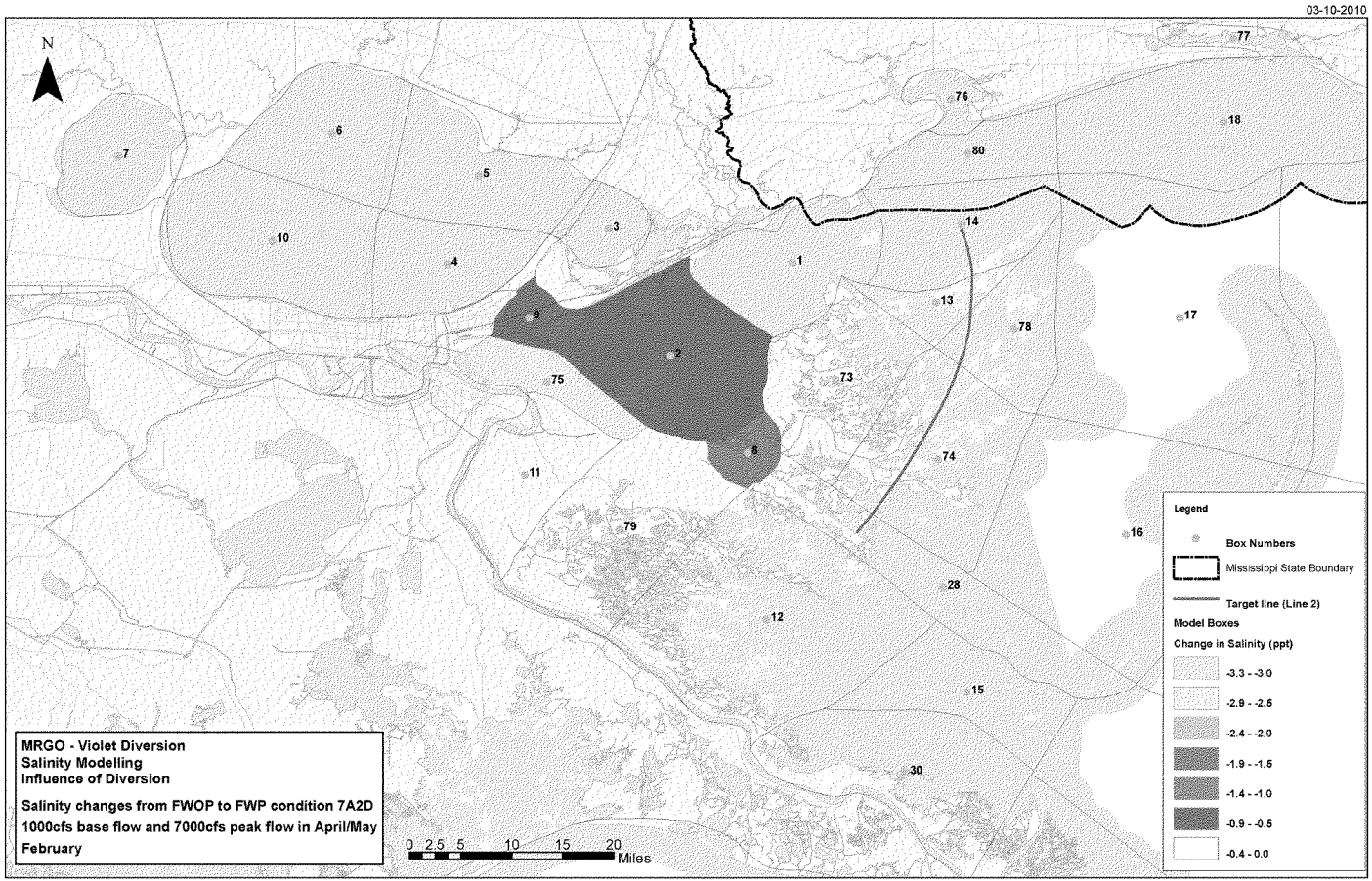


Figure E29. Influence Map showing change from FWOP to 7A2D in February.

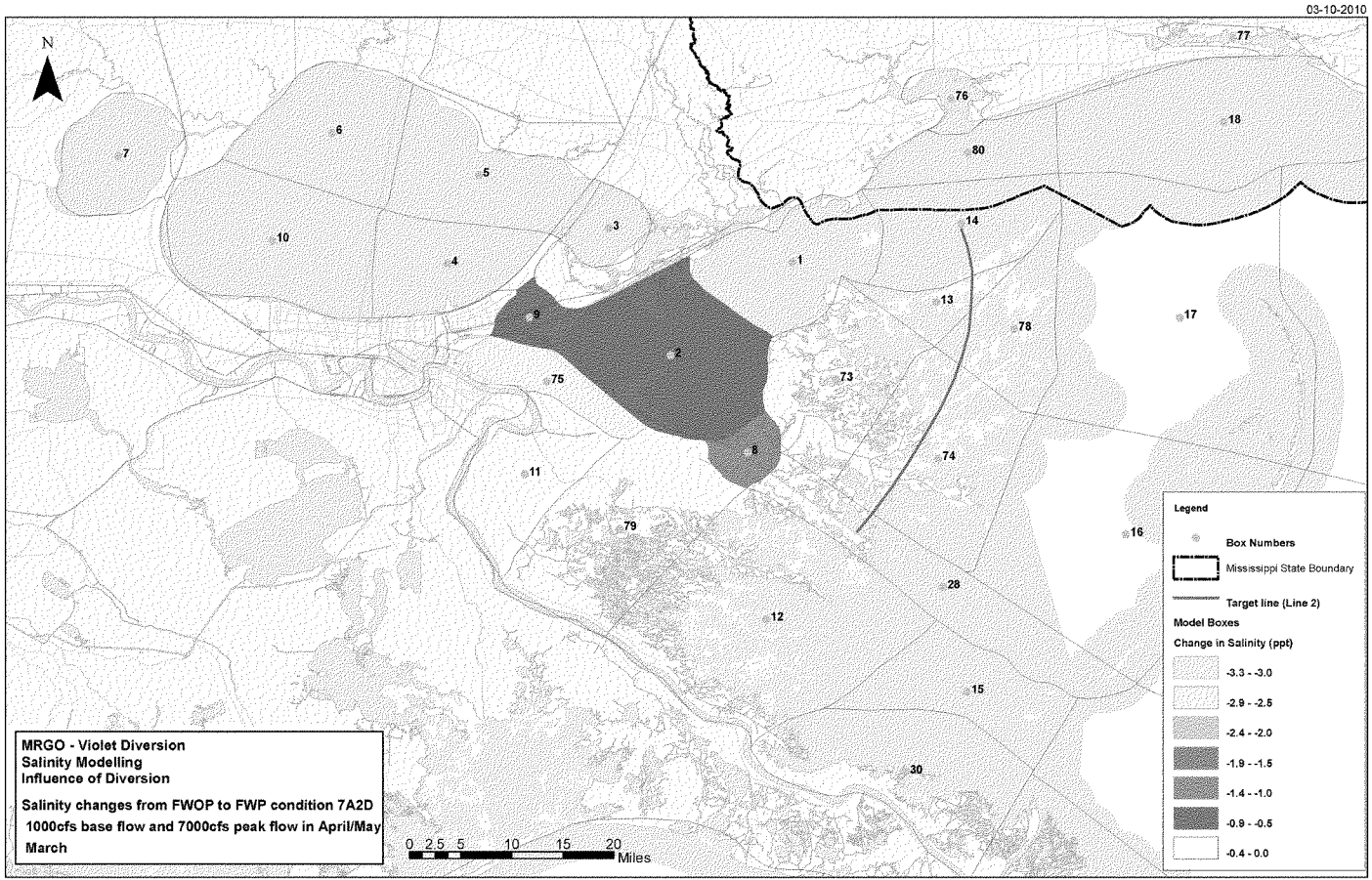


Figure E30. Influence Map showing change from FWOP to 7A2D in March.

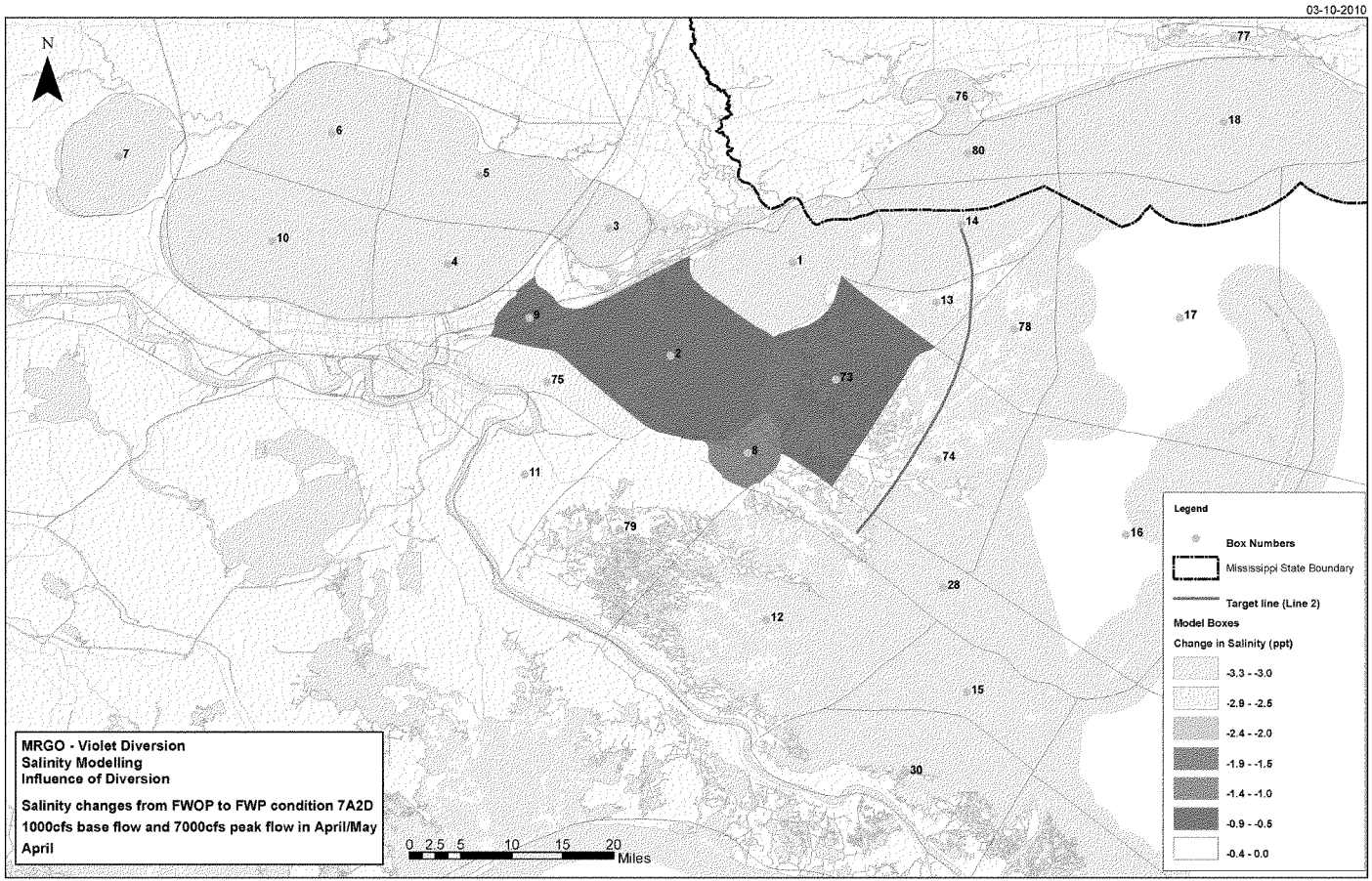


Figure E31. Influence Map showing change from FWOP to 7A2D in April.

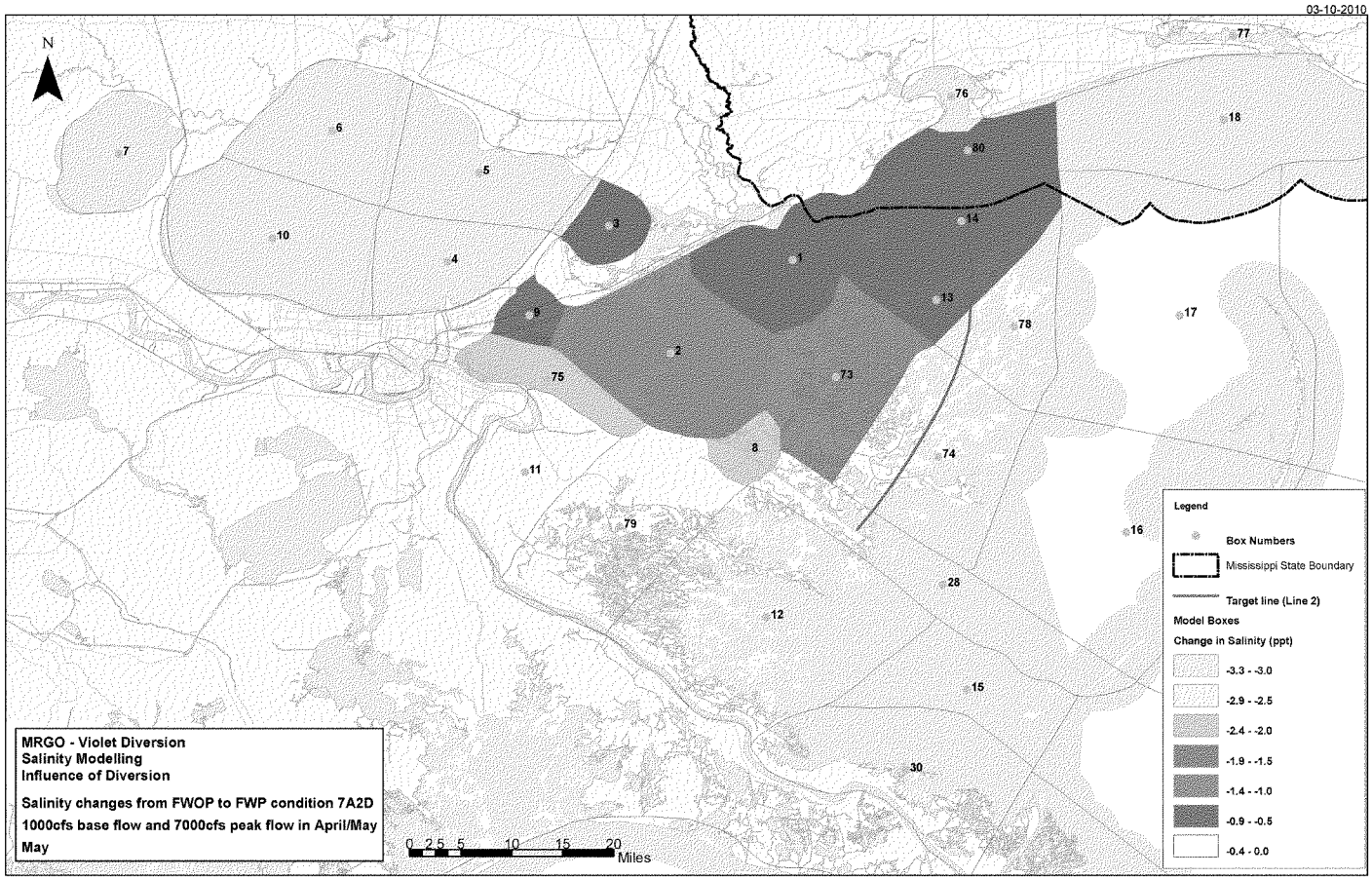


Figure E32. Influence Map showing change from FWOP to 7A2D in May.

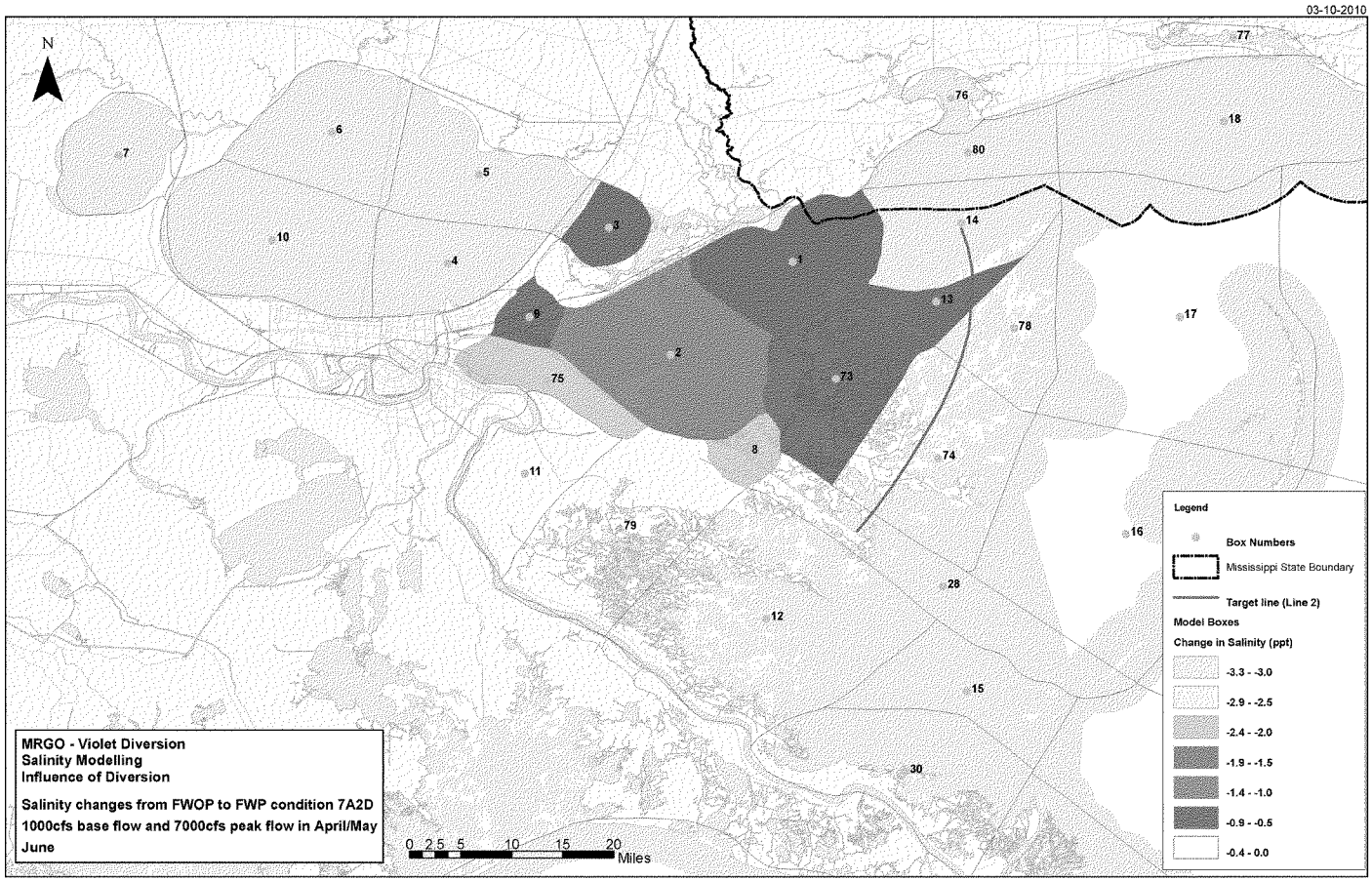


Figure E33. Influence Map showing change from FWOP to 7A2D in June.

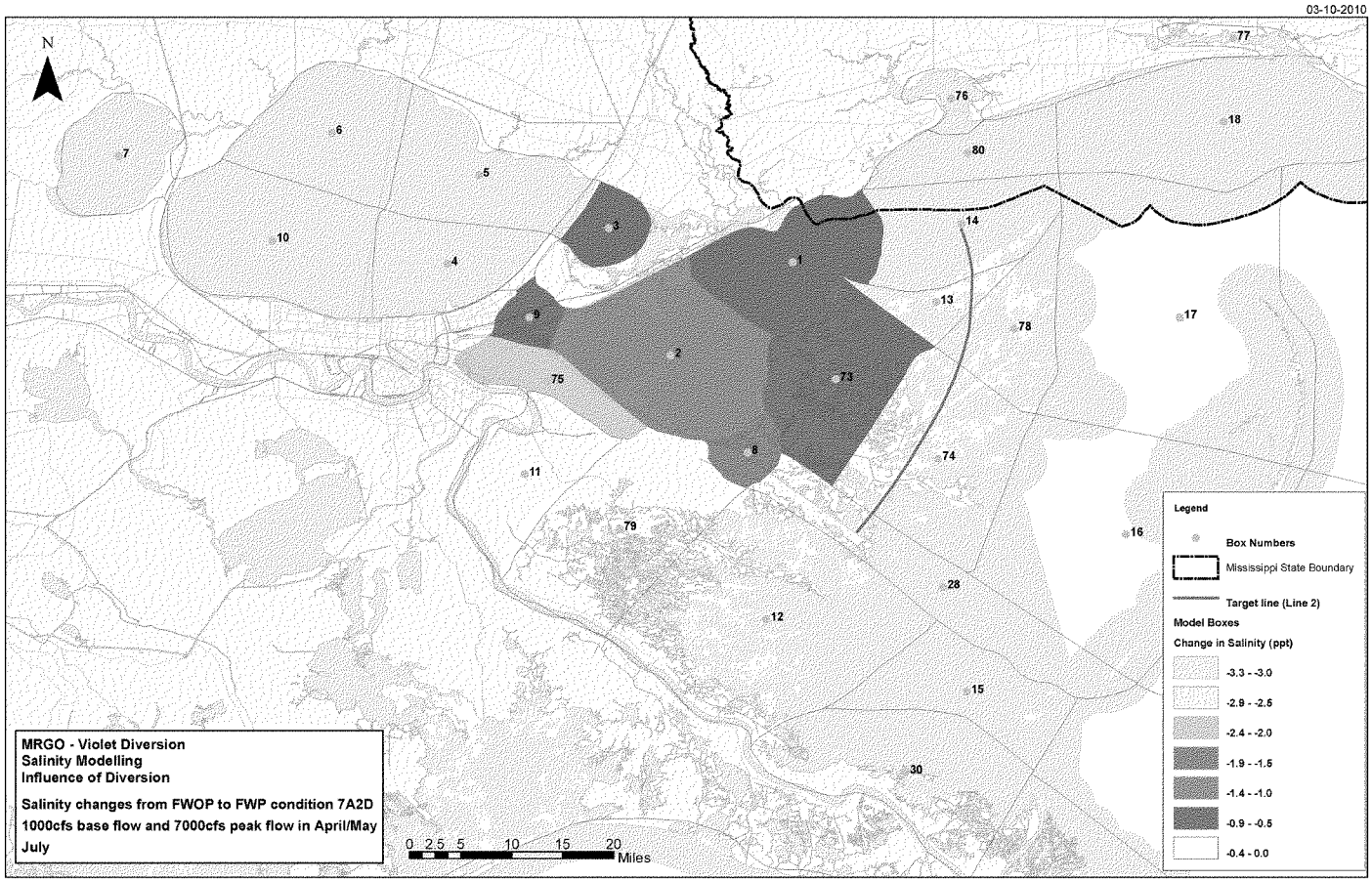


Figure E34. Influence Map showing change from FWOP to 7A2D in July.

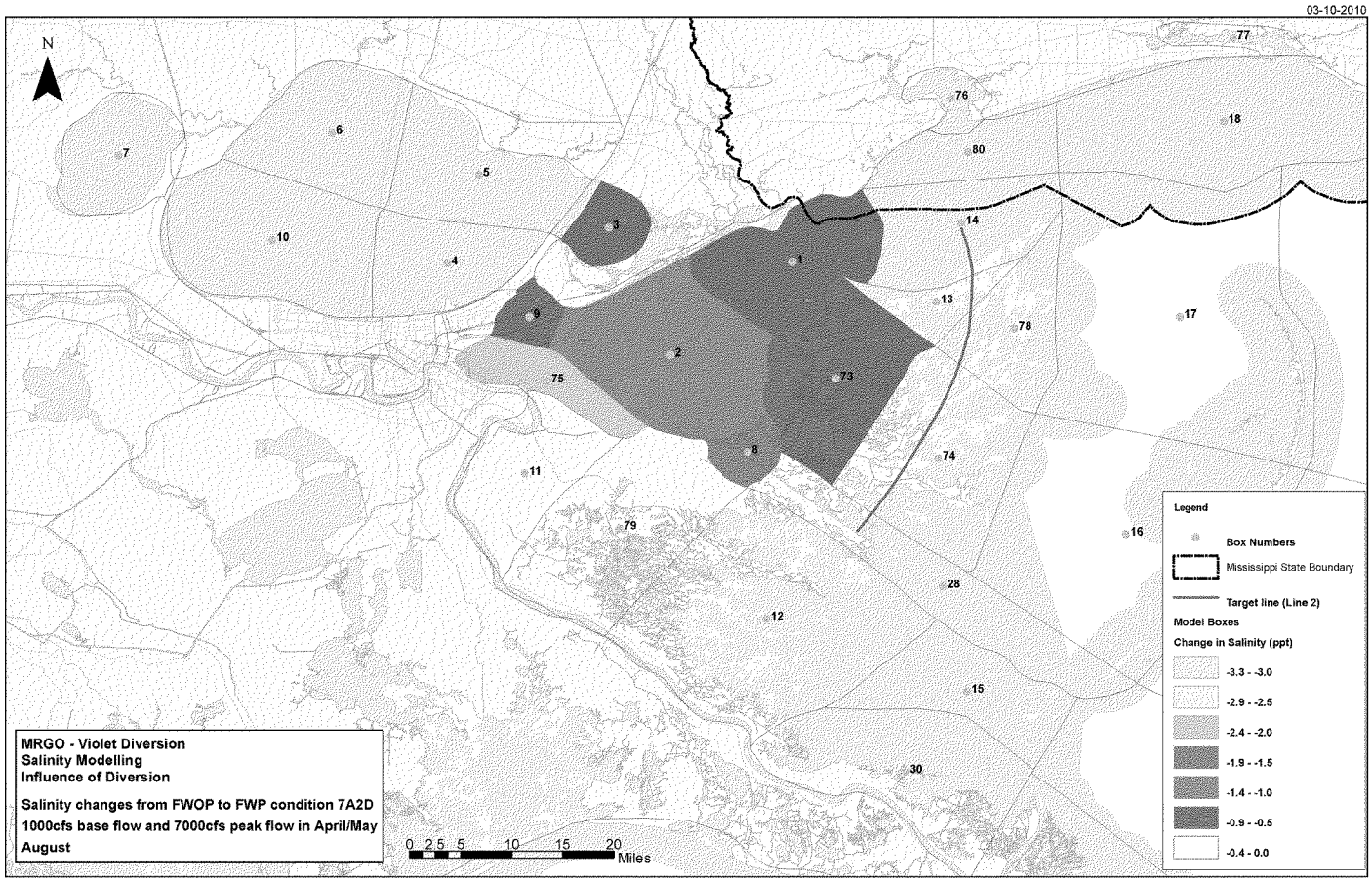


Figure E35. Influence Map showing change from FWOP to 7A2D in August.

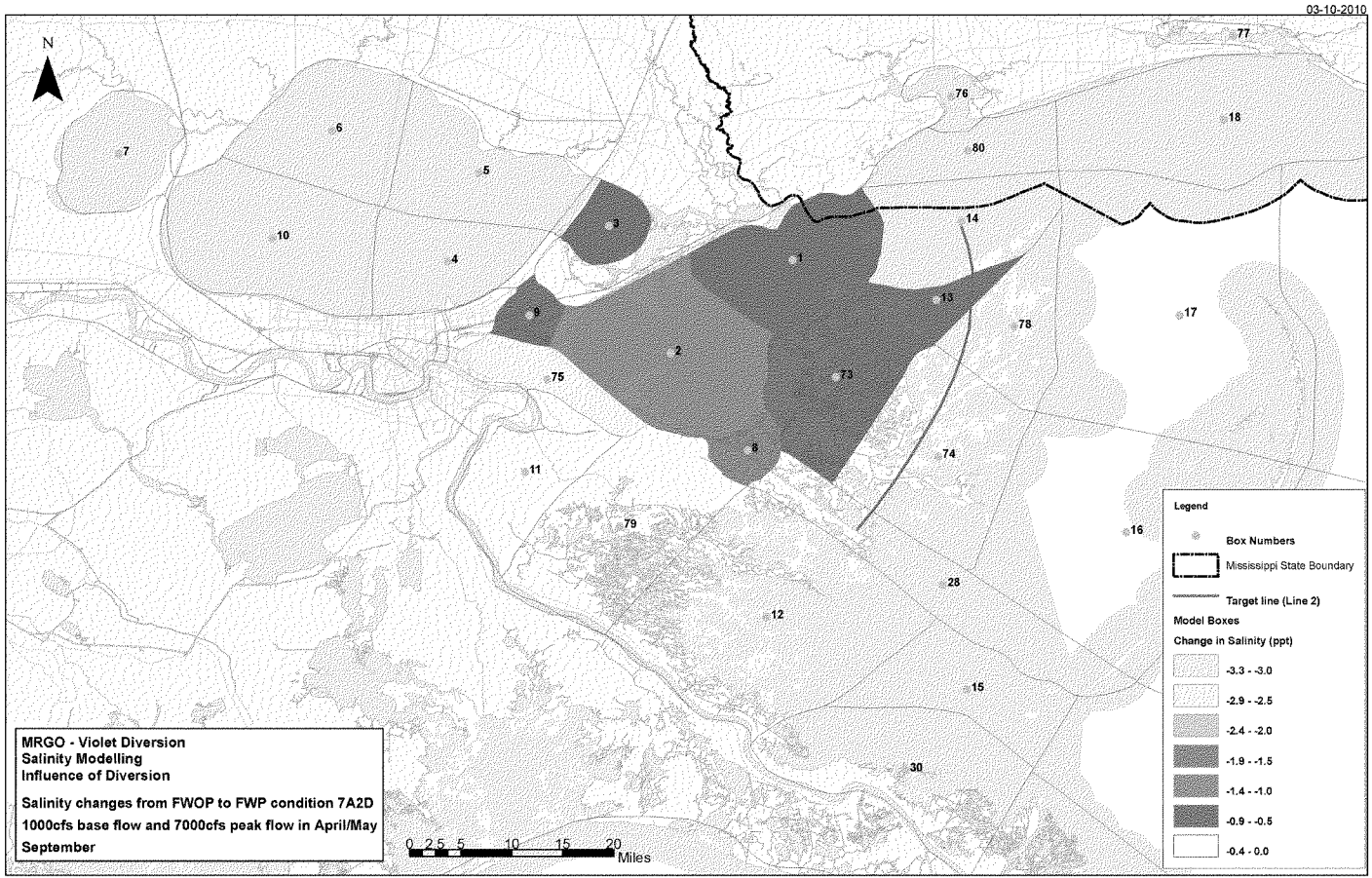


Figure E36. Influence Map showing change from FWOP to 7A2D in September.

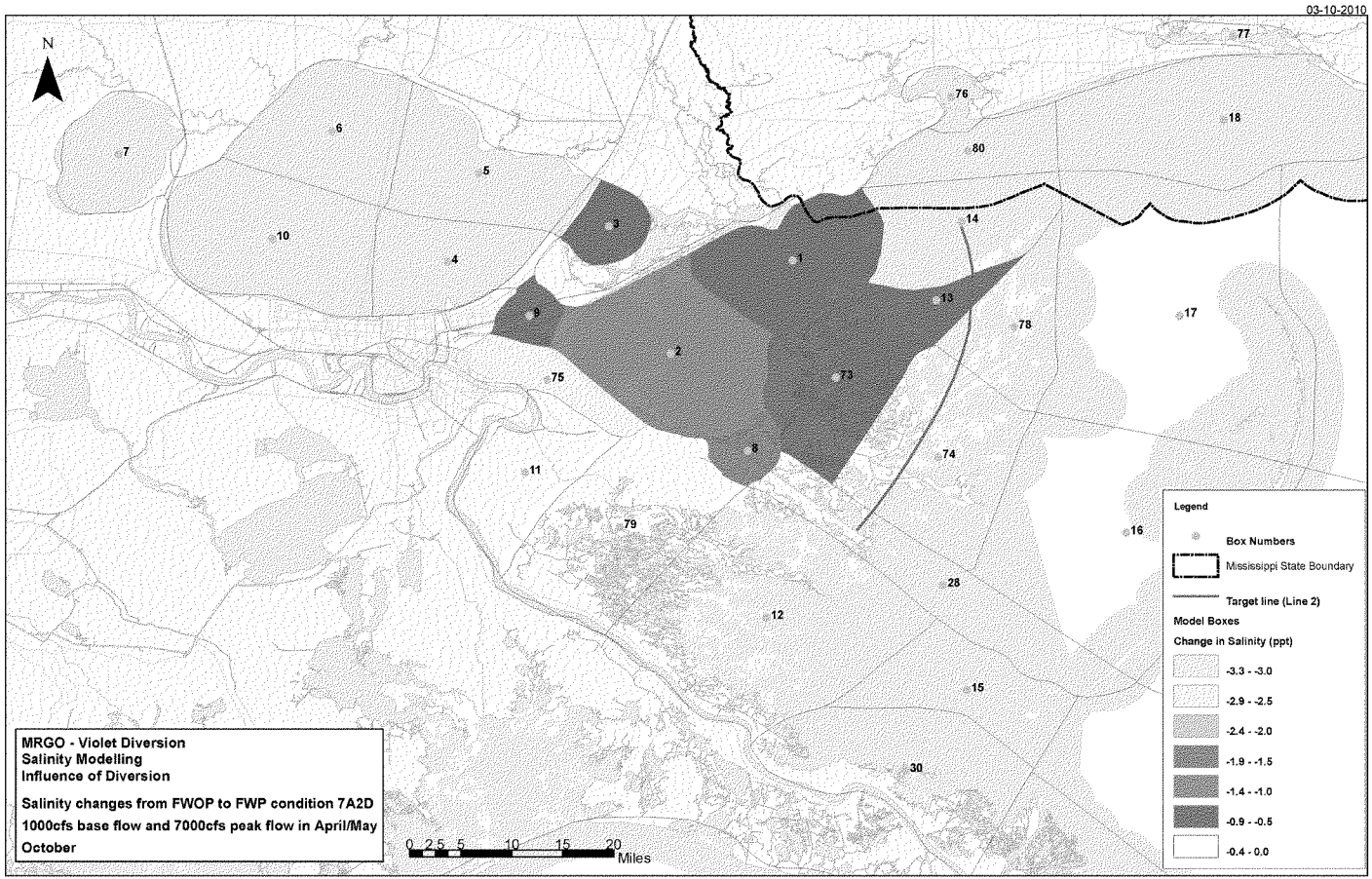


Figure E37. Influence Map showing change from FWOP to 7A2D in October.

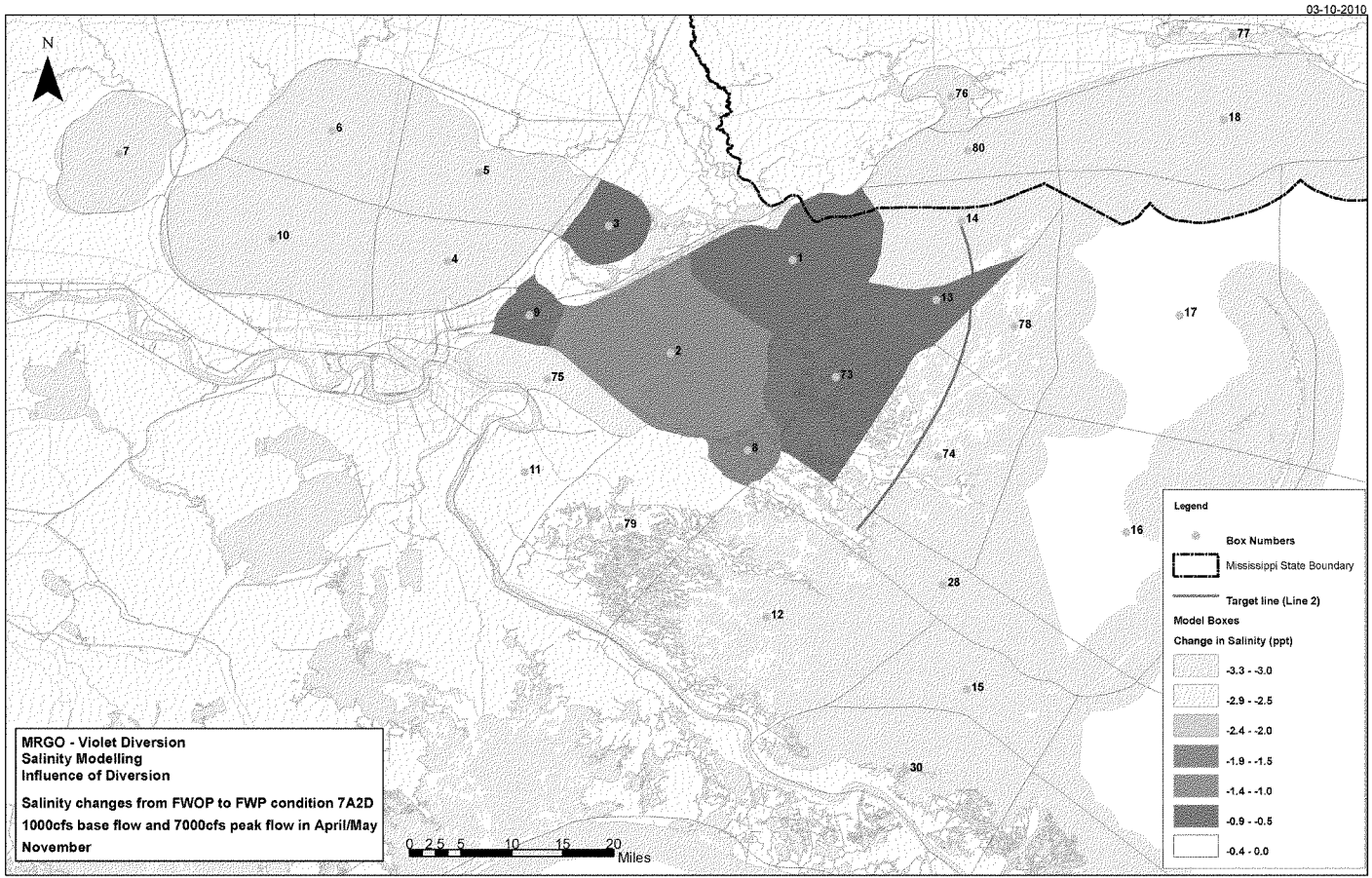


Figure E38. Influence Map showing change from FWOP to 7A2D in November.

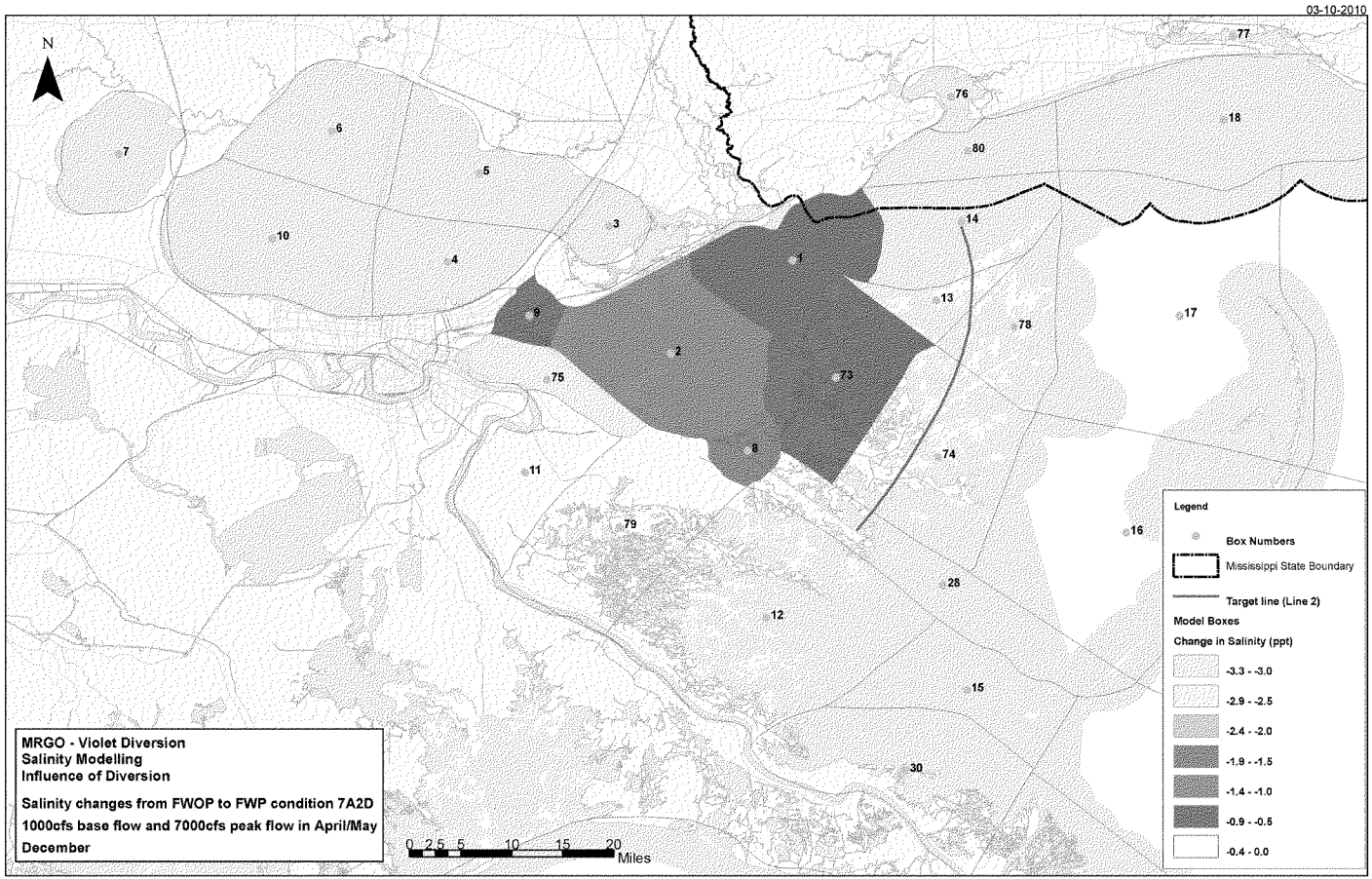
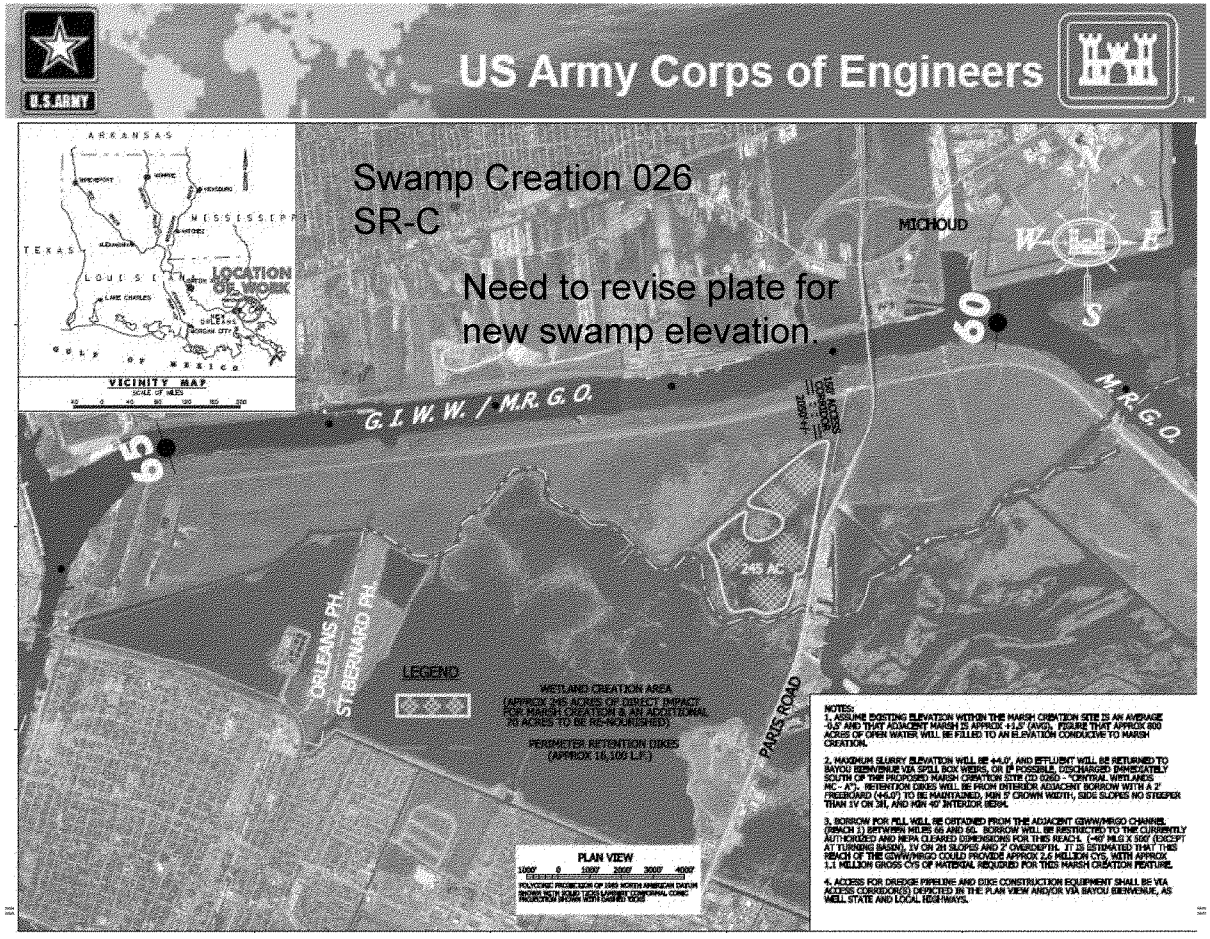


Figure E39. Influence Map showing change from FWOP to 7A2D in December.

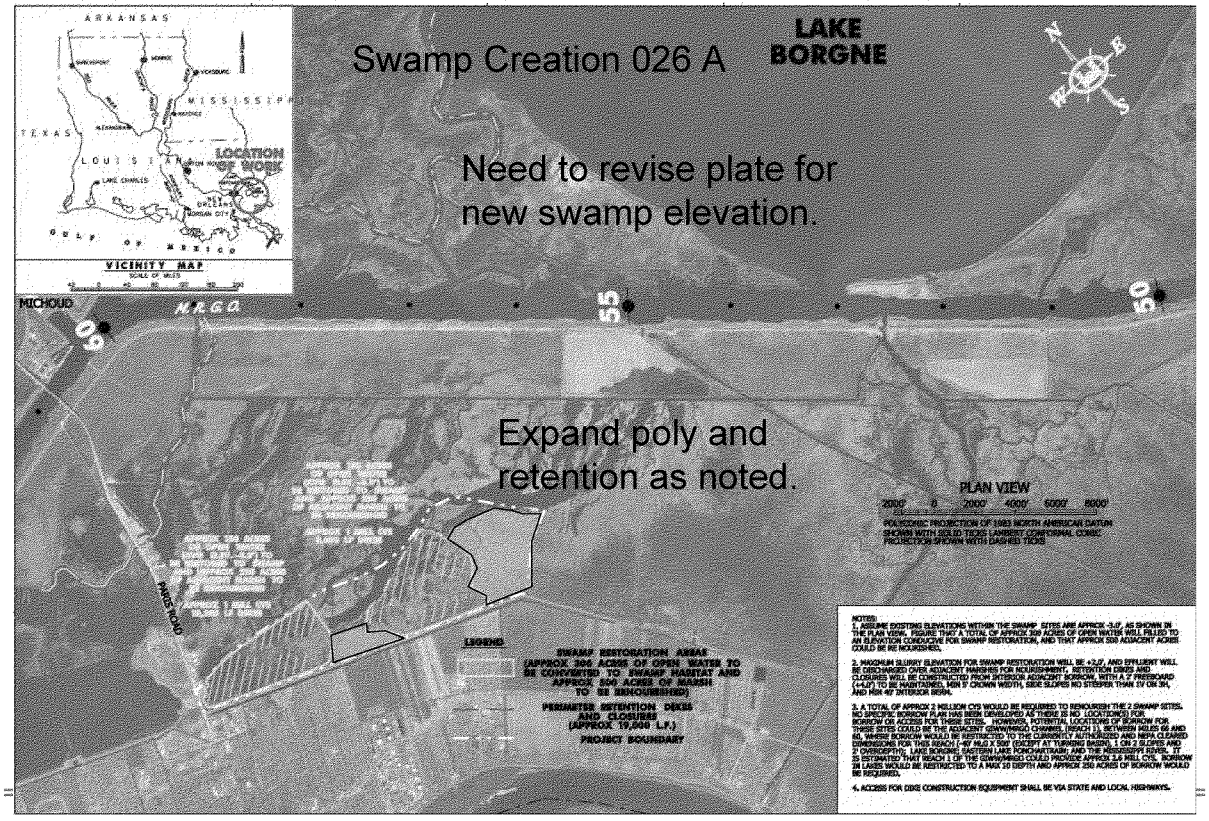
APPENDIX F

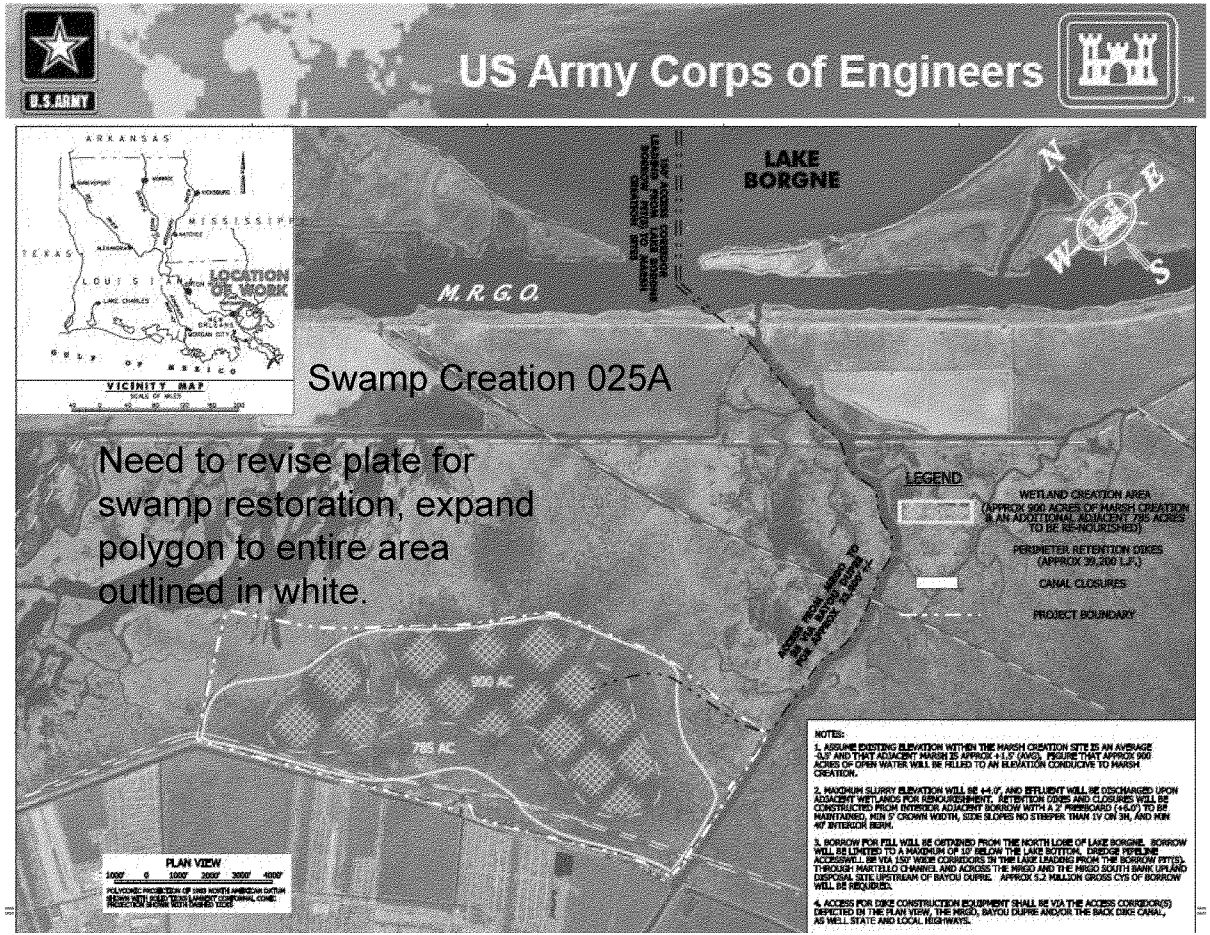
CENTRAL WETLANDS AREA RESTORATION PLANS

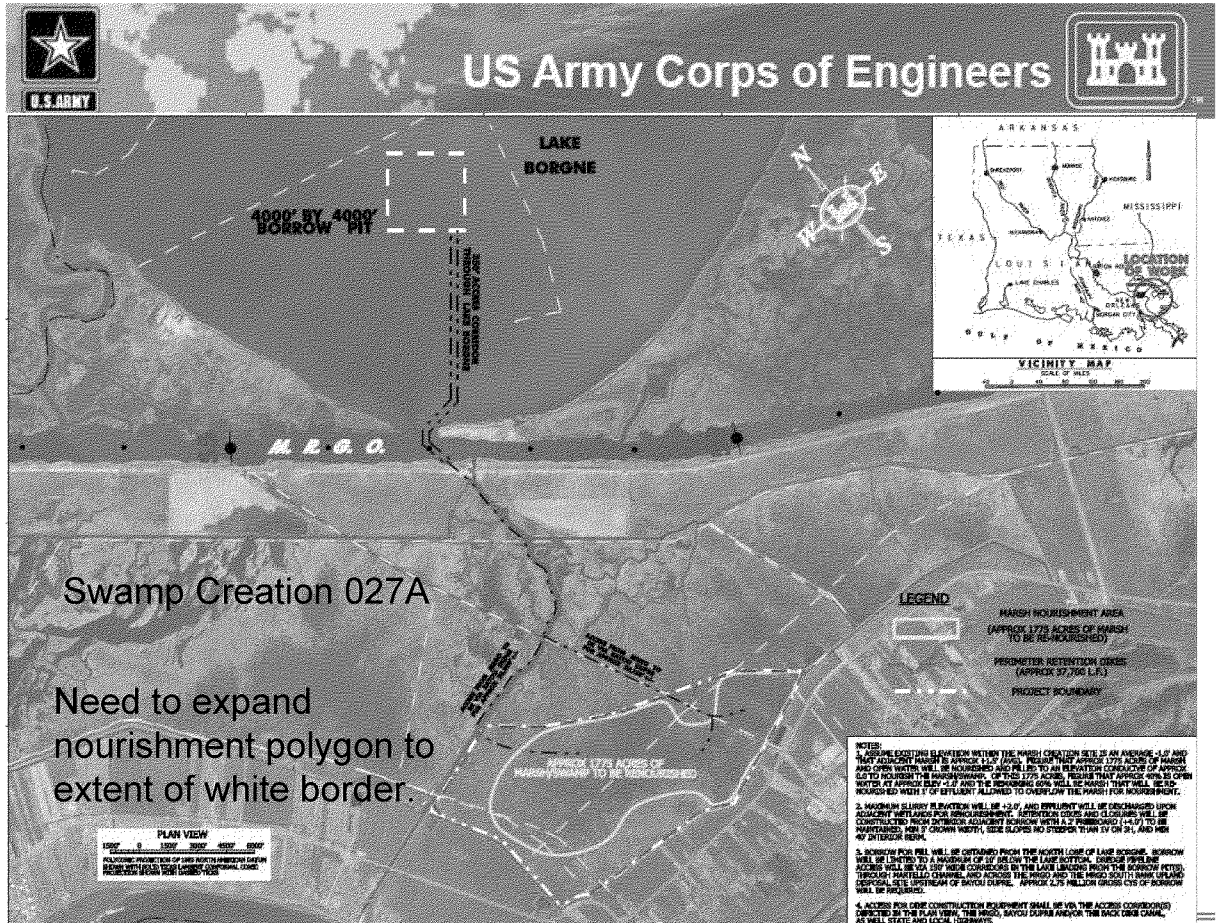

US Army Corps of Engineers
U.S.ARMY
Swamp Creation 026
SR-C
Need to revise plate for new swamp elevation.
ARKANSAS
MISSISSIPPI
TEXAS
LOUISIANA
LOCATION OF WORK
VICINITY MAP
MICHOUD
G. I. W. W. / M.R. G. O.
M.R. G. O.
65
60
245 AC
ORLEANS PH.
ST. BERNARD PH.
PARIS ROAD
LEGEND
WETLAND CREATION AREA
(APPROX 245 ACRES OF DIRECT IMPACT FOR MARSH CREATION & AN ADDITIONAL 70 ACRES TO BE RE-NOURISHED)
PERIMETER RETENTION DIKES
(APPROX 16,100 L.F.)
PLAN VIEW
NOTES:
1. ASSUME EXISTING ELEVATION WITHIN THE MARSH CREATION SITE IS AN AVERAGE -0.5' AND THAT ADJACENT MARSH IS APPROX +1.5' (AVG). FIGURE THAT APPROX 800 ACRES OF OPEN WATER WILL BE FILLED TO AN ELEVATION CONDUCIVE TO MARSH CREATION.
2. MAXIMUM SLURRY ELEVATION WILL BE +4.0', AND EFFLUENT WILL BE RETURNED TO BAYOU BIENVENUE VIA SPILL BOX WEIRS, OR IF POSSIBLE, DISCHARGED IMMEDIATELY SOUTH OF THE PROPOSED MARSH CREATION SITE (ID 026D - "CENTRAL WETLANDS MC - A"). RETENTION DIKES WILL BE FROM INTERIOR ADJACENT BORROW WITH A 2' FREEBOARD (+6.0') TO BE MAINTAINED, MIN 5' CROWN WIDTH, SIDE SLOPES NO STEEPER THAN 1V ON 3H, AND MIN 40' INTERIOR BERM.
3. BORROW FOR FILL WILL BE OBTAINED FROM THE ADJACENT GIWW/MRGO CHANNEL (REACH 1) BETWEEN MILES 65 AND 60. BORROW WILL BE RESTRICTED TO THE CURRENTLY AUTHORIZED AND NEPA CLEARED DIMENSIONS FOR THIS REACH. (-40' MLG X 500' (EXCEPT AT TURNING BASIN), 1V ON 2H SLOPES AND 2' OVERDEPTH. IT IS ESTIMATED THAT THIS REACH OF THE GIWW/MRGO COULD PROVIDE APPROX 2.6 MILLION CYS, WITH APPROX 1.1 MILLION GROSS CYS OF MATERIAL REQUIRED FOR THIS MARSH CREATION FEATURE.
4. ACCESS FOR DREDGE PIPELINE AND DIKE CONSTRUCTION EQUIPMENT SHALL BE VIA ACCESS CORRIDOR(S) DEPICTED IN THE PLAN VIEW AND/OR VIA BAYOU BIENVENUE, AS WELL STATE AND LOCAL HIGHWAYS.

US Army Corps of Engineers

U.S. ARMY

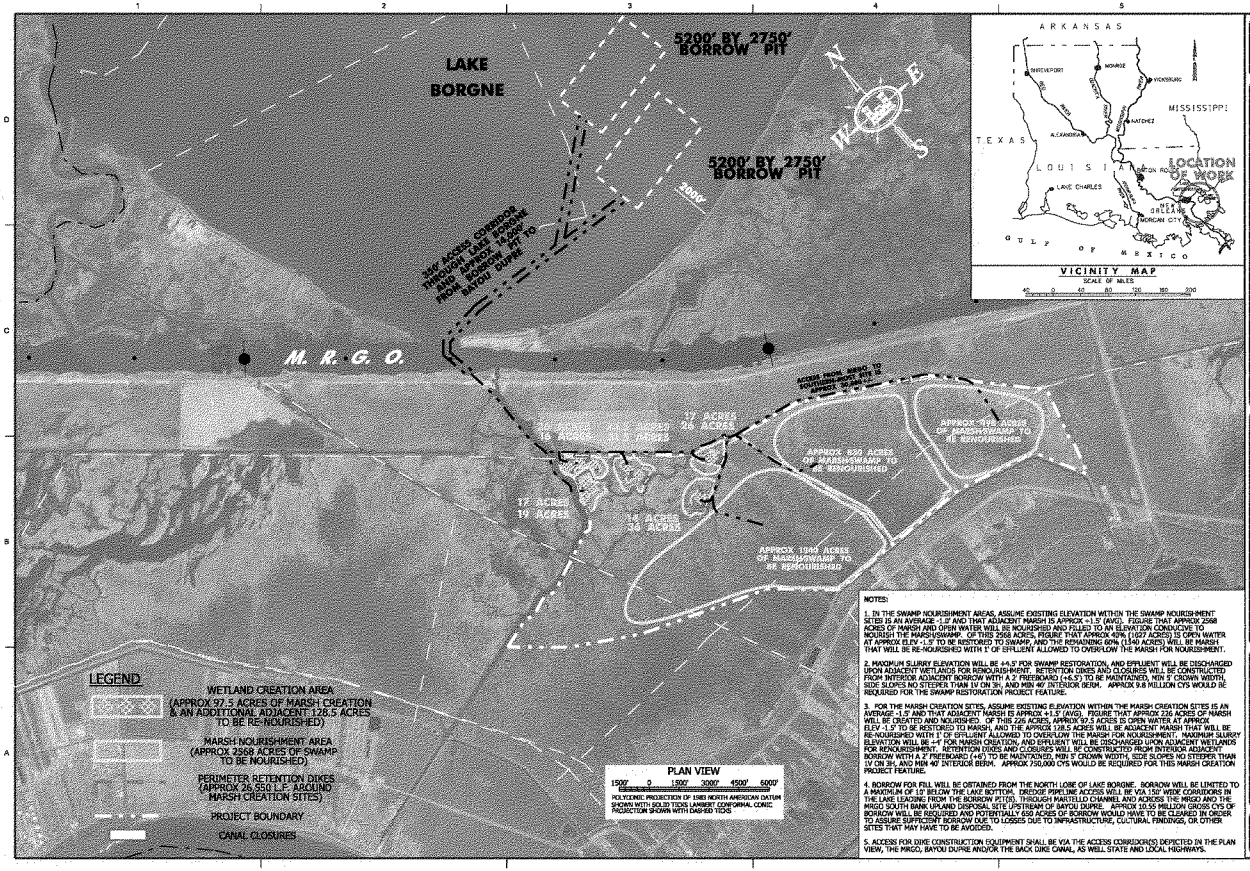



US Army Corps of Engineers
U.S. ARMY
ARKANSAS
MISSISSIPPI
TEXAS
LOUISIANA
LOCATION OF WORK
GULF OF MEXICO
VICINITY MAP
LAKE BORGNE
M.R.G.O.
Swamp Creation 025A
Need to revise plate for swamp restoration, expand polygon to entire area outlined in white.
LEGEND
WETLAND CREATION AREA
(APPROX 900 ACRES OF MARSH CREATION & AN ADDITIONAL ADJACENT 785 ACRES TO BE RE-NOURISHED)
PERIMETER RETENTION DIKES
(APPROX 39,200 L.F.)
CANAL CLOSURES
PROJECT BOUNDARY
900 AC
785 AC
PLAN VIEW
NOTES:
1. ASSUME EXISTING ELEVATION WITHIN THE MARSH CREATION SITE IS AN AVERAGE -0.5' AND THAT ADJACENT MARSH IS APPROX +1.5' (AVG). FIGURE THAT APPROX 900 ACRES OF OPEN WATER WILL BE FILLED TO AN ELEVATION CONDUCIVE TO MARSH CREATION.
2. MAXIMUM SLURRY ELEVATION WILL BE +4.0', AND EFFLUENT WILL BE DISCHARGED UPON ADJACENT WETLANDS FOR RENOURISHMENT. RETENTION DIKES AND CLOSURES WILL BE CONSTRUCTED FROM INTERIOR ADJACENT BORROW WITH A 2' FREEBOARD (+6.0') TO BE MAINTAINED, MIN 5' CROWN WIDTH, SIDE SLOPES NO STEEPER THAN 1V ON 3H, AND MIN 40' INTERIOR BERM.
3. BORROW FOR FILL WILL BE OBTAINED FROM THE NORTH LOBE OF LAKE BORGNE. BORROW WILL BE LIMITED TO A MAXIMUM OF 10' BELOW THE LAKE BOTTOM. DREDGE PIPELINE ACCESSWILL BE VIA 150' WIDE CORRIDORS IN THE LAKE LEADING FROM THE BORROW PIT(S), THROUGH MARTELLO CHANNEL AND ACROSS THE MRGO AND THE MRGO SOUTH BANK UPLAND DISPOSAL SITE UPSTREAM OF BAYOU DUPRE. APPROX 5.2 MILLION GROSS CYS OF BORROW WILL BE REQUIRED.
4. ACCESS FOR DIKE CONSTRUCTION EQUIPMENT SHALL BE VIA THE ACCESS CORRIDOR(S) DEPICTED IN THE PLAN VIEW, THE MRGO, BAYOU DUPRE AND/OR THE BACK DIKE CANAL, AS WELL STATE AND LOCAL HIGHWAYS.

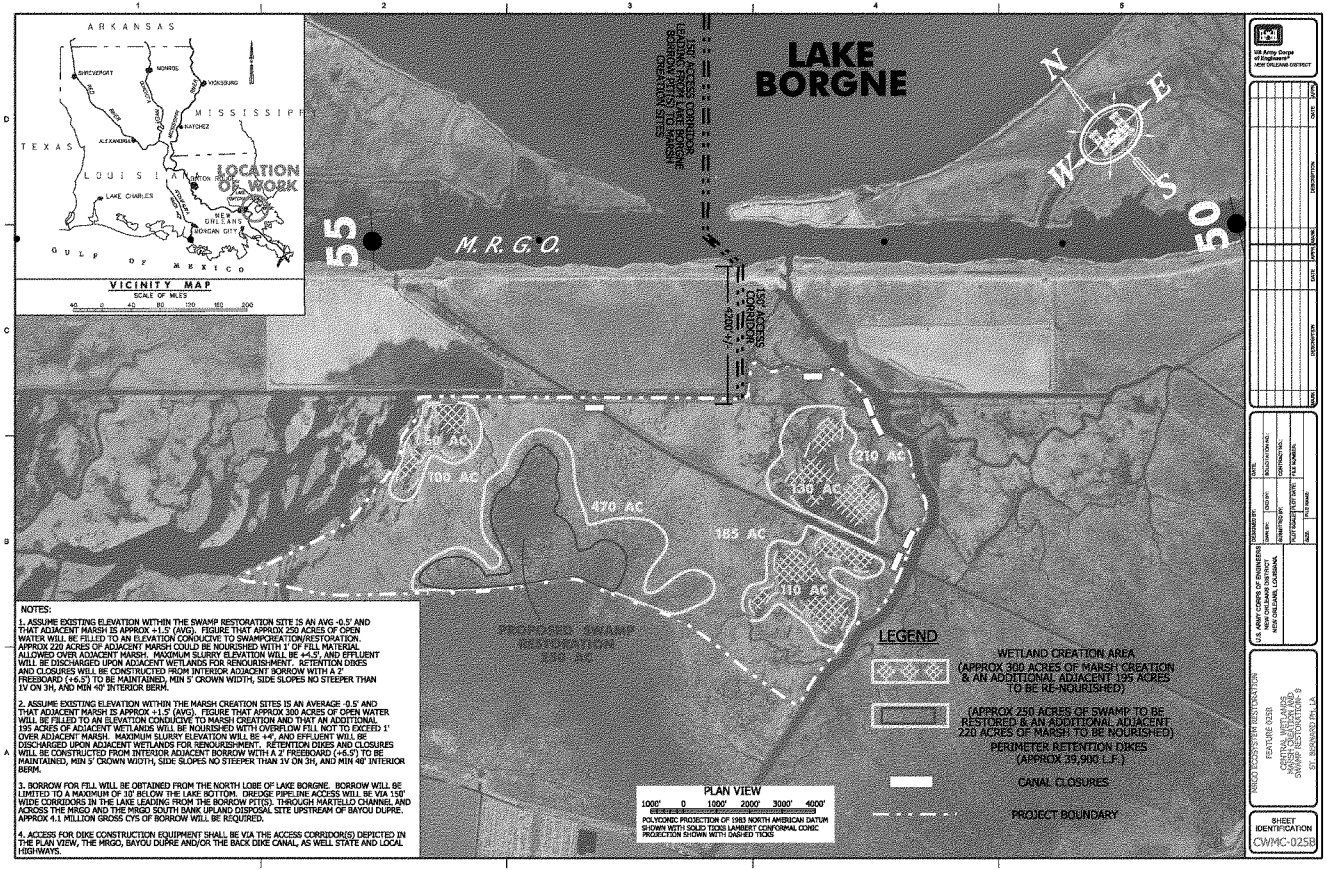


Swamp Creation 027A

Need to expand nourishment polygon to extent of white border.



027B Central Wetlands MC - C.dgn 8/28/2009 5:40:36 PM



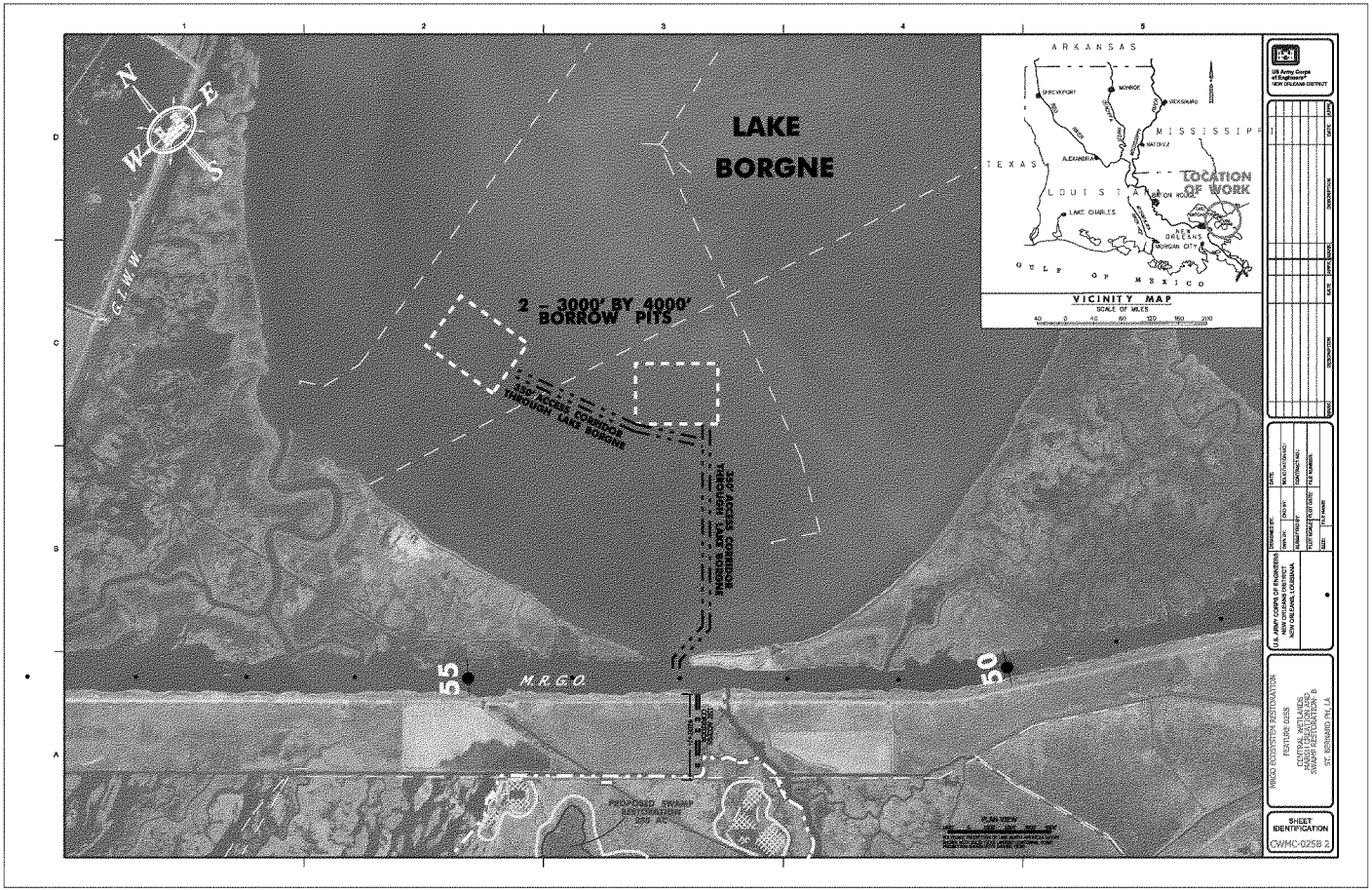
NOTES:

1. ASSUME EXISTING ELEVATION WITHIN THE SWAMP RESTORATION SITE IS AN AVG -0.5' AND THAT ADJACENT MARSH IS APPROX +1.5' (AVG). FIGURE THAT APPROX 250 ACRES OF OPEN WATER WILL BE FILLED TO AN ELEVATION CONDUCIVE TO SWAMPCREATION/RESTORATION. APPROX 220 ACRES OF ADJACENT MARSH COULD BE NOURISHED WITH 1' OF FILL MATERIAL ALLOWED OVER ADJACENT MARSH. MAXIMUM SLURRY ELEVATION WILL BE +4.5', AND EFFLUENT WILL BE DISCHARGED UPON ADJACENT WETLANDS FOR RENOURISHMENT. RETENTION DIKES AND CLOSURES WILL BE CONSTRUCTED FROM INTERIOR ADJACENT BORROW WITH A 2' FREEBOARD (+6.5') TO BE MAINTAINED, MIN 5' CROWN WIDTH, SIDE SLOPES NO STEEPER THAN 1V ON 3H, AND MIN 40' INTERIOR BERM.

2. ASSUME EXISTING ELEVATION WITHIN THE MARSH CREATION SITES IS AN AVERAGE -0.5' AND THAT ADJACENT MARSH IS APPROX +1.5' (AVG). FIGURE THAT APPROX 300 ACRES OF OPEN WATER WILL BE FILLED TO AN ELEVATION CONDUCIVE TO MARSH CREATION AND THAT AN ADDITIONAL 195 ACRES OF ADJACENT WETLANDS WILL BE NOURISHED WITH OVERFLOW FILL NOT TO EXCEED 1' OVER ADJACENT MARSH. MAXIMUM SLURRY ELEVATION WILL BE +4', AND EFFLUENT WILL BE DISCHARGED UPON ADJACENT WETLANDS FOR RENOURISHMENT. RETENTION DIKES AND CLOSURES WILL BE CONSTRUCTED FROM INTERIOR ADJACENT BORROW WITH A 2' FREEBOARD (+6.5') TO BE MAINTAINED, MIN 5' CROWN WIDTH, SIDE SLOPES NO STEEPER THAN 1V ON 3H, AND MIN 40' INTERIOR BERM.

3. BORROW FOR FILL WILL BE OBTAINED FROM THE NORTH LOBE OF LAKE BORGNE. BORROW WILL BE LIMITED TO A MAXIMUM OF 10' BELOW THE LAKE BOTTOM. DREDGE PIPELINE ACCESS WILL BE VIA 150' WIDE CORRIDORS IN THE LAKE LEADING FROM THE BORROW PIT(S). THROUGH MARTELLO CHANNEL AND ACROSS THE MRGO AND THE MRGO SOUTH BANK UPLAND DISPOSAL SITE UPSTREAM OF BAYOU DUPRE. APPROX 4.1 MILLION GROSS CYS OF BORROW WILL BE REQUIRED.

4. ACCESS FOR DIKE CONSTRUCTION EQUIPMENT SHALL BE VIA THE ACCESS CORRIDOR(S) DEPICTED IN THE PLAN VIEW, THE MRGO, BAYOU DUPRE AND/OR THE BACK DIKE CANAL, AS WELL STATE AND LOCAL HIGHWAYS.



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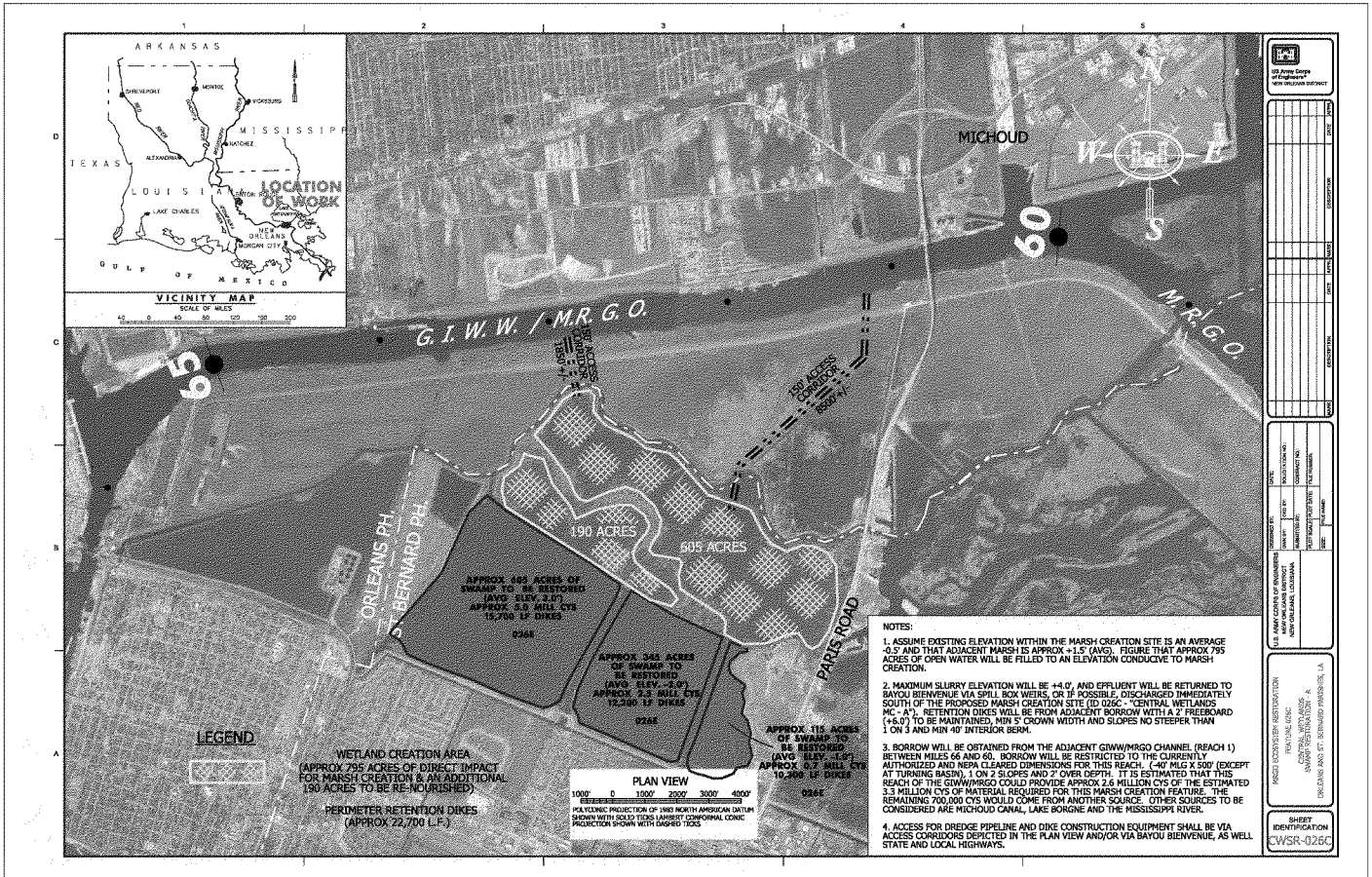

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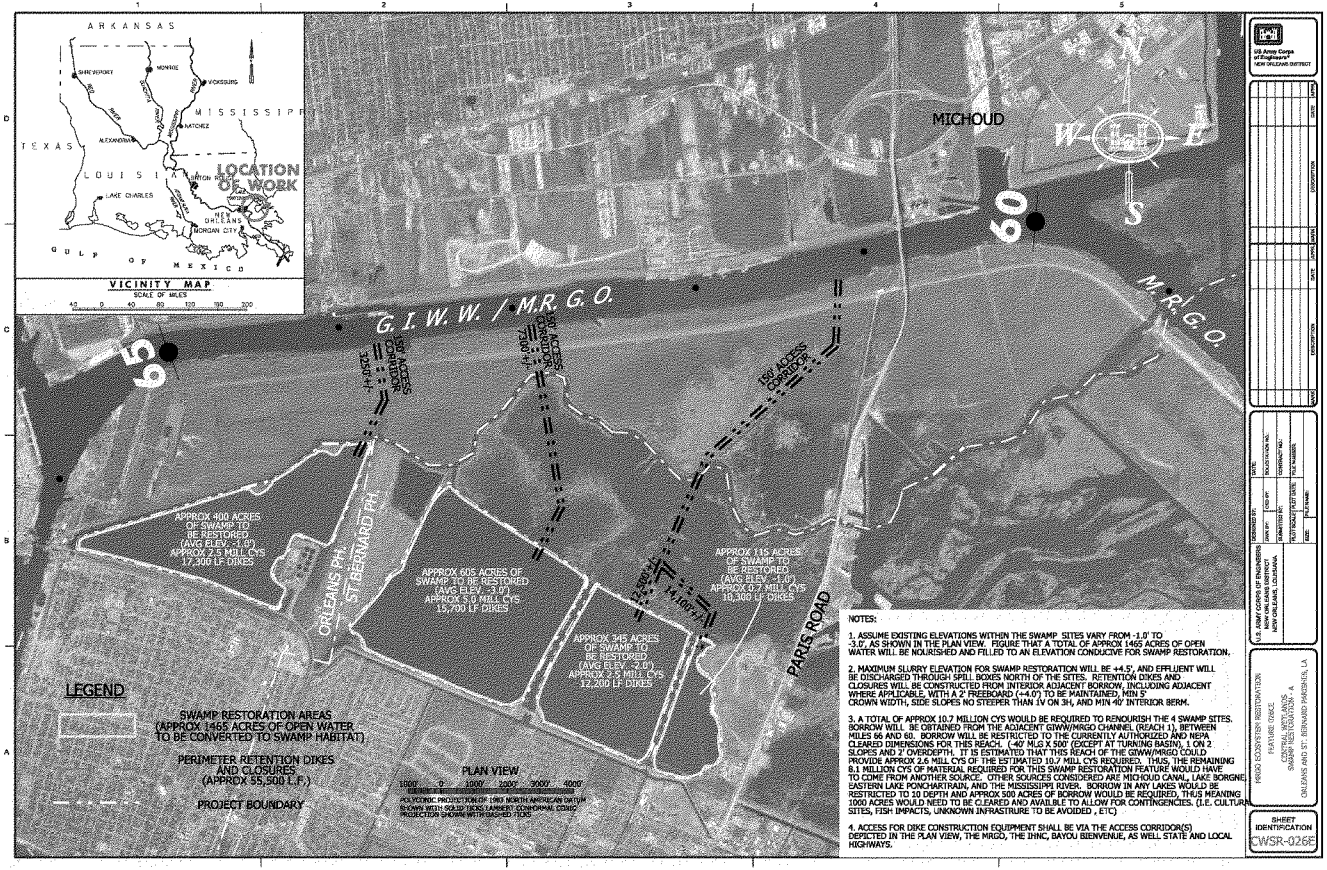

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APPENDIX G

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New Orleans - Central Wetlands Area

Hydrodynamic modelling study

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New Orleans - Central Wetlands Area

Hydrodynamic modelling study

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Evans Graves Engineering Inc

12 March 2010
Final draft report
9V1141.25

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1 INTRODUCTION

1.1 Background

The United States Army Corps of Engineers, New Orleans (USACE) is currently working on a feasibility study to aid in the development of the MRGO Ecosystem Restoration Plan (ERP). The main goal of this plan is to restore and maintain estuarine habitat areas affected by the MRGO navigation channel. In addition, in the coming years the USACE plans restoration of the wetlands by both swamp and marsh recreation. This will result in local areas of increased bed levels and changed vegetation.

Part of the ERP is to divert flow from the Mississippi River through the Central Wetlands Area (CWA), into the MRGO, and ultimately into the Biloxi Marsh. The purpose of this effort is to reduce the salinity in the Biloxi Marsh to enhance the Louisiana and Mississippi oyster production and promote the sustainability of coastal wetlands. The current salinity ranges from 14 ppt in April to 24 ppt in November. For the production of oysters, the salinity should range, ideally, between 8 ppt in April to 17 ppt in November. Meeting this reduced salinity regime at least 40 to 50 percent of the time is a goal of the MRGO Ecosystem Restoration Plan. The proposed solution to achieve this is for fresh water to be diverted from the Mississippi River, through the CWA, towards the Biloxi Marsh.

Regarding the above, the project calls for a study to investigate the hydrodynamic effect of the inflow of fresh water into the CWA for the present situation and for the restored scenario. The impact of the flow through the diversion and how this affects the salinity and the hydrodynamic physics in the channels are to be investigated.

The model simulations are to be undertaken using a detailed, 2-dimensional MIKE21-HD model. The results from these hydrodynamic simulations should be able to address the initial feasibility questions relating to the diversion of flows through the CWA.

The Biloxi Marsh is located between Lake Borgne on the north and west, the MRGO on the south and Chandeleur Sound on the east. The CWA is located between the Saint Bernard Parish to the south and west, Lake Borgne and the MRGO on the east and the IHNC to the north. Figure 1 in Annex 1 shows the project Area.

1.2 Objective

The results from the MIKE21 simulation runs should be able to address the feasibility questions relating to the diversion of flows through the CWA. The following objectives or key questions were formulated:

1. What is the impact of the base flow through the diversion? How does it affect salinity in the CWA?
2. Does the proposed change in topography for the restored marsh impact the base flows, water levels and discharges?
3. What happens during periods of peak diversion flows? Where does the water go? What is the flow split through the existing structures? Is a new outfall needed? How extensive is flooding (frequency levels etc) inside the CWA? Are new channels needed within the wetlands?
4. What are the impacts of localized flooding due to the new diversions?
5. What are the impacts of sea level rise on the marsh?

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The developed model will then be available for further runs if needed to answer more of the operational issues as additional effort.

1.3 Report outline

Chapter 2 presents the methodology in which the modeling scenarios, conditions and study approach are discussed. The characteristics of the model are discussed in Chapter 3 in terms of relevant hydrodynamic conditions.

Chapter 4 presents the hydrodynamic model setup and calibration. Questions regarding the boundaries and model settings are answered and the results of calibration and validation are presented. The model results for the different scenario's are discussed in Chapter 5. The report finishes with the conclusions and remarks in Chapter 6.

1.4 Conventions and definitions

Vertical reference level
Water levels and depths mentioned in this study are given in feet with reference to NAVD88 (2004.65). However the model is a European model and works according to international SI conventions. For this reason some plots direct from the model may be in meters. Special attention to the figure annotation is therefore needed.
Conversion between feet and meters: 1 meter = 3.28 feet, 1 foot = 0.3048 m.

Current directions
Current directions refer to the direction towards which the current is flowing. Current directions are always given as bearings (clockwise with respect to (wrt) North). The unit is degrees, where 360 degrees cover the circle. For example: current direction 90° means that the current is flowing towards the East.

Wind directions
All directions referred to in this study are given in the nautical convention, which means that for winds, the direction refers to the direction where the winds are coming from and is measured positive in degrees from true north. This means that winds from a direction of 0°N are coming from the north and winds with direction 270°N are coming from west.

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2 METHODOLOGY

2.1 Introduction

In the early stages of the project, the affects of flushing fresh water through the CWA towards the MRGO and the Biloxi Marsh, were generated by applying the UNO Mass Balance Model [3]. This model led, as expected due to the very limited resolution of the box model, to a very coarse generalized hydrodynamic result in the CWA. To improve the understanding of the CWA area, a more detailed modeling effort was recommended to investigate the effects in this area.

To assess the effects and flow characteristics inside the CWA in more detail, the development of a detailed 2-dimensional hydrodynamic model was needed. Specifically for understanding the hydrologic affects of a near Violet diversion on the Central Wetland Area (CWA) and to better understand the timing and discharge of diverted Mississippi River water through the CWA into the MRGO and ultimately into the Biloxi Marsh.

For this study, the Hydrodynamic Module of MIKE21 (MIKE21-HD) with flexible mesh has been applied. MIKE21, a software package from DHI, is a widely used, state of the art integrated modeling package for application in coastal- and port areas. The hydrodynamic module solves the shallow water equations, depth-averaged, over a 2-dimensional plane, which implies that the salinity is calculated as a depth averaged concentration. This approach is justified if vertical mixing occurs within short distances of the source and no significant stratification occurs, which is what is expected to happen.

Although detailed, the modeling effort at this stage was still aimed at establishing the generalized physics of the reaction of the hydraulics in the CWA to the proposed diversion flows.

2.2 Modeling Scenarios

The following scenarios will be considered.

Scenario	Description	Bathymetry	Diversion Flow
1	Baseline	Existing	Nil
2	Existing with 1000cfs	Existing	1000cfs
3	Restored with 1000cfs	Restored	1000cfs
4	Restored with 7000cfs	Restored	7000cfs
5	Sea Level Rise	Restored	1000cfs

[1] Baseline scenario
This scenario reflects the actual existing situation. This scenario includes the initial bathymetry, vegetation and structures and includes the normal tidal flows through the inlets at Bayou Dupre and Bayou Bienvenue. The most recent bathymetry was used for this scenario. Calibration and validation of the model is per definition done for this scenario as this reflects the most representative conditions during which the measurements were done. The model will cover the CWA and extends only as far into the MRGO to enable the flows within the gates to be established.

[2] *Existing with 1000 cfs Scenario*
The existing with 1000 cfs scenario considers the situation with existing bathymetry but with the 1000cfs base flow from the Mississippi. The purpose is to investigate

the impacts of increasing diversion flows on the current geometry before any future restoration.

The following split of flows is applied:

- 870 cfs through the new diversion channel
- 100 cfs through the old Violet Canal
- 30 cfs through the wastewater re-use scheme

Figure 2.1 shows the flow stations for this baseline scenario with 1000 cfs.

[3] *Restored with 1000 cfs scenario*
This scenario reflects the restored situation. Swamp restoration and marsh nourishment has taken place, resulting in local areas of increased bed levels and changed vegetation. The proposed bathymetry, topography and vegetation map has been provided by the USACE MRGO restoration team. The same 1000cfs base flow condition from scenario 2 is to be applied. A new larger channel will be introduced through the marshland to transfer flow from the back levee into the more open water areas of the existing marshland and potentially through to the MRGO and a possible third gate location.

[4] *Restored with 7000 cfs scenario*
This scenario is almost to the same as scenario 3, covering the restored marshland situation. However, this scenario reflects the 7000cfs peak flow in April and May. This scenario includes a ramping up of flows from the base flow condition (1000cfs) to the peak over a timeframe of 14 days. It also includes a third structure into the MRGO with controls to restrict outflow into the MRGO if required. The initial scenario will be established to divert approximately 6000cfs through the new structure.

[5] *Sea level rise*
This scenario reflects the restored scenario with the base flow of 1000cfs (like scenario 3), but will take into account the impact of potential sea level rise on the stage and salinity within the CWA. It is proposed to consider a high range sea level rise value of 3.7ft (1.12 m) [3].

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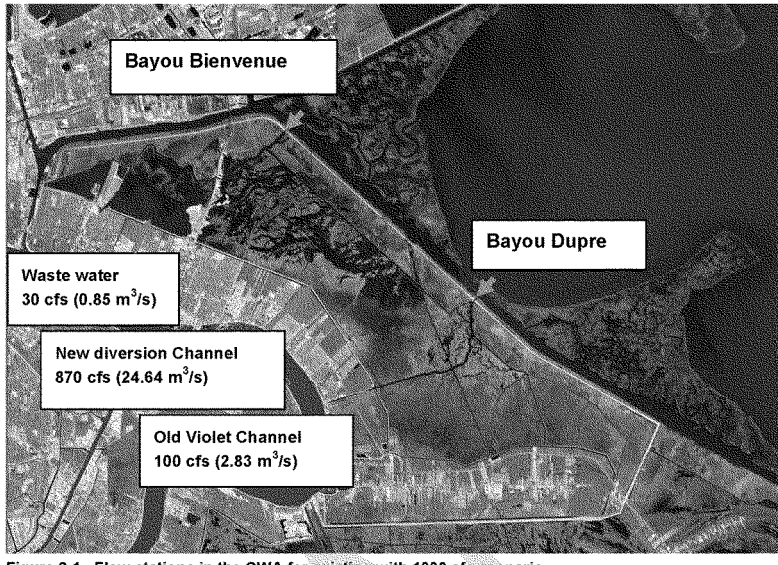

Figure 2.1 - Flow stations in the CWA for existing with 1000 cfs scenario.

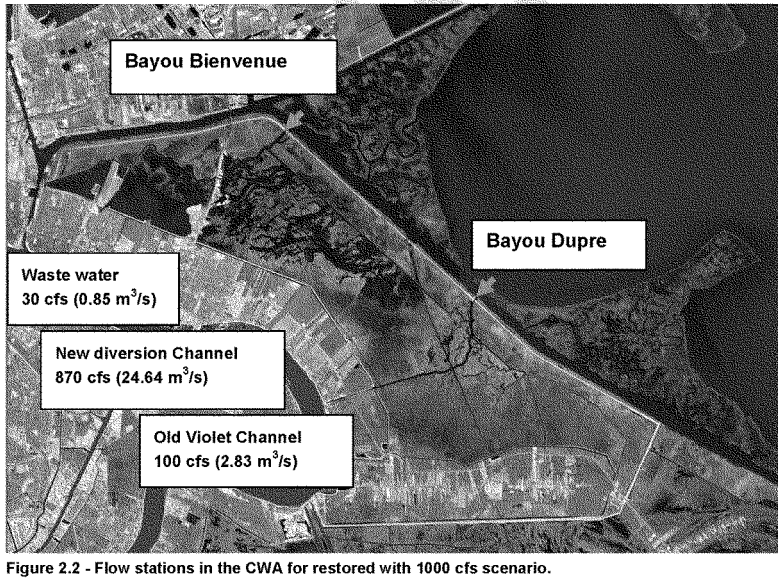

Figure 2.2 - Flow stations in the CWA for restored with 1000 cfs scenario.

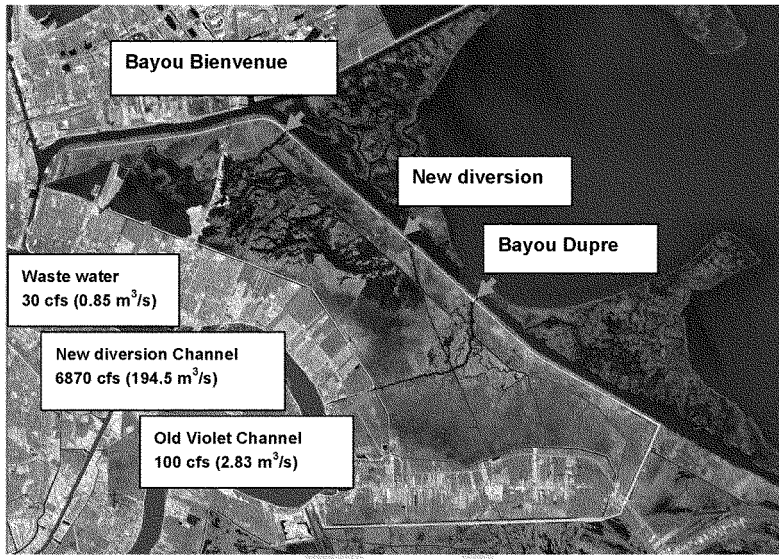

Figure 2.3 - Flow stations in the CWA for baseline with 7000 cfs scenario.

2.3 Approach

To answer the key questions the following approach was applied.

Step 1: Collect data and analyze the actual hydrodynamic system of the CWA

Step 2: Model setup of the baseline scenario
- Step 2.1: Define model area and define model forcings;
- Step 2.2: Setup bathymetry and land classification;
- Step 2.3: Setup computational grid;
- Step 2.4: Define model boundaries and (initial) model settings

Step 3: Calibration and validation of the baseline scenario against measurements
- Step 3.1: Calibration on water levels;
- Step 3.2: Calibration on salinity;
- Step 3.3: Validation of water levels;

Step 4: Production runs for the different scenarios
- Step 4.1: Setup and production run *Existing with 1000 cfs scenario;*
- Step 4.2: Setup and production run *Restored with 1000 cfs scenario;*
- Step 4.3: Setup and production run *Restored with 7000 cfs scenario;*
- Step 4.4: Setup and production run *Sea level rise;*

Step 5: Analyze model results production runs;

Step 6: Sensitivity analysis;

Step 7: Presentation of results and main conclusions

The details of the choices regarding model settings, boundary conditions, calibration and validation locations and periods, bathymetry, computational grid and the setup of the different scenarios are presented in the following chapters.

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3 CHARACTERISTICS OF MODEL AREA

3.1 Introduction

The CWA is located between the Saint Bernard Parish to the south and west, Lake Borgne and the MRGO on the east and the IHNC to the north. The area of the wetland is approximately 31,000 acres (12,500 hectares) with a southeast to northwest length of 15.5 miles (25 km) and a width of 3 miles (5 km). The area consists of low lying land with a level between 1 and 3 ft above NAVD88 (2004.65). The canals and other water bodies have a bottom level of approximately -3 ft to -11 ft. The vegetation in the area consists of mainly emergent Herbaceous wetlands, areas of woody wetland and open water. In addition, there are some areas with developments of low intensity (mainly along the Paris Road).

The Biloxi Marsh is located between Lake Borgne on the north and west, the MRGO on the south and Chandeleur Sound on the east. This area is not included within the model domain, because the key questions are only focused on the hydrodynamic conditions within the CWA.

3.2 Tidal conditions

The tides in the water bodies around the CWA are principally diurnal. The tidal range around the CWA is about 1.2 feet from MLW to MHW. This tidal range is measured at a station located near the Bayou Dupre floodgates. In Lake Maurepas the tidal range is 0.3 ft, in Lake Pontchartrain 0.5 ft and 1.4 ft in the Chandeleur Sound. Mean water levels are affected by winds, freshwater runoff, and seasonal trends in the Gulf of Mexico. Sustained winds can raise or lower peak astronomical tide levels by several feet for short periods of time. The mean water levels are lower in winter and midsummer while higher in spring and fall. Currents and circulation are controlled by tides, winds, freshwater discharges, and Gulf currents and, to a lesser extent, baroclinic conditions [3].

Table 3.1 - Historic monthly means at NOAA station Shell Beach (feet, data referred to MSL)[1]

Year	Month	Highest	MHHW	MHW	MSL	MTL	MLW	MLLW	Lowest
2008	12.00	1.46	0.53	0.48	-0.22	-0.31	-1.09	-1.09	-2.31
2009	1.00	1.13	0.27	0.13	-0.54	-0.57	-1.28	-1.34	-2.15
2009	2.00	1.19	0.38	0.30	-0.35	-0.33	-0.97	-1.09	-2.08
2009	3.00	2.96	0.81	0.77	0.05	0.01	-0.57	-0.75	-2.06
2009	4.00	2.21	0.84	0.73	0.10	0.03	-0.68	-0.78	-1.85
2009	5.00	2.78	1.00	0.98	0.31	0.30	-0.36	-0.42	-1.39
2009	6.00	1.30	0.52	0.51	-0.23	-0.24	-0.99	-1.03	-1.54
2009	7.00	1.03	0.51	0.45	-0.24	-0.26	-0.96	-1.01	-1.46
2009	8.00	1.76	0.98	0.86	0.25	0.23	-0.40	-0.49	-1.30
2009	9.00	3.39	1.54	1.43	0.94	0.89	0.35	0.28	-0.46
2009	10.00	2.71	1.33	1.30	0.73	0.73	0.15	0.10	-0.62
2009	11.00	5.23	1.40	1.35	0.68	0.63	-0.10	-0.09	-1.03

The water levels measured at a NOAA station in Lake Borgne, (Shell Beach), show the variation of the mean sea level during a year. This annual fluctuation in sea level is due to thermal expansion of the upper layers of the Gulf of Mexico.

[1] Source: http://tidesandcurrents.noaa.gov/station_info.shtml?stn=8761305+Shell+Beach,+LA

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3.3 Wind conditions

Most of the time, winds in the southern Louisiana estuaries are calm to light. At Shell Beach, the wind speed is less than 10 m/s (about 20 knots, 5 Beaufort) for about 95% of the time (measured in 2009) and 99% of the time, during 2009, wind speeds are less than 13 m/s (about 25 knots, 6 Beaufort).

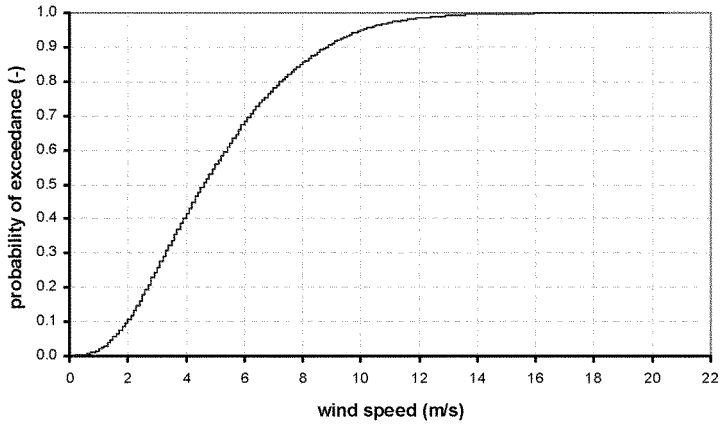

Figure 3.1 - Probability of exceedance of wind speeds at NOAA station Shell Beach (based on hourly data for 2009)

Occasionally, the area is affected by strong winds from hurricanes (tropical storms that occur mainly during summer and fall) or frontal systems (mainly during winter).

The frontal systems generally approach from the north. Northern winds, preceding a frontal passage cause a set down on the continental shelf and this allows for gravity drainage of the estuary. The frontal systems have a more persistent wind speed and wind direction than the tropical storms (USACE, 2009).

The tropical storms are characterized by very strong winds, of which the direction and speed can change within hours during passage of the storm. When the storm approaches the region from the south, it is accompanied by strong to very strong winds from the east and southeast. These winds push the shelf waters inland, piling up the water in a significant rise of water level, commonly called a storm surge (USACE, 2009).

In the coastal area, winds have a strong impact on coastal water levels. Winds from a southerly direction may push water into the bays and lakes, frequently raising water levels in the upper part of the estuarine zone.

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3.4 Salinity

Figure 3.2 and Table 3.2 show the average salinity for the Biloxi marshes and the area of Chandeleur Sound. During the summer and fall, the salinity reaches it highest values. During this time of the year, the influences from freshwater sources are at a minimum. For more information about the salinity of the area and the impact of the freshwater sources, reference should be made to the report of USACE (2009) about the proposed freshwater diversion in the vicinity of Violet.

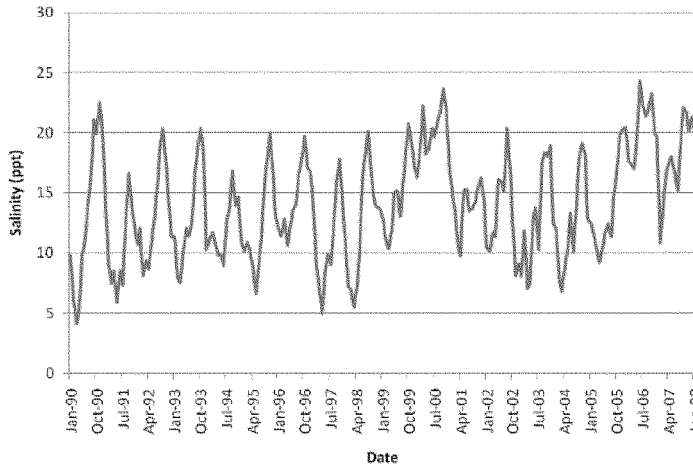

Figure 3.2 - Salinity variations in the area of Chandeleur Sound from 1990 to 2008

Table 3.2 - Average salinity for the Biloxi Marshes (in ppt) (McAnally 1997).

	jan	feb	mar	apr	may	Jun	jul	aug	sep	oct	nov	dec
Salinity (ppt)	19.5	16.5	15	14	15	17	20.5	22	23	24	24	23

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4 MODEL SETUP, CALIBRATION AND VALIDATION

4.1 Introduction

This chapter describes the setup, calibration and validation of the numerical model which will be used to evaluate the several scenarios as described in Chapter 2.

The modeling approach is outlined with a short description of the field data used and the applied model. Sections 4.2 to 4.5 describe the setup for the schematization and calibration. Section 4.6 describes the results of the model calibration and validation.

4.2 Applied model

The model simulations were done using the hydrodynamic module (HD) of the MIKE21 package of the Danish Hydraulic Institute (MIKE21-HD). This program is developed for modeling of non-steady water flow and the transport of dissolved matter. MIKE21-HD solves the two-dimensional (depth averaged) shallow-water equations for arbitrary boundary conditions. The equations are solved by a finite volume method (DHI, 2008) on a rectangular or a triangular grid (in this study a triangular grid was used). For this project, MIKE21-HD was used in the one layer mode which implies that the velocities and salinity levels are calculated by the model as depth-averaged values. The following contributions are included in the momentum equations:

- acceleration due to changes in the local velocity (convective accelerations);
- earth rotation;
- water level gradients;
- horizontal momentum exchange due to eddy viscosity;
- density differences (horizontally), due to salinity variations;
- bed friction;
- wind influences;

Wind generated waves are not taken into account in this study.

4.3 Model setup

The hydrodynamic model includes the total area of the CWA. The open boundary on the 'offshore' side is formed by the MRGO. Tidal water levels and salinities varying along this boundary are imposed to force the hydrodynamic model. The diversions are applied as boundaries in the model at which an inflowing discharge is specified.

In addition to the hydrodynamic equations, the density equations are solved which is required to calculate the spreading of saline or fresh water into the model area. Temperature gradients are neglected.

The calculated salinity gradients are fed back to the hydrodynamic equations, which establish a coupling between the water flow and the salinity at runtime.

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4.3.1 Computational grid

Figure 4.1 shows a part of the computational grid. The layout of the grid is based on the locations of the several channels inside the CWA. Inside the channels, the grid is much finer than outside the channels. The channels are represented in the grid with at least 1 grid cell at the lowest part of the channel and 1 grid cell on each slope. Because of the small width of some of the channels, this requires a large amount of computational points (about 78,000), a short computational time step and long simulation times. The grid resolution varies from 15ft in the channels to 200ft in the flat higher located areas.

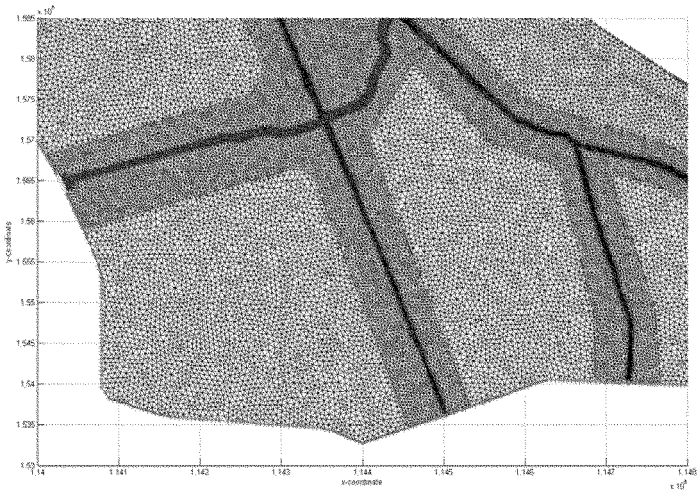

Figure 4.1 - Part of the computational grid and the open boundaries. Blue is the MRGO boundary, green is the Violet channel boundary and red is the land boundary (closed).

The following has been taken into account when designing the grids:

- the dimensions of an individual cell, partly based on the dimensions of the channels;
- the total number of computational points;
- the orthogonality of the individual cells;
- the spatial variation of the dimensions of the cells;
- the areas in which the grid has to be refined

The optimum computational grid is a compromise between the above items and the geographic limits of the model.

4.3.2 Bathymetry and levees

The model bathymetry is shown in Figure 4.2. This bathymetry is based on a combination of Lidar data, surveys of the Violet Canal and the Bayou Bienvenue collected for other projects, and additional channel and open water survey undertaken by UNO as part of this study. All the data has been combined in a bathymetric and topographic database based on NAD 1983 State Plane Louisiana South FIPS 1702 (m) for positional coordinates and NAVD88 (2004.65) for elevation. As shown in the figure,

all main channels are implemented in the model. The MRGO (bottom level -10 m, -32.8 feet), is partly included and is used as a model boundary.

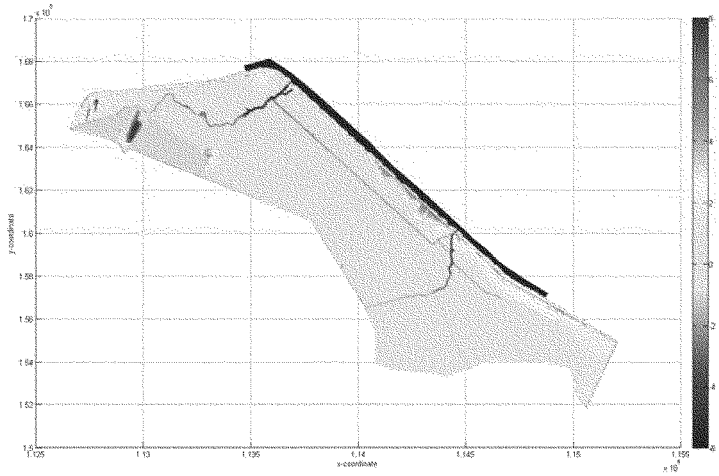

Figure 4.2 - Bathymetry of the CWA, as implemented in the model. Values are in m w.r.t. the reference level.

The levees and Paris Road are included within the bathymetry; however, due to the coarser grid cells in some of those areas, the height of these features is not very well represented. At some locations, water would be able to flow into the CWA or over the Paris road at elevations well below the actual levels. For this reason the levees and Paris Road have been implemented in the model as weirs (line elements with a certain height and width). The weirs are shown in Figure 4.3, the heights are based on values from the more detailed topographic data. These weirs restrict the potential for flooding over the levees and Paris Road. No weirs have been included where channels pass through these structures.

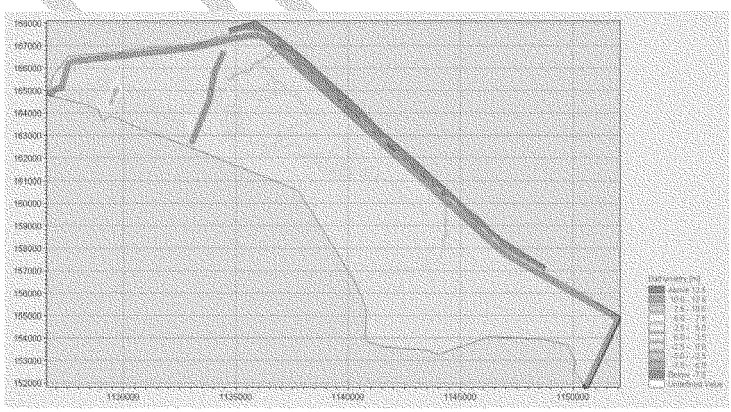

Figure 4.3 - Location of the levees (brown line), implemented as weirs. Values are in m w.r.t. the reference level

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4.3.3 Bed Resistance

A spatially varying bed resistance based on land classification maps of the CWA was applied in the model domain. The bed resistance as applied in the model is shown in Figure 4.4.

The land classification maps are linked with bed resistance values (Manning – n), which is based on earlier work by FEMA (2007).

In the MIKE21 software, the bed resistance can be included in two ways: a Chezy coefficient or a Manning coefficient. The main difference is that the Chezy coefficient depends on the water depth. Both coefficients are linked by the following formula (as implemented in the MIKE software):

$C = Mh^{1/6}$, with

C = Chezy coefficient ($m^{1/2}/s$)
M = Manning - M coefficient ($m^{1/3}/s$)
h = (local) water depth (m)

In this formulation, both parameters are smoothness coefficients. An increase of the value of M or C relates to a lower bed resistance. In this model the Manning - M coefficient is used, which is defined by: M = 1/n. The Manning - M coefficient can be seen as a roughness coefficient, thus: increasing M relates to a larger roughness.

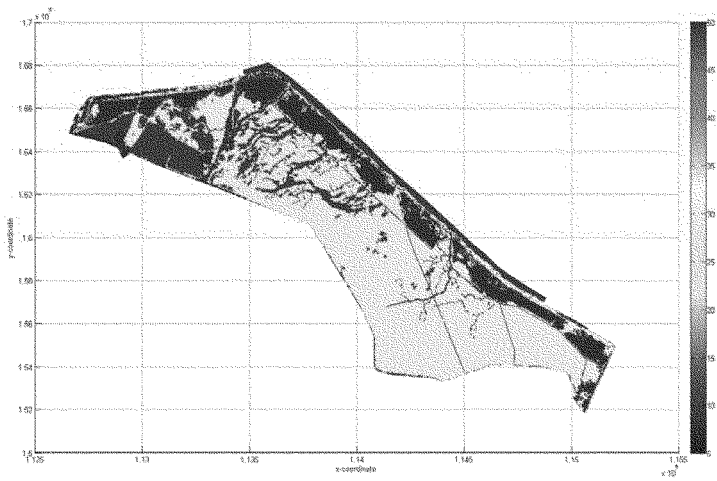

Figure 4.4 - Bed resistance map, values as Manning M coefficients

Table 4.1 shows all the types of land classification used in this model, together with their Manning values.

Most of the area consists of Emergent Herbaceous Wetlands and Woody Wetlands.

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Table 4.1 - Land classification with corresponding Mannings n (From FEMA, 2007) and M values.

Land Classification	Manning, n	Manning, M
Barren Land	0.030	33.3
Cultivated crops	0.040	25.0
Deciduous forest	0.160	6.3
Developed, high intensity	0.121	8.3
Developed, low intensity	0.120	8.3
Developed, medium intensity	0.120	8.3
Developed. open space	0.035	28.6
Emergent Herbaceous Wetlands	0.035	28.6
Grassland, Herbaceous	0.035	28.6
Mixed Forrest	0.170	5.9
Open water	0.020	50.0
Pasture. Hay	0.033	30.3
Shrub / Scrub	0.070	14.3
Woody wetlands	0.140	7.1

4.3.4 Boundary conditions

Water levels

The water level is defined at the open boundary within the MRGO. The applied water levels for the calibration are shown in Figure 4.5 and for the validation in Figure 4.6. These figures show the water levels measured at the eastern side of the Bienvenue and Dupre gates. Between the stations the water levels were linearly interpolated. The water level data were provided by USACE [4] .

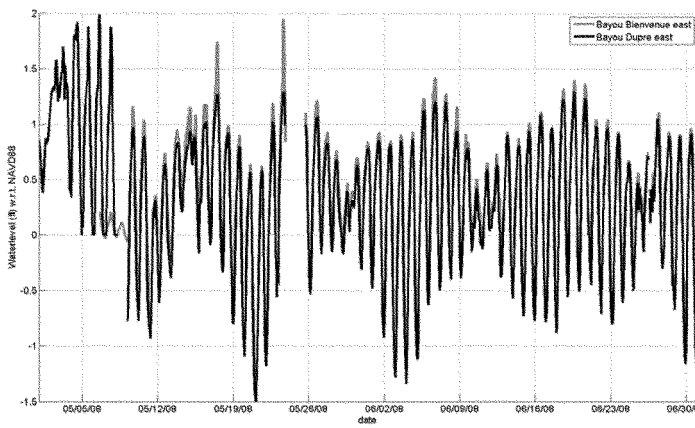

Figure 4.5 - Water level (ft) boundary conditions at the MRGO for the calibration period in 2008

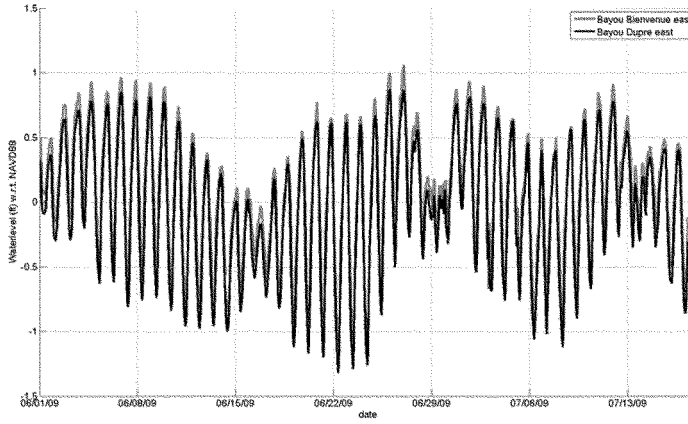

Figure 4.6 - Water level (ft) boundary conditions at the MRGO for the validation period in 2009

Salinity

The salinity values (in ppt) are prescribed at the MRGO boundary (measured at the Bayou Bienvenue structure) . It is assumed that the salinity is uniform along the boundary, but varies in time. This time variation for the validation period is shown in Figure 4.7. Two types of variation can be distinguished: the short term variations which are associated with the tide and have a cyclic character and the fluctuations which have a time span in the order of a few days. These variations have a non-cyclic character and are much larger than the short term variations. The nature of these variations is unknown but may be attributed to wind variations and/or rainfall events.

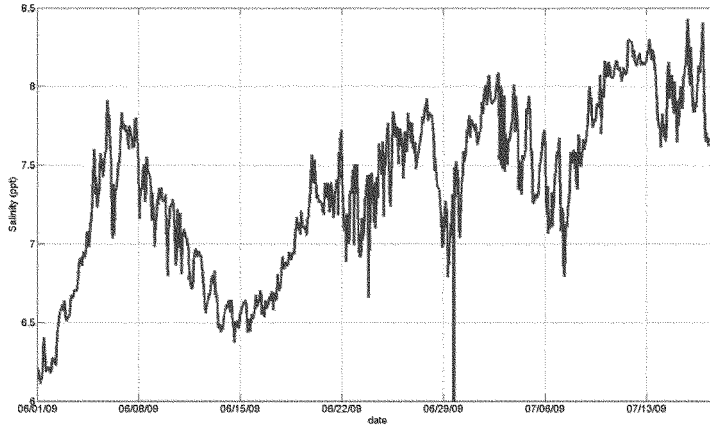

Figure 4.7 - Salinity (ppt) boundary condition at the MRGO for the validation period in 2009

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Wind and Rainfall

Wind conditions and rainfall are taken as being uniform over the whole domain as no spatial data was available to account for spatial variations. The wind and rainfall data for the calibration and validation period is shown in Figure 4.8 and Figure 4.9 respectively. Data was collected at the Bayou Bienvenue Structure

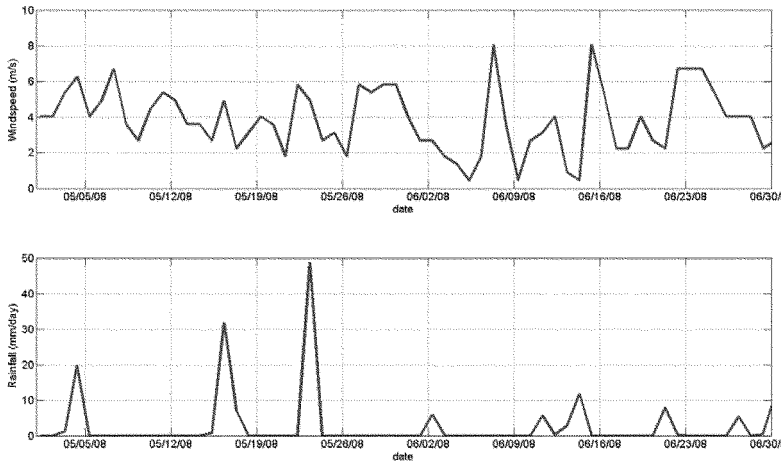

Figure 4.8 - Wind speed (m/s) and rainfall (mm/day) during the calibration period in 2008.

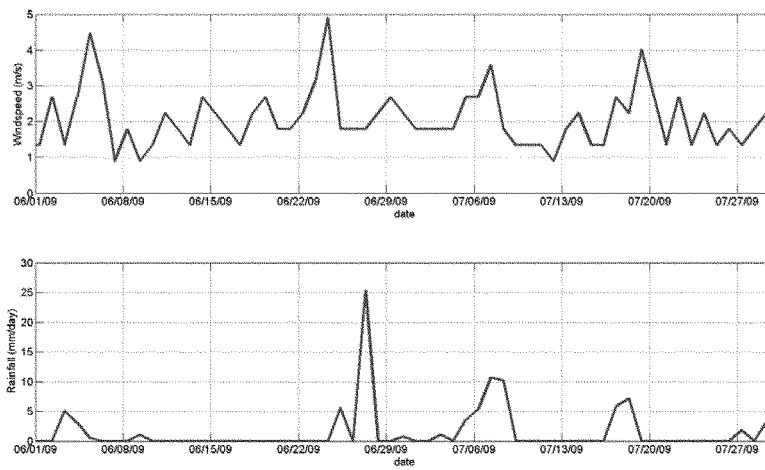

Figure 4.9 - Wind speed (m/s) and rainfall (mm/day) during the validation period in 2009.

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Note that the maximum wind speed during the simulation period was 8 m/s (26.2 ft/s), which is Beaufort 4. Such wind conditions will cause no significant effects on the hydrodynamic conditions within the model domain.

Rainfall is limited to a few days during the computational period. From comparison between model results with and without rain it was concluded that the effect of rain on the water levels is negligible. However, for completeness, rainfall was taken into account in all runs. Evaporation is neglected in the model simulations, as no data was available about this parameter. Like rainfall, it is expected that evaporation will have a minor impact on the model results.

4.4 Model settings

Model settings govern the behavior of the model and indicate which processes are taken into account. Table 4.2 gives an overview of the final model settings (after calibration and validation) applied for the study. For a detailed description of the settings, reference is made to the users' manual of MIKE21-HD [1].

Note that the applied values are in fact the settings as selected at the final stage of the calibration process, which is reported in Sections 4.5 and 4.6. The selected settings of the various model parameters gave the best results over a number of runs with the flow model.

Table 4.2 - Final model settings for the simulations

Description	Settings
Bathymetry	See Figure 4.2
Time set interval	1800 sec (for output storage)
Minimum time step	0.01 sec
Maximum time step	30 sec
Critical CFL number	0.8
Flooding and drying	Included, default values: h_{dry}=0.005 m, h_{flood}=0.05 m and h_{wet}=0.1m
Density	Function of salinity, reference temperature 27 °C, reference salinity 6.5 ppt
Bed resistance	Manning, varying in domain; See figure 4.4
Horizontal eddy viscosity	Smagorinsky formulation with a constant coefficient of 0.28
Coriolis	Varying in domain
Wind	Varying in time, constant in domain (figures 4.8-4.9), friction constant = 0.001255
Precipitation	Varying in time, constant in domain (figures 4.8-4.9)
Structures	Weirs, see figure 4.3
Salinity – Equation	Minimum 0 ppt, maximum 45 ppt
Salinity – Solution technique	Time and space: higher order scheme
Salinity – Dispersion	Dispersion coefficient, constant in domain; 1.85 m2/s
Salinity – Initial conditions	Constant in domain: 2 ppt

4.5 Calibration

4.5.1 General

Usually, a flow study can be split up into a calibration/validation stage and a production stage. In the calibration stage a check is made whether the model can reproduce the observed parameters and tidal movement for the existing situation. The purpose of

model calibration is to match the model results with the measurements and increase the accuracy of the model predictions.

The tidal movement is characterized by water levels, current velocities and directions and can be influenced by adjusting (within the limits of their uncertainties) for instance the bed roughness, the local depths, the boundary conditions or other numerical or physical parameters. As a result of the calibration, a set of parameters becomes available which 'describe' the processes for the existing situation in a proper way, particularly in the area of interest. In the present study, salinity is also a parameter of interest.

The model was calibrated for two parameters: water level and salinity. In a first step, the hydrodynamic part of the model was tuned by comparing computed and observed water levels. Typical parameters adapted in this step were the bed roughness and the local water depth.

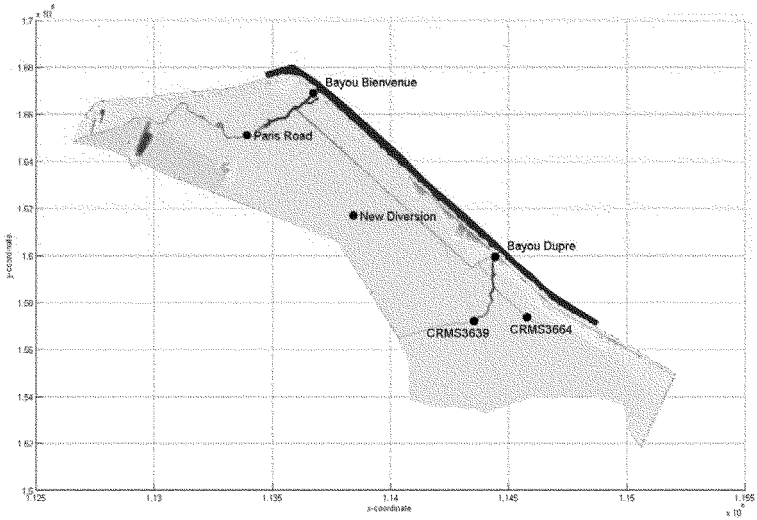

Figure 4.10 - Model output points. CRMS points were used for the calibration and validation

In a second step, the transport processes are tuned. These processes govern the distribution of fresh/saline water within the model domain and are determined by convection and diffusion processes. A typical parameter adapted in this step was the diffusion coefficient. This coefficient may be constant for the whole domain or spatially varying. Given the timeframe for undertaking the present study, this parameter was taken as constant within the domain.

The calibration was done based on measured water levels for the period May 2008 to June 2008 and salinity measurements for the period June 2009 to July 2009. No good quality salinity data was available for the period in 2008. For this reason, the salinity was calibrated for the period in 2009, which is the same period used for the validation of the water levels. Validation for the salinity was not possible, due to the limited amount of good quality data.

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The hydrodynamic model was calibrated based on measured water levels at two locations inside the CWA, CRMS3639 and CRMS3664 (Figure 4.10). Unfortunately, no data points were available in the northern part of the CWA.

4.5.2 Results

Water levels

The final results of the calibration process are shown in Figure 4.11 and Figure 4.12. These figures show time series of the water levels for the period 10 May 2008 – 30 June 2008, for both calibration points. For location CRMS3664, the water levels are biased low (under predicted). For location CRMS3639 they are over predicted. This observation is also shown in the scatter plots in Figure 4.13.

During the calibration process, several parameters are modified to match the model results with the observations. First, the bed resistance in the open water parts of the model was adjusted. After the first series of simulations, it was concluded that the bed resistance has a minor influence on the water levels in the CWA.

In a second step, the bathymetry of some water parts was adjusted based on more recent bed level data that became available during the study. This resulted in a deepening of some channels and improved the model results. However, the tidal amplitude in the model domain was too large which was caused by an over prediction of in- and out flowing water during a tidal cycle. For this reason, the bed level in the Bayou Dupre opening was raised in several steps.

The simulation with the optimum settings is shown in the final results in Figure 4.11 and Figure 4.12.

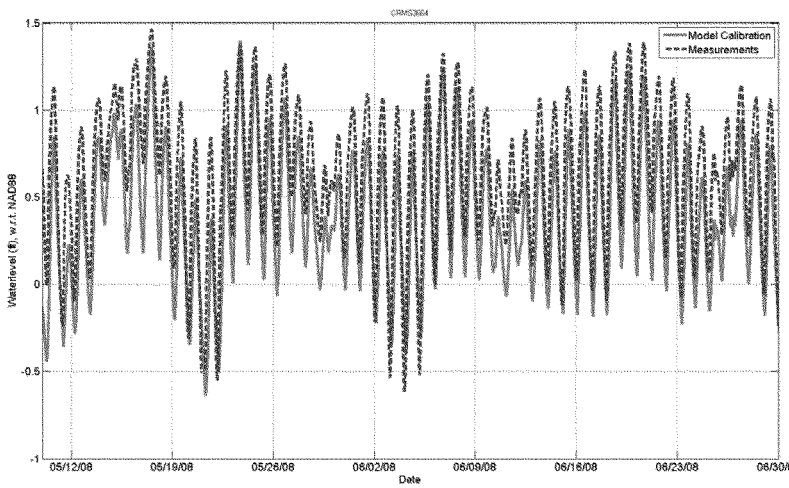

Figure 4.11 - Final results of calibration, time series of water level at point CRMS3664

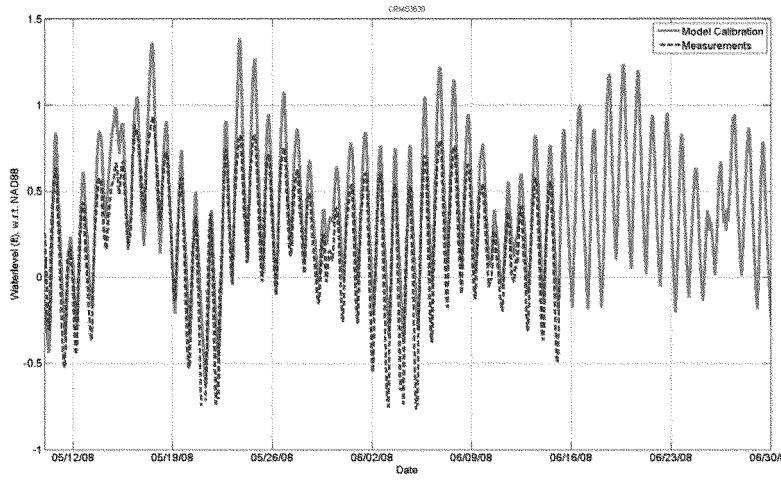

Figure 4.12 - Final results of calibration, time series of water level at point CRMS3639

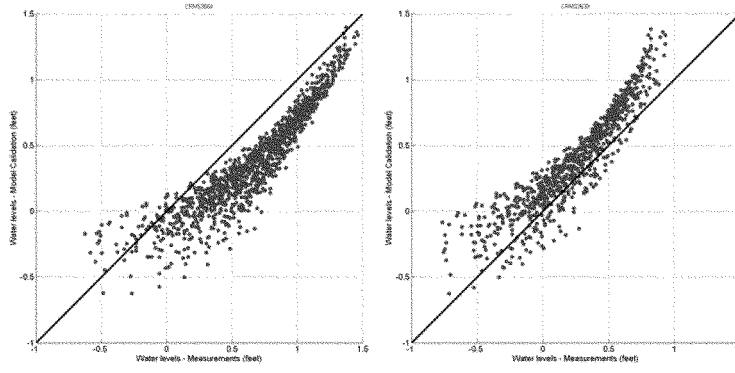

Figure 4.13 - Scatter plots, water level measurements vs. model results for the locations CRMS3664 (left) and CRMS3639 (right).

As shown in the Figure 4.11 to Figure 4.13, the water levels are somewhat over- and under predicted by the model, but the correlation between the model and the measurements (shown in the scatter plots) is acceptable. This over- and under prediction is explained by the uncertainty in the reference level of the measurements.

A difference of 0.2 – 0.3 m (0.66 – 1 ft) was found between the water level measurements at the boundary and for a location within the model domain for the calibration period.

It was concluded that the measured water levels in the domain are approximately 0.2 m (0.66 ft) too high (compared to the water levels in MRGO). For this reason, these were reduced by 0.2 m (0.66 ft) at both locations. However, given the uncertainty about the vertical datum of the measurements, it is possible that this correction should be different for each location.

A tidal analysis was carried out to get the tidal amplitude and -phase of the main components (K_1 and O_1) of the computed and the observed water levels. Figure 4.14 shows the result of that tidal analysis. The predicted phase of the main components matches very well with the measured phase, as well the amplitude of the O1 component. However the amplitude of the K1 in the model is somewhat over predicted.

Overall it can be concluded that the model results of the water levels match the measurements for this calibration period. The accuracy of the predictions is in the order of 0.3 ft.

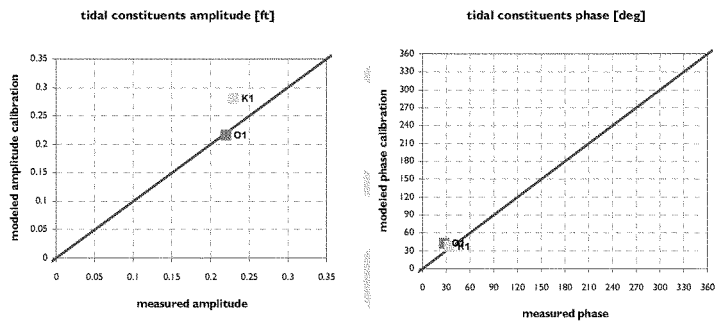

Figure 4.14 - Results of tidal analysis of final calibration run: amplitude (left) and phase (right) for location CRMS3664

Salinity

After the calibration for the water levels, several model runs were made to tune the model predictions for salinity. As noted in Section 4.3.4, the non-tidal oscillations of the salinity level are much larger than the variations associated with the tide. Such oscillations may be related to influences such as (local) rainfall and/or wind. Typical parameters varied in this stage of the calibration are the dispersion formulation, value of the dispersion coefficient and the initial conditions.

Several runs were required to get model results that are within the same order of magnitude as the observations. This may be related to the fact that the calibration locations are located at sheltered locations within small creeks and shallow water.

The best result, as shown in Figure 4.15 was achieved using a dispersion coefficient of 1.85 m^2/s and an initial salinity concentration of 2 ppt. Note that the first five days are considered as the spin up period and as such the starting concentration rapidly moves towards the values observed and therefore plays little if any role in the final calibration results. Figure 4.15 shows the results during a two-week period. The figure shows that the (moving) average value is roughly the same as the observation. However, the daily fluctuations seem to be difficult to capture. Predicting these correctly would require a

local calibration requiring spatially varying model dispersion coefficients. This is both time consuming, and potentially of little value once the bathymetry and flow conditions are radically changed throughout the life of the project. Therefore the global coefficients were used for this modelling effort.

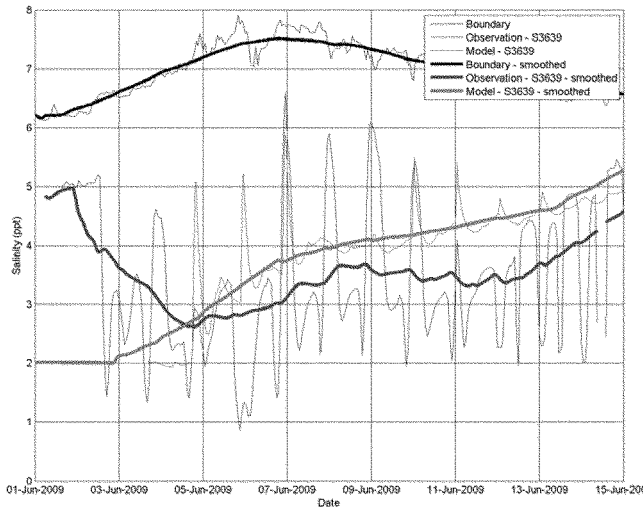

Figure 4.15 - Calibration result of salinity

4.6 Validation

4.6.1 General

A validation run was done in order to validate the model against measurements not used for the calibration. The purpose of this is to verify the accuracy of the model and check whether the model is suitable for use in arbitrary situations.

The validation was done based on measured water levels for the period June 2009 to July 2009.

4.6.2 Results

Figure 4.16 and Figure 4.17 show time series for the water levels, both measured and predicted, at the locations CRMS3664 and CRMS3639. As shown in the figures, the predicted water levels match (much) better with the measurements than during the calibration period. At the location CRMS3664 the high waters match very well, the low waters are somewhat over predicted.

At location CRMS3639, the modelled water levels are just above the measured levels.

These observations are also shown in the scatter plots in Figure 4.18. The correlation between the predicted water levels and measured water levels is better than for the calibration period, most of the data points are near the 1:1 line.

For low water the scatter around the line is larger, which means that the model over predicts the water levels by about 0.15 -0.3 ft.

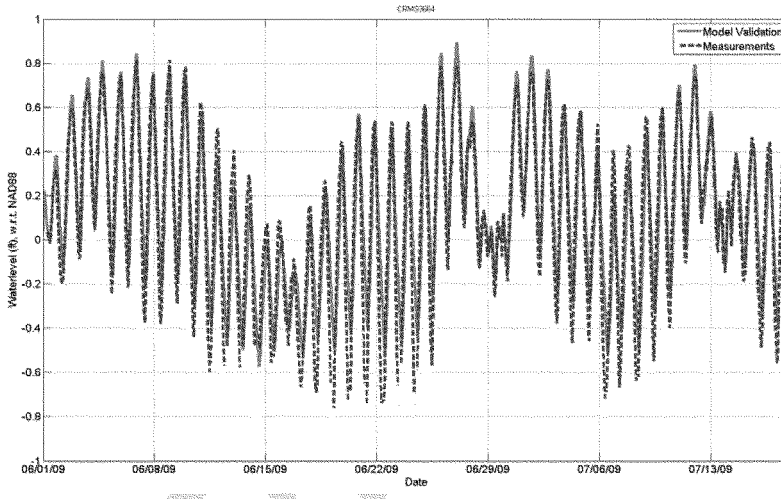

Figure 4.16 - Final results of validation, time series of water level at point CRMS3664

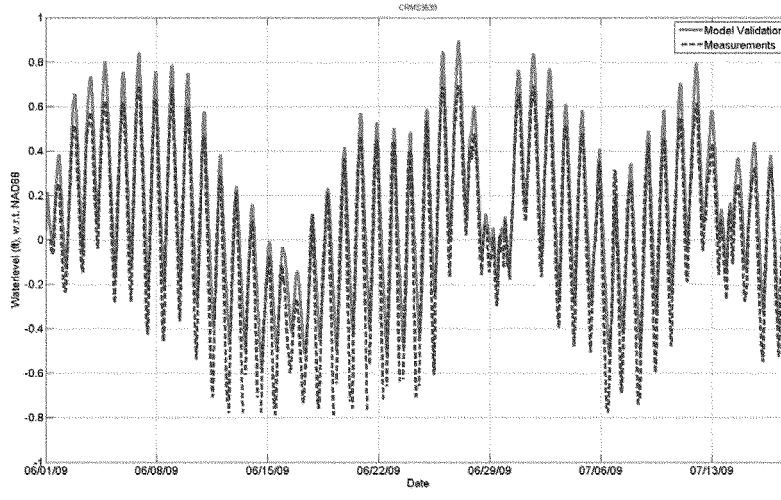

Figure 4.17 - Final results of validation, time series of water level at point CRMS3639

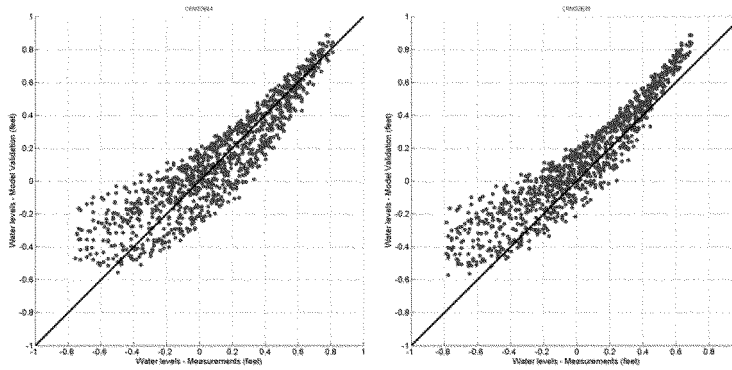

Figure 4.18 - Scatter plots validation period, water level measurements vs. model results for the locations CRMS3664 (left) and CRMS3639 (right).

Also for the validation period, a tidal analysis for the main components was carried out, for both observation points. Figure 4.19 shows the results. The predicted phase of the components is in line with the measurements. However, the predicted tidal amplitude is under predicted for both components and for both locations. The difference is about 0.03 - 0.065 ft between the measurements and the model results. However, for the calibration period the tidal amplitude is a bit too large. This means that the amplitude is during some periods too low and during some periods too large. However, overall the model predictions match the measurements within an acceptable error margin.

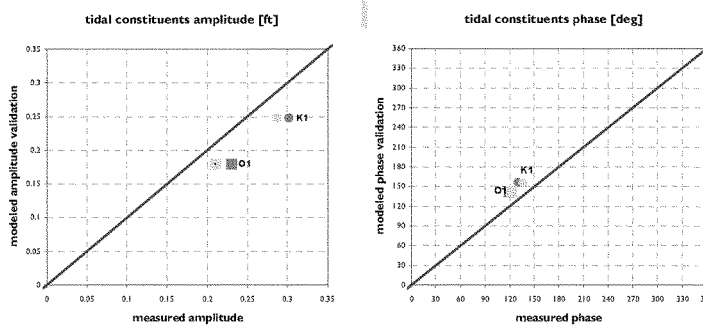

Figure 4.19 - Results of tidal analysis of final validation run: amplitude (left) and phase (right) for location CRMS3664. Red points CRMS3664, green points CRMS3639

The modeling team consider the accuracy of the model sufficient and it was decided that no further calibration and validation of the modeled water levels was required and that the model can be used to simulate the effects of the fresh water outflows on the hydrodynamic conditions and salinity in the CWA and to address the main objectives of the study.

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5 HYDRODYNAMIC MODEL RESULTS

5.1 Introduction

This chapter describes the results of the hydrodynamic simulations for the different scenarios of which the layouts are presented in Section 2.2.

For each scenario, the following results are presented and analyzed:
- Discharge distribution (flow split) through the different outfalls to the MRGO;
- Water levels, current velocities and salinity at 4 specific locations (shown in Figure 4.10) and basic statistical values for the whole area (mean and maximum values).

The simulation period for all scenarios is 1 to 30 June 2009 during which 2 spring – neap cycles are simulated.

5.2 Model results for Baseline scenario (1)

The water levels and salinity values for the baseline scenario are presented in the previous chapter within the discussion on the calibration of the model. The same parameters, as well as the current velocities, are also plotted for the other scenarios. Effects of the scenarios with respect to the baseline scenario can be determined from those figures.

Flow split

Figure 5.1 shows the discharge distribution over the Bayou Dupre and Bayou Bienvenue outflows to the MRGO. The discharges through the openings fluctuates with the tide. The maximum discharge through the Bayou Bienvenue is much larger (about 1500 – 3000 cfs) than through the Bayou Dupre (300 -700 cfs).

The average discharges are low, about 9.3 cfs for Dupre and -19.2 cfs for Bienvenue. Positive discharge is defined as flowing into the MRGO, negative discharge is defined as flowing into the CWA. Although the values appear to show a small net inflow into the CWA this is small when compared to the flows through the structures (2% or less) and is within the tolerances of the model and so the model is effectively balanced.

Water levels

The maximum water levels in the area are shown in Figure F1 and the mean water levels in Figure F6. As shown in both figures, a small water level gradient from north to south is seen. The water levels are higher near Bayou Bienvenue, maximum 1 – 1.05 feet, whereas near Bayou Dupre the maximum levels are almost 0.1 feet lower.

Inside the CWA this variability is lower, except the western part. In that area the maximum water levels are limited to 0.6 – 0.8 feet, probably caused by the blocking effect of Paris Road.

Current velocities

The maximum current velocities are generally low. Figure H1 shows that the maximum velocities In the channels in the CWA this is low, approximately 0.3 – 0.6 ft/s. In the small channels, as well as the open water parts, the current velocities drop to almost 0 ft/s.

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Salinity

Figure 5.2 shows the average salinity during the simulation period for the baseline scenario. See also Figure G1. The average salinity along the channels in the CWA decreases from the value outside in the MRGO. Within the central wetlands, the mean salinity is typically about 4 ppt. In the Violet Channel the mean salinity drops to 2 ppt in the most western part.

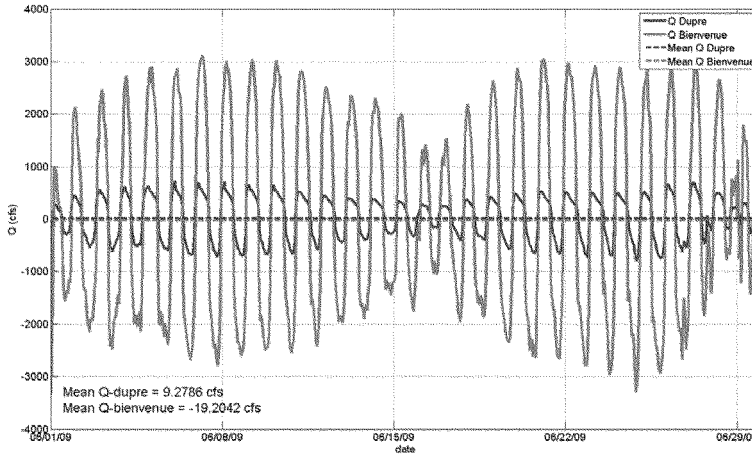

Figure 5.1 - Discharge distribution over the Bayou Dupre and Bayou Bienvenue for the baseline scenario.

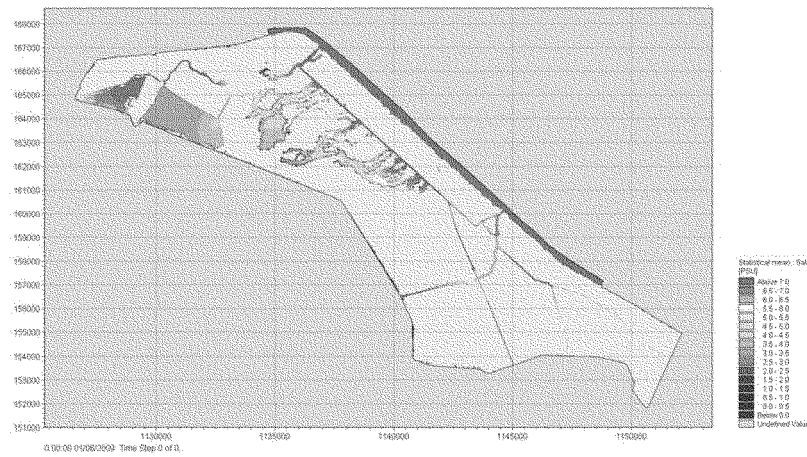

Figure 5.2 - Average salinity in the baseline scenario

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5.3 Model results for Existing with 1000 cfs scenario (2)

5.3.1 Model adjustments

This section presents the results of the existing with 1000 cfs inflow through the new diversion. For this scenario the model was adjusted on several points. The new diversion channel was implemented in the bathymetry (Figure 5.3), the bed level of the channel is set to -3 feet w.r.t. the reference level of the model. The roughness in the channel was changed to an 'open water' classification.

The 1000 cfs inflow was split between 3 inflow locations (as indicated with the red arrows in Figure 5.3) according to the configuration of Figure 2.1:

- New diversion : 870 cfs
- Violet channel : 100 cfs
- Waste water outlet : 30 cfs

For the new diversion and the Violet channel, 2 new open boundaries were created, with a constant discharge. The waste water outlet is modelled as a source point in the model, with a constant discharge. The water from all fresh water inlets has a salinity of 0 ppt.

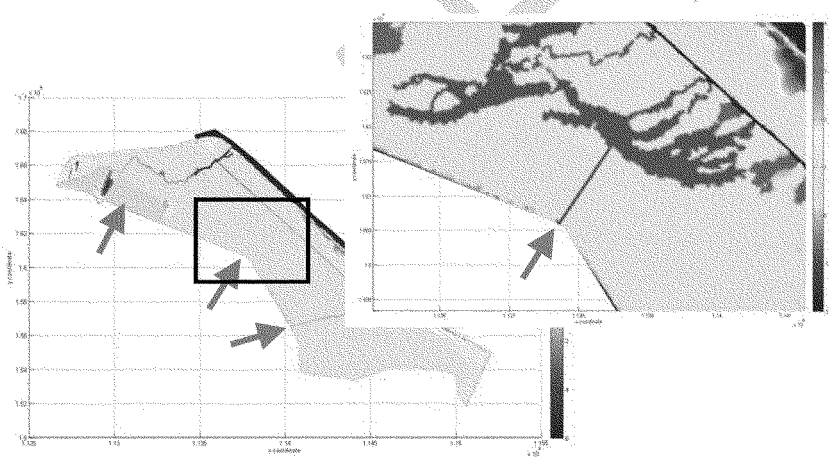

Figure 5.3 - Bathymetry for the existing with 1000 cfs scenario. The inflow locations are shown in red.

5.3.2 Results

Flow Split

Figure 5.4 shows the temporal variation and the average discharge distribution over the Bayou Dupre and Bayou Bienvenue gates. The maximum discharge through the Bayou Bienvenue is again much larger (about 1800 – 3400 cfs) than through the Bayou Dupre (300 – 1000 cfs). On average about 385 cfs flows through the Bayou Dupre and 596 cfs

through Bayou Bienvenue. The discharge distribution is roughly 40 % Dupre and 60 % Bienvenue.

The total outflow in to the MRGO is approximately 1000 cfs, which is the same as the total discharge input on the model boundaries. This concludes that the water that flows into the CWA, also flows out to the MRGO and that no storage occurs during the simulation period.

Water levels

Annex B shows the model results on the 4 specified locations inside the CWA. Water levels are presented in Figures B1 – B4.

At the end of the new diversion channel, the water level increases significantly. In the actual situation only during high waters is the area flooded. In the baseline scenario with 1000 cfs, the water levels increase to 0.3 – 1.1 feet and the tidal range is about 0.1 – 0.5 feet at that location.

At the Paris Road and at Bayou Bienvenue there is hardly any change in water levels. However at the Bayou Dupre, the water level increases by approximately 0.1 – 0.5 feet and the tidal range decreases by almost 0.3 feet during high waters.

Annex F shows 2D figures of the maximum and mean water levels in the area. For the baseline scenario with 1000 cfs the maximum water levels are found in the new diversion channel (above 1.2 feet) and in the adjacent wetlands (1 – 1.1 feet). Also the mean water level increases most in those areas, in the channel by over 0.7 feet and in the wetlands around 0.6 feet.

Current velocities

Current velocity plots are shown in Figures B5 – B8. The current velocity inside the new channel is approximately 2.5 ft/s. At the Paris Road no changes in velocities were observed. At the Bayou Dupre and Bayou Bienvenue there are some changes, but hardly in the maximum values. At Bienvenue the maximum velocity increases slightly by 0.1 ft/s during ebb flow (to the MRGO). Overall the velocities during ebb flow are larger than during flood flow (to the CWA). During flood flow the current velocities decrease by almost 0.2 – 0.3 ft/s at Bienvenue. This can be explained by the extra freshwater outflow from the CWA into the MRGO increasing the ebb flow and decreasing the flood flow. At the Bayou Dupre hardly any flood flow can be distinguished due to this freshwater outflow. Annex H shows the maximum velocities in the area. The only significant change is observed in the new diversion channel, with maximum velocities of about 1.5 – 2.5 ft/s. In the adjacent wetlands the maximum velocities increase slightly to approximately 0.5 ft/s.

Salinity

The salinity plots are shown in Figures B9 – B12. The salinity in the new diversion channel drops to 0 ppt, whereas in the baseline scenario during high water peaks of 2 – 5 ppt were computed. At the Paris Road the salinity fluctuates around 1 - 3 ppt in the baseline scenario with 1000 cfs as compared to 4 – 7 ppt in the baseline scenario.
At the Bayou Bienvenue the salinity drops to 1 – 2 ppt during ebb flow (due to fresh water outflow), but does not change (w.r.t. the baseline situation) at flood flow. In the baseline scenario values of 6 – 8 ppt were found.

At the Bayou Dupre the salinity drops to almost 0 ppt in the baseline scenario with 1000 cfs. Only at high water inflow, the salinity levels increase locally, but don't reach the baseline values of 6 – 8 ppt.

Figure 5.5 (also shown in Annex G) shows the averaged salinity for the whole area. Compared to the baseline scenario, the wetland area in the centre of the CWA, almost becomes fresh, with salinity values of 0 – 0.5 ppt. Also the main channels in the systems, for example the Violet Channel, become fresh (mean of 0.5 ppt). Near the Bayou Bienvenue the mean salinity is higher, around 4 – 5 ppt.

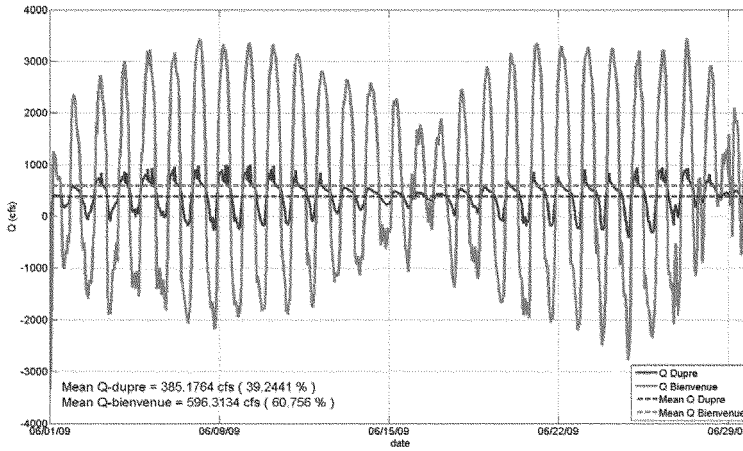

Figure 5.4 – Discharge (cfs) through the Bayou Dupre (Blue) and Bayou Bienvenue (red) gates. Dashed line indicates the mean discharge through the gates.

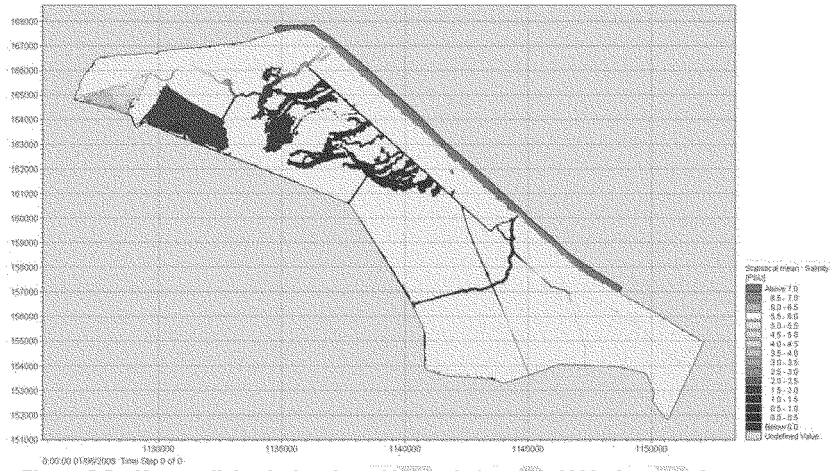

Figure 5.5 – Mean salinity during June 2009, existing with 1000 cfs scenario.

5.4 Model results Restored with 1000 cfs scenario (3)

5.4.1 Model adjustments

This section presents the results of the restored with 1000 cfs inflow through the new diversion scenario. The restored situation is characterized by a new diversion channel, which is wider and deeper and runs through to the levees along the MRGO.

The new channel is approximately 328 feet wide and has a bed level at -12 feet w.r.t. the reference level. In this scenario there is no open connection with the MRGO, the channel is closed by a weir, located near the outflow point to the MRGO. Figure 5.6 shows the location of the new diversion channel and the bathymetry.

In addition the bed level in some areas within the wetlands was increased and the land classification was adjusted. Figure 5.7 shows the new bed resistance map, which was created from the new land classification maps. Most of the area in the western part of the CWA is now classified as woody wetlands. Other raised areas are defined as emergent herbaceous wetlands.

The 1000 cfs inflow was again diverted over 3 inflow locations, with the same distribution as in the baseline 1000 cfs scenario:

- New diversion : 870 cfs
- Violet channel : 100 cfs
- Waste water outlet : 30 cfs

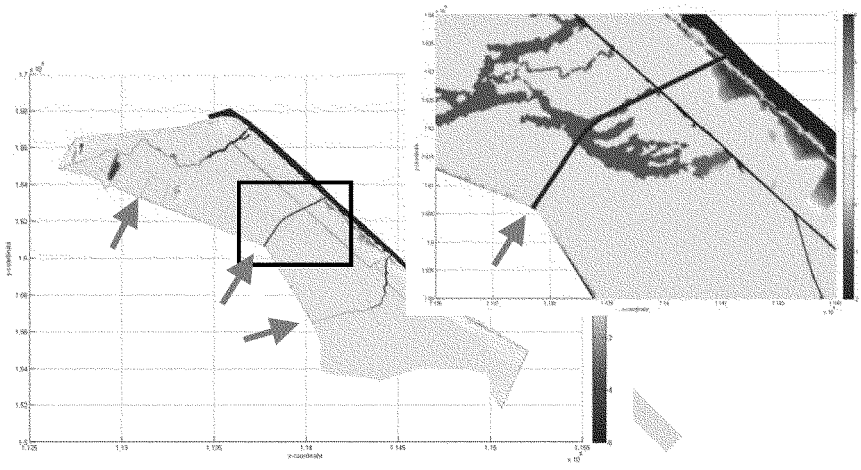

Figure 5.6 – Bathymetry for the Restored scenario. In red the new inflow locations.

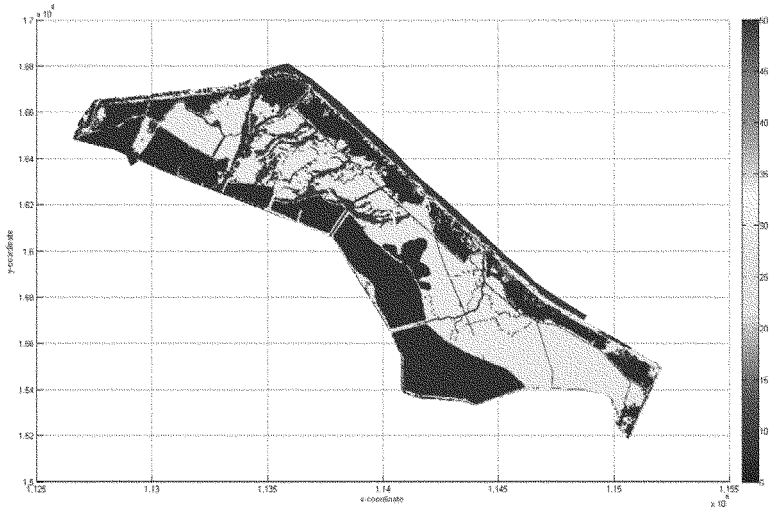

Figure 5.7 – Bed resistance map for the Restored scenario

5.4.2 Results

Flow Split

Figure 5.8 shows the discharge distribution over the Bayou Dupre and Bayou Bienvenue for this scenario including the mean discharges.

The inflow of fresh water is the same as in the previous scenario, 1000 cfs, with only the lay out of the new channel and the surrounding wetlands being changed.

These changes cause a small change is discharge distribution over the two openings: with 377 cfs (38 %) flows through the Bayou Dupre and 626 cfs (62 %) through Bayou Bienvenue. In the baseline scenario the ratio was 40 % - 60 %. Again, the total outflow is almost the same as the 1000 cfs which is put in at the model boundaries.

The discharge through the opening to the MRGO from the new diversion is 0 cfs as intended; the channel is blocked by the weir.

Water levels

Annex C shows the model results at the 4 specific locations inside the CWA. Water levels are presented in figures C1 – C4.

The results of the water levels are almost the same as the results of the existing with 1000 cfs scenario. At the end of the new diversion channel the water levels increase to 0.2 – 1.1 feet. Only the tidal range increases slightly to 0.1 – 0.6 feet.

Also at the Paris Road the tidal range slightly increase by approximately 0.1 – 0.3, to 0.5 – 1.6 feet. At Bayou Bienvenue there is again hardly any change in water levels. However at the Bayou Dupre the water level increases by approximately 0.1 – 0.5 feet and the tidal range decreases by almost 0.3 feet during high waters.

Annex F shows 2D figures of the maximum and mean water levels in the area. For the restored scenario with 1000 cfs the maximum water levels are found in the new diversion channel (1.1 feet) and in the adjacent wetlands (also 1.1 feet).

Compared to the existing scenario with 1000 cfs, a larger area is affected by the fresh water outflow, but the maximum level in the new channel is lowered by 0.1 feet. The maximum water level in the Violet Channel becomes 1.0 – 1.05 feet

Also the mean water level increases most in the new channel and surrounding wetlands, in the channel to 0.55 – 0.60 feet and in the wetlands to 0.40 – 0.60 feet.

The higher water levels in the north-western part of the CWA can the explained by the wastewater outflow, which flows on to a piece of land which is increased in level and also in roughness. This results in less flow to the neighbouring channels and the water is stored in the area.

Current velocities

The figures of the current velocities are shown in Annex C (Figures C5 – C8).

The current velocity inside the new channel drops significantly due to the deepening and widening of the channel. The mean velocity is about 0.3 – 0.35 ft/s at the end of the new diversion channel.

Due to the restoration works in the wetlands the velocity also decreases at the location of the Paris Road to almost half of the velocities in the baseline scenario.

At Bayou Bienvenue, the same pattern is observed as in the existing with 1000 cfs scenario: The maximum velocity slightly increases by 0.1 ft/s during ebb flow and decreases by almost 0.2 – 0.3 ft/s during flood flow. Again, the velocities during ebb flow are larger than during flood flow.

Annex H shows the maximum velocities in the area. Compared to the existing with 1000 cfs scenario, the most significant changes are found in the new diversion channel. The maximum velocity is limited to approximately 0.3 ft/s, whereas in the existing with 1000 cfs scenario the maximum velocities were about 1.5 – 2.5 ft/s.

Salinity

Annex C shows the salinity plots at the 4 locations, Figures C9 – C12. The water in the new diversion channel is completely fresh, 0 ppt. At the Paris Road the salinity fluctuates around 1 - 2 ppt, which is slightly lower than in the existing with 1000 cfs scenario. At the Bayou Bienvenue the salinity drops to 1 – 2 ppt during ebb flow (due to fresh water outflow), but does not change at flood flow. In the baseline scenario values of 6 – 8 ppt were found.

At the Bayou Dupre the salinity drops to almost 1 ppt. Only at high water does the salinity increase, but does not reach the value of the baseline scenario of around 6 – 8 ppt.

Figure 5.9 (also shown in Annex G) shows the monthly averaged salinity for the whole area. The overall picture is the same as in the existing with 1000 cfs scenario. The fresh water discharge from the Mississippi causes a decrease in salinity, not only in the wetland area in the centre of the CWA, but also in the main channels like the Violet channel.

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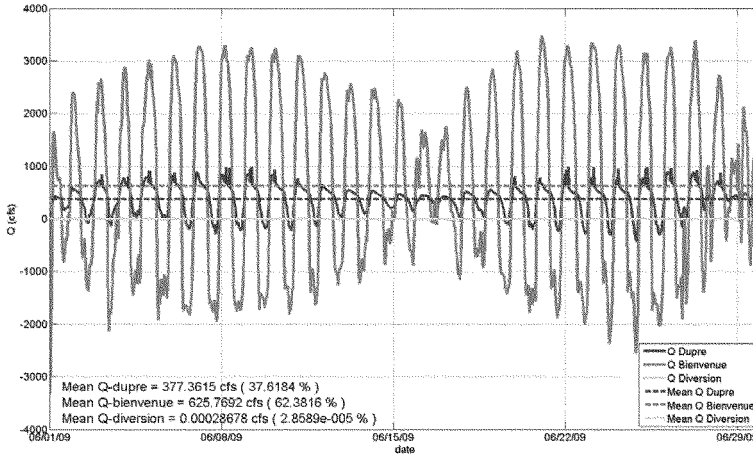

Figure 5.8 – Discharge (cfs) through the Bayou Dupre (Blue), Bayou Bienvenue (red) and new Diversion (green) gates. Dashed line indicate the mean discharge through the gates.

Figure 5.9 – Mean salinity during June 2009, Restored with 1000 cfs scenario.

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5.5 Model results Restored with 7000 cfs scenario (4)

5.5.1 Model adjustments

This section presents the results of the restored with 7000 cfs inflow through the new diversion scenario. The model input for this scenario is the same as for the restored with 1000 cfs scenario, except from the fresh water discharge through the new diversion channel.

The 7000 cfs outflow is diverted over 3 inflow points, according to the configuration in Figure 2.3:

- New diversion : 6870 cfs
- Violet channel : 100 cfs
- Waste water outlet : 30 cfs

The discharges in the Violet channel and the waste water outlet are the same as in the previous scenario. Most of the fresh water inflow flows through the new channel. For this reason the blockage of the new channel near the MRGO was removed. The aim was to fix the discharge through this channel at around 6000 cfs. To maintain this discharge, a control structure might be needed if the free outflow is too large.

5.5.2 Results

Flow Split

Figure 5.10 shows the discharge distribution over the Bayou Dupre, Bayou Bienvenue and the new diversion for this scenario, as well as the mean discharges.

Due to the opening of the new diversion channel, most of the discharge is through the new channel, 5660 cfs or 81.8 %. The discharge through the new channel was intended to be around 6000 cfs, however, even without a control structure this level was not achieved with the size of channel proposed. Approximately 1260 cfs flows through the other two openings (479 cfs through Dupre and 781 through Bienvenue).

Including a structure at the end of the new channel will potentially result in lower discharges through the channel and will increase the discharge through the two Bayou's.

Water levels

Annex D shows the water levels of this scenario at the four locations (Figure D1 – D4). Due to the larger fresh water discharge through the new diversion channel, the water level at the end of the new diversion channel increases significantly. Peak levels are found at 1.4 feet and the tidal range becomes 0.2 – 0.9 feet. For the baseline scenario this was 0.1 – 0.6 feet.

Also, near the Paris Road, the water levels increase during high water by about 0.2 – 0.3 feet w.r.t. the baseline scenario, but decreases during low water (about 0.2 feet). At Bayou Bienvenue a small increase of 0.1 feet was found, however at the Bayou Dupre the effect appears to be larger.

Annex F shows 2D figures of the maximum and mean water levels in the area. For this restored with 7000 cfs scenario the maximum water levels are higher in the new

diversion channel (above 1.2 feet) and in the adjacent wetlands (also above 1.2 feet). The area which is affected by the fresh water inflow is more than in the other scenarios. Mean water levels in the channel and the surrounding wetlands are above 0.7 feet.

Although the water levels in and near the new channel increase significantly, no flooding of the higher wetlands areas occur. This means that the water levels do not reach the level of the banks of the channel. It is expected that sea level rise will influence the flooding of the area.

Current velocities

The current velocity in the new channel (Annex D Figures D5 – D8) fluctuates around 2.5 ft/s, which is almost the same as the velocity in the smaller channel in the existing with 1000 cfs scenario. Although there is a larger discharge the channel also has larger dimensions which limits the velocities. The current velocities at the other locations show the same results as in the other scenarios with additional fresh water inflow.

The maximum flow velocities for the whole area are shown in Figure H4. Inside the new diversion channel, the flow velocities increase to above 2.1 ft/s, which is significantly larger than in the other channels within the CWA.

Salinity

Due to the large fresh water discharge, the CWA area almost completely becomes fresh. This is shown in the mean salinity, Figure 5.11 and G4. The mean salinity in all major channels and wetland parts is 1 ppt or below. Even at the MRGO a plume of fresher water is found at the outflow of the new diversion. Only at the main channel near the Bayou Bienvenue does higher salinity values penetrate slightly into the area.

The time series Figures (D8 – D12) at the four locations support these findings. At the point in the new channel and near Bayou Dupre the salinity drops to 0 ppt.
At the Paris Road the salinity drops to an equilibrium value of 0.2 – 0.3 ppt.
Only at the Bayou Bienvenue the salinity fluctuates with the tide, just as with the other scenarios: it drops to 1 – 2 ppt during ebb flow (due to fresh water outflow), but does not change noticeably at flood flow.

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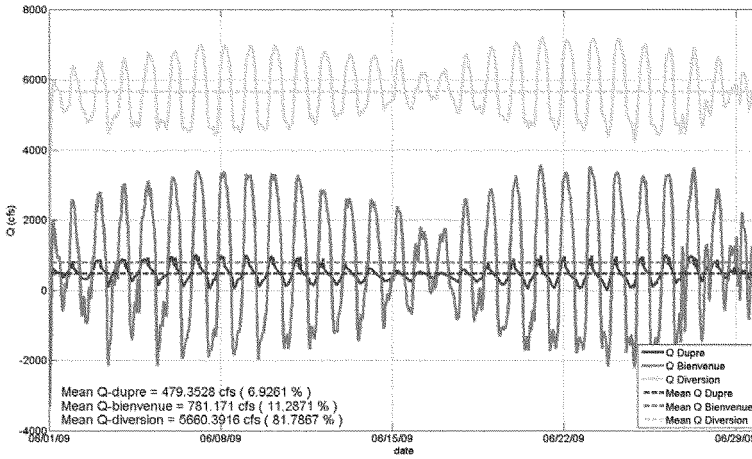

Figure 5.10 – Discharge (cfs) through the Bayou Dupre (Blue), Bayou Bienvenue (red) and new Diversion (green) gates. Dashed line indicate the mean discharge through the gates.

Figure 5.11 – Mean salinity during June 2009, Restored with 7000 cfs scenario.

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5.6 Model results Sea Level Rise (restored with 1000 cfs and SLR scenario) (5)

This section presents the results of the restored with 1000 cfs inflow through the new diversion and a sea level rise of 3.7 ft.

5.6.1 Model adjustments

The basic input of the scenario is taken from the restored with 1000 cfs scenario.All the input files are the same, except for the water level boundary at the MRGO. These water levels are raised by 3.7 feet, using the high range of sea level rise estimates. This value was established as part of the wider Ecosystem restoration Study [3]. The new boundary conditions are shown in Figure 5.12.

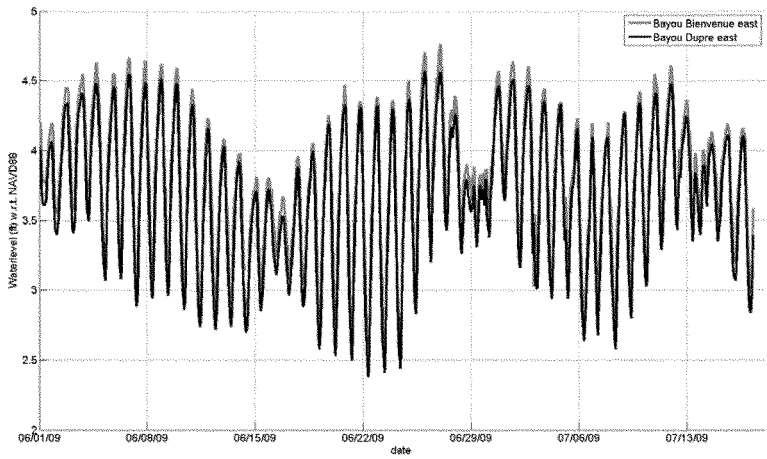

Figure 5.12 – Water level boundaries along the MRGO for the Sea level rise scenario.

- It has been assumed that the land classification does not change due to sea level rise. Marsh and swamp areas which are flooded have not been changed to open water, because of the shallow water depth and the influence of the existing vegetation.
- No allowance has been made for growth of the marsh and swamp over the period of sea level rise.
- It has been assumed that the salinity at the model boundary does not change. The same dataset has been taken as for the other scenarios. In reality the salinity may change with the increase in water levels. However, it is unknown what effect the sea level rise will have on the salinity in the MRGO. For this reason it is assumed that the salinity does not change.
- It has been assumed that the tidal amplitude at the boundary is the same as in the original situation. The water levels are increased with a constant value of 3.7 feet. In reality it is possible that the tidal wave may be deformed if the sea level rises, due to a different geometry or bed resistance. As a result the tidal amplitude might change. However, nothing is known about this interaction in this situation. For this reason the tidal amplitude is taken as in the other scenarios.

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5.6.2 Results

Flow Split

Figure 5.13 shows the discharge distribution over the Bayou Dupre, Bayou Bienvenue and the new diversion for this scenario, as well as the mean discharges.

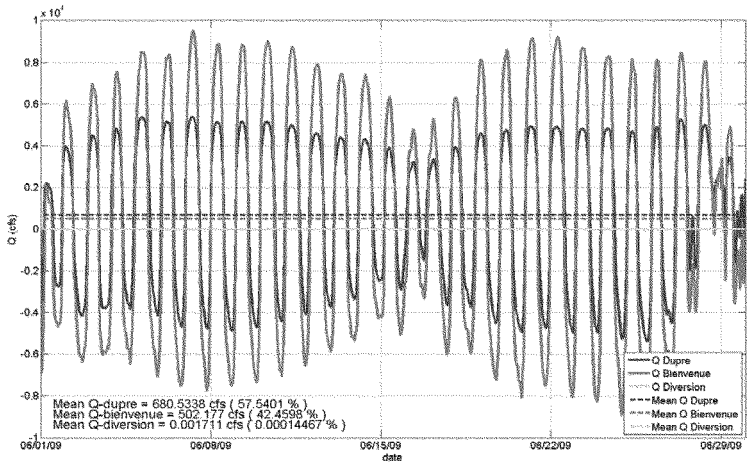

Figure 5.13 – Discharge (cfs) through the Bayou Dupre (Blue), Bayou Bienvenue (red) and new Diversion (green) gates. Dashed line indicate the mean discharge trough the gates.

Due to the sea level rise, the maximum discharges through the Bayou Dupre and Bayou Bienvenue opening increase significantly. The maximum discharge through Bienvenue is now 5000 – 9000cfs, which was 1500 – 3500 cfs in the original restored with 1000 cfs scenario, so about 3 times larger.

Through Dupre the maximum discharge increases to 3000 – 5000 cfs. This was 600 – 1000 cfs, so approximately 5 times larger.

The mean discharges are in the same order as the restored scenario with 1000 cfs, as the total fresh water outflow does not change. However, the flow split over the Dupre and Bienvenue outflows changes. In this scenario 680 cfs flows through Dupre (57,5 %) and 502 flows through Bienvenue (42.5 %). The ratio was 38 % Dupre and 62 % Bienvenue. So, the sea level rise causes a shift in discharge distribution: the majority of the discharge is now through the Bayou Dupre.

The discharge through the opening in the new diversion channel is 0 cfs, as the channel is closed by a weir structure.

Water levels

The water levels increase significantly in this scenario. As shown in Figures F5 to F10, a large part of the CWA area is flooded due to the 3.7 feet increase of sea level. All coloured parts in this figure are now flooded.

Figures E.1 – E.4 show the water levels at the 4 specified locations.

At all locations the water levels increase by almost 3,7 feet. The tidal range inside the CWA decreases. At location number 1, in the new diversion channel, the tidal range becomes 0.1 – 0.5 feet. In the original restored with 1000 cfs scenario the tidal range was 0.1 – 0.6 feet.

At the Paris Road, the tidal range completely damps out. In this scenario it becomes 0.1 – 0.5, whereas it was 0.5 – 1.6 feet in the original restored scenario.

This is also the case at Bienvenue: tidal range in this scenario is 0.2 – 0.8 feet, originally it was 0.4 – 1.7 feet. The same holds for the Bayou Dupre outflow.

Peak water levels are found at 4.3 - 4.4 feet for all locations.

Current velocities

Whereas the tidal range decreases, the current velocities increase in both Bayou's. Peak velocities inside Bienvenue are approximately 2.7 ft/s, at Dupre it is 2.1 ft/s. In the restored with 1000 cfs scenario this is respectively 1.5 ft/s and 0.5 ft/s. Inside the Dupre outflow the velocities increase significantly. This is also due to the increased discharge through that opening.

At the Paris Road the same order of current velocities are as in the baseline scenario, however this is an increase with respect to the restored 1000 cfs scenario. In this scenario the velocities decreased with respect to the actual situation.

Figure H5 shows the peak velocities of the whole area. Maximum velocities inside the CWA are found in the two main channels which run from the both Bayou's into the wetlands. Velocities of 0.8 – 1.0 ft/s are found in those channels. In the rest of the CWA area, the velocity does not exceed 0.5 ft/s.

Salinity

Due to the sea level rise, the salinity can penetrate more easily into the CWA area.

Figure 5.14 (also shown in annex G5) shows the mean salinity in the CWA. In the areas near the both Bayou's the mean salinity becomes 4 – 6 ppt, whereas the central part of the area is influenced by the fresh water inflow from the new diversion channel (salinity 0 -2 ppt). Also in the area western of the Paris Road, the water becomes saltier with mean salinity of 3 – 4 ppt.

These effects are also shown at the 4 specified locations. At point nr 1 the salinity is below 0.5 ppt. Near the Paris Road the salinity fluctuates with the tide: at peak flood the salinity is 6 – 7 ppt, during ebb the salinity drops to 3 – 4 ppt.

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At both the Bayou Dupre and the Bayou Bienvenue the salinity during flood matches the values of the baseline scenario: 6.5 – 8 ppt.

During low tide the salinity drops at both Bayou's: at Dupre to 3 – 4 ppt, at Bienvenue to 4 – 5 ppt.

The salinity inside the CWA fluctuates with the tide. Figures 5.15 and 5.16 show the salinity during respectively high water and low water. During high high water salinity values of above 7 ppt are found west of the Paris Road. During low water the maximum salinity is approximately 4 ppt. Also notice the number of white cells during low water (figure 5.16), which indicates that these cells have become dry.

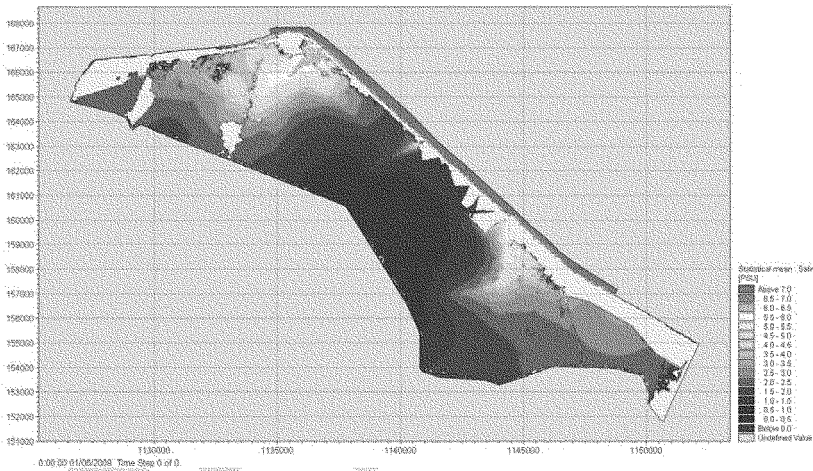

Figure 5.14 – Mean salinity during June 2009, restored scenario with 1000 cfs including Sea level rise.

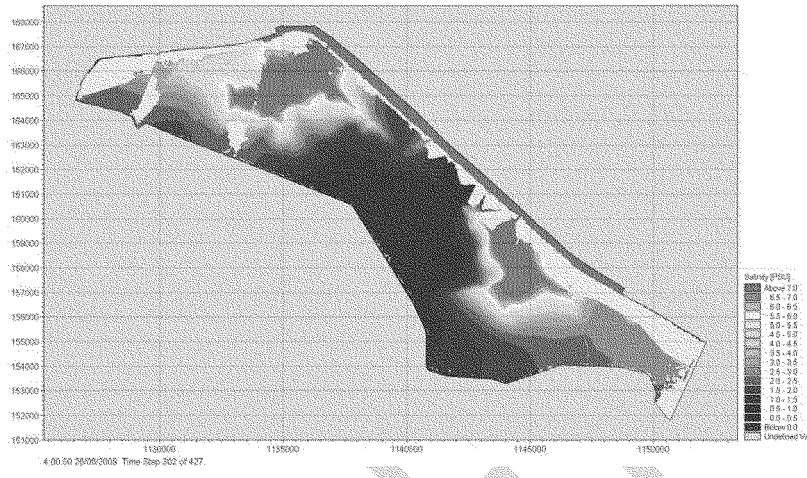

Figure 5.15 – Salinity during high water, 26th June 2009, 4h00.

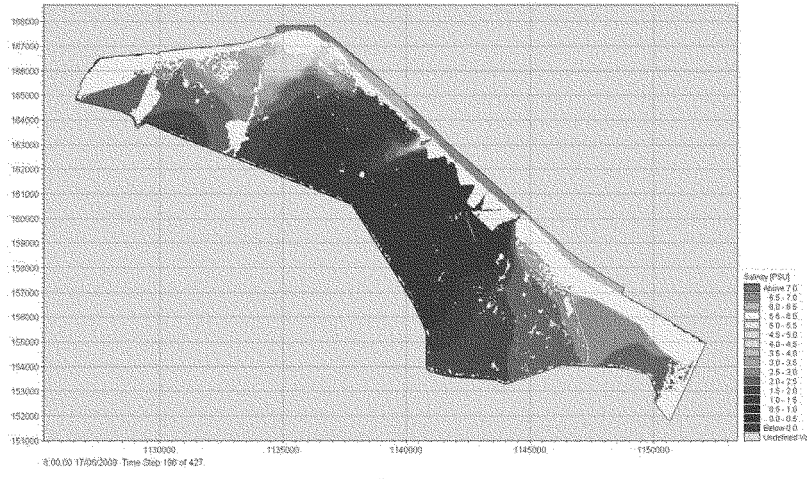

Figure 5.16 – Salinity during low water, 17th June 2009, 8h00.

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5.7 Summary and Discussion

Table 5.1 - Discharge distribution for all scenarios

	Baseline Scenario	Existing with 1000 cfs	Restored with 1000 cfs	Restored with 7000 cfs	Sea level rise
Discharge:					
Dupre	9.3 cfs	385 cfs	377 cfs	479 cfs	681 cfs
Bienvenue	-19.2 cfs	596 cfs	626 cfs	781 cfs	502 cfs
Diversion	-	-	-	5660 cfs	-
Discharge %:					
Dupre	-	39.2 %	37.6 %	3.9 %	57.5 %
Bienvenue	-	60.8 %	62.4 %	11.3 %	42.5 %
Diversion	-	-	-	81.8 %	-

Table 5.2 - Water levels, current velocities and salinity for all scenarios

	Baseline Situation	Existing with 1000 cfs	Restored with 1000 cfs	Restored with 7000 cfs	Sea level rise
Water levels					
Dupre	-0.55 – 0.9 feet	-0.1 – 0.9 feet	-0.1 – 0.9 feet	-0.2 – 1.1 feet	3.3 – 4.4 feet
Bienvenue	-1.1 – 1 feet	-1 – 1.1 feet	-1 – 1 feet	-1 – 1.1 feet	3.1 – 4.4 feet
Diversion	Dry – 0.9 feet	0.1 – 1.1 feet	-0.15 – 1.1 feet	0.7 – 1.4 feet	3.4 – 4.4 feet
Paris Road	-0.9 – 0.9 feet	-0.7 – 0.95 feet	-1 – 1.1 feet	-1 – 1.1 feet	3.4 – 4.4 feet
Currents					
Dupre	Max 0.5 ft/s	Max 0.45 ft/s	Max 0.45 ft/s	Max 0.55 ft/s	Max 2.2 ft/s
Bienvenue	Max 1.4 ft/s	Max 1.5 ft/s	Max 1.5 ft/s	Max 1.5 ft/s	Max 2.8 ft/s
Diversion	Max 0 ft/s	Max 2.7 ft/s	Max 0.35 ft/s	Max 2.7 ft/s	Max 0.3 ft/s
Paris Road	Max 0.8 ft/s	Max 0.8 ft/s	Max 0.55 ft/s	Max 0.55 ft/s	Max 0.85 ft/s
Salinity					
Dupre	6 – 8 ppt	0 – 7 ppt	1 – 7 ppt	0 ppt	2 – 8 ppt
Bienvenue	6 – 8 ppt	0.5 – 8 ppt	0.5 – 8 ppt	0 - 8 ppt	3.5 – 8 ppt
Diversion	Peaks 2 – 5 ppt	0 ppt	0 ppt	0 ppt	0 – 0.5 ppt
Paris Road	4 – 7 ppt	1 – 3 ppt	1 – 2 ppt	0.3 ppt	3 – 7.5 ppt

Discharge distribution:

- The amount of water which flows into the CWA, also flows out to the MRGO. In the baseline situation the in and outflow through both of the Bayou's is balanced.
- For the 1000cfs diversion scenarios the mean discharge splits approximately 40 % through Dupre and 60 % through Bienvenue,. Also the maximum discharge fluctuations with the tide are much larger at Bienvenue than at Dupre. Bienvenue (3 – 5 times larger).
- In the restored scenario with 7000 cfs, 5660 cfs (82 %) flows out through new diversion without a structure (planned 6000 cfs). No structure was needed in the model for this case, however in reality a structure will be needed to prevent inflow from the MRGO at times of low or no diversion and also to act as a flood defence in times of storm surge.
- Due to the sea level rise, the maximum discharges trough the Bayou Dupre and Bayou Bienvenue opening increase significantly, respectively 5 and 3 times larger then in the restored scenario with 1000 cfs. The mean discharges are in the same

order, but the flow split over the Dupre and Bienvenue outflows changes. The majority of the discharge is now trough the Bayou Dupre, 57.5 %.

Water levels, current velocities and salinity:

- Water levels increase with the increased inflows in the diversion noticeably at Bayou Dupre: 0.1 – 0.5 feet. The tidal range also decreases by around 0.3 feet at that location. At Bienvenue and near the Paris Road, the water level change is less.
- The fresh water inflow does not result in flooding of the higher wetlands, not even during 7000 cfs outflow. The new and existing channels are large enough to keep the inflow within their profile.
- At the Bayou Bienvenue the flow velocities during ebb are larger than during flood. With the fresh water inflow, the ebb flow increases by 0.1 ft/s and the flood flow decreases by 0.2 – 0.3 ft/s. This occurs in all scenarios.
- At the Bayou Dupre the flow velocities do not change in magnitude, only in phase due to the fresh water inflow.
- Flow velocities increase significantly in the new diversion channel, with maximum values of 2.7 ft/s. Bed protection inside the channel might be needed.
- In the restored situation flow velocities decrease near the Paris Road by almost 0.3 ft/s.
- Due to the fresh water inflow, the salinity decreases. In the case of the 7000 cfs inflow at all locations, except Bayou Bienvenue, the water becomes fresh. In the case of 1000 cfs inflow the salinity at Paris Road drops to 1-3 ppt and near Dupre to 0 – 1 ppt with some peaks to 7 ppt.
- In all cases with fresh water inflow the water near Bienvenue becomes fresh (1 – 2 ppt) during ebb flow, but is still saltier during flood flow (around 7 ppt).
- In all scenarios with fresh water inflow the central area (near the new channel) and the main channels (like the Violet channel) become fresh (approximately 0.5 ppt).
- The water levels increase significantly in the sea level rise scenario: peak water levels are found at 4.3 - 4.4 feet for all locations.
- The current velocities increase in both Bayou's: Peak velocities inside Bienvenue are approximately 2.7 ft/s, at Dupre it is 2.1 ft/s.
- Due to the sea level rise, the salinity can penetrate more easily into the CWA area, however the salinity inside the CWA fluctuates with the tide.

Although the salinity model is not very well calibrated, this will not have a large influence on the conclusions. The effect of the fresh water inflow on the salinity in the CWA is large; salinity values drop to zero in the main channels and larger water bodies. It is expected that this will not change if the model is better calibrated.

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6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following objectives or key questions were formulated in Section 1 and the results presented above were targeted at answering these 5 questions:

1. What is the impact of the base flow through the diversion? How does it affect salinity in the CWA?
2. Does the proposed change in topography for the restored marsh impact the base flows, water levels and discharges?
3. What happens during periods of peak diversion flows? Where does the water go? What is the flow split through the existing structures? Is a new outfall needed? How extensive is flooding (frequency levels etc) inside the CWA? Are new channels needed within the wetlands?
4. What are the impacts of localized flooding due to the new diversions?
5. What are the impacts of sea level rise on the marsh?

Question 1

The base flow (1000cfs) generally lowers salinity levels within the CWA but raises levels and flow rates to some degree. The increase in water levels is generally < 0.25ft across the wetland - see Figure 6.1.

Figure 6.1 - Comparison of the Existing with 1000cfs and Baseline Scenarios for Peak Water Level.

Question 2

The change in topography due to marsh and swamp recreation has little impact on the flows, levels and salinity values within the CWA, particularly with the increased channel designed to transfer the higher flows from the Mississippi River to the MRGO.

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The water level increase is greatest to the west of Paris Road where the impact of the sewage treatment works discharge is felt together with the increase in marsh and wetland - see Figure 6.2

Figure 6.2 - Comparison of Restored with 1000cfs with Baseline Scenarios for Peak Water Level

Question 3

Initial screening before developing the Mike21 model suggested that a third structure would be needed to prevent excessive flows in the existing channels and extensive flooding.

Therefore during periods of peak flow the water was diverted mainly directly to the MRGO via the new channel. The flow split through the existing structure followed the same proportions as with the 1000cfs background flow. There is some raising of water levels with the 7000cfs flow, but it was kept within the new and existing channels when the majority of the flow was passed directly to the MRGO - see Figure 6.3

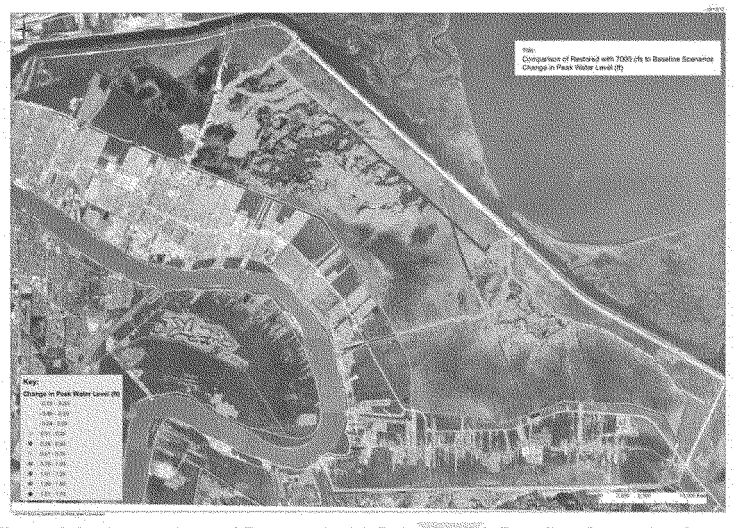

Figure 6.3 - Comparison of Restored with 7000cfs with Baseline Scenarios for Peak Water Level

Question 4

The new diversions have no influence on the water levels outside of the channels. For the 1000cfs scenario, in the central area the effect is less than 0.5ft, for the 7000cfs scenario, the effect is less than 1ft. Flow velocities increase within the channels.

Question 5

About 80% (rough estimate) of the area will flood during high waters for the SLR scenario. This will change drastically the hydrodynamic behaviour for the whole area and will likely indirectly induce morphological changes to the area. More areas will experience larger salinity levels.

6.2 Recommendations

Model Improvements

The model at present has been calibrated to meet the needs of the investigation. However calibration data was limited, particularly in spatial extent, and further model calibration could lead to improved model accuracy in some areas. Points of improvement could be:

- Provide measurements of water levels, current velocities and salinity in the northern part of the CWA, to calibrate the model in that area as well.
- Carry out current velocities measurements within the whole area. The flow model has not been calibrated with current velocities.
- Undertake discharge measurements in both the Bayou Dupre and the Bayou Bienvenue openings to the MRGO. The model can be calibrated on the instantaneous discharge, or mean discharge through both openings, to match

the amount of water flow in and out of the CWA in the model, with the present situation.

- Additional calibration on salinity by varying the dispersion coefficient over the model domain. This would require more data points in the area, to provide spatially distributed salinity data. It may also be of limited value once the marshland had been restored as this would change some of the spatial characteristics.

Besides further calibration, an extension of the model domain could also be considered. A larger model could investigate the effects of the freshwater inflow in to the MRGO and the Lake Borgne and Biloxi marsh.

However, improved boundary conditions would be required within the MRGO and Lake Borgne, the run time of the model would increase, and significant modifications would be required to adequately reflect the new IHNC barrier. In addition we understand that there are other models which cover this areas which could be used to understand any impacts from the diversion.

In the current model, the results within the MRGO are influenced by the boundary effects of the model and therefore the salinity, flow and water level values derived within the MRGO should not be used.

Additional Investigations

The model could be used to consider a range of operational scenarios, and to test adaptive management options. The inclusion of the structure at the end of the new diversion channel would allow for the discharge to be controlled, thus raising levels within the CWA and increasing flows within the channels.

Also concerns with respect to stagnation in the outer reaches of the Marsh could be investigated further, together with potential options for improving base flow in these areas to improve long term water quality.

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REFERENCES

[1] DHI (2009), MIKE21 Flow Model FM, Hydrodynamic and Transport Module, Scientific Documentation.

[2] FEMA (2007). Flood Insurance Study, Volume 1 of 2: Southeastern Louisiana Engineering Methods - ADCIRC, preliminary version, April 2007

[3] United States Army Corps of Engineers, 2009. Mississippi River – Gulf Outlet (MRGO) Ecosystem Restoration Study Louisiana and Mississippi. Hydraulics and hydrology. Preliminary Hydrodynamic and Hydraulic Modeling for a proposed Freshwater Diversion in the vicinity of Violet, Louisiana. October 2009.

[4] www.rivergauges.com

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Annex A
Project Area

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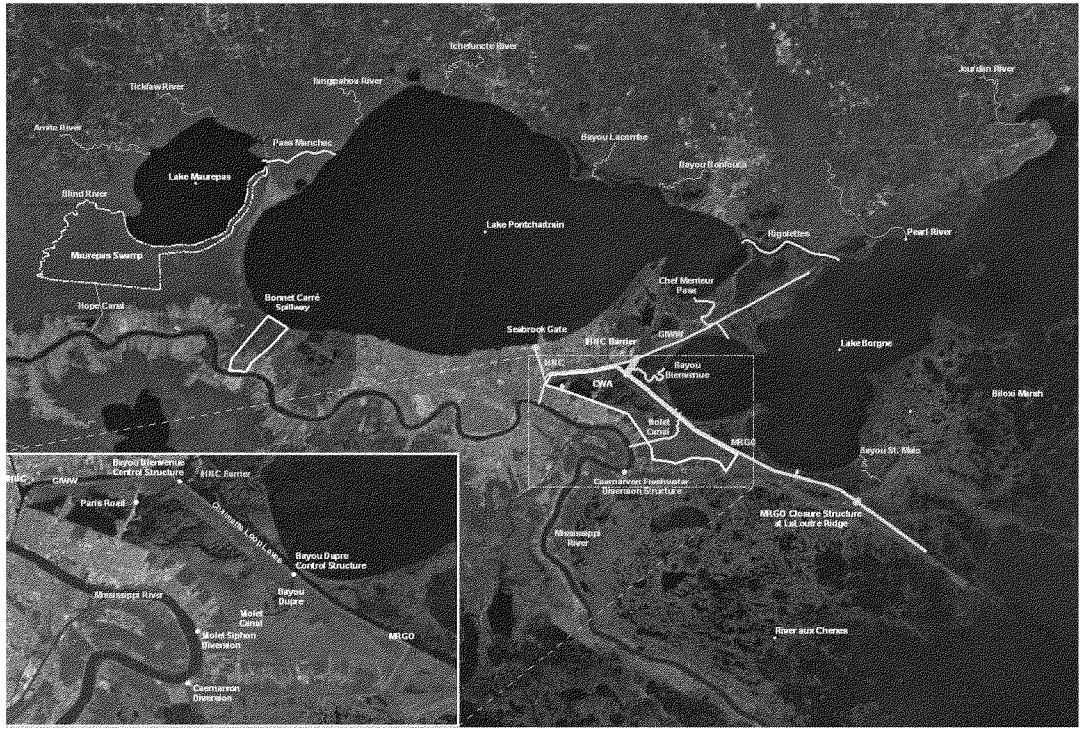
Tchefuncte River
Tangipahoa River
Tickfaw River
Jourdan River
Arrate River
Pass Manchac
Bayou Lacombe
Bayou Bonfouca
Lake Maurepas
Blind River
Lake Pontchartrain
Rigolettes
Pearl River
Maurepas Swamp
Chef Menteur Pass
Bonnet Carré Spillway
Rope Canal
Seabrook Gate
HRC Barrier
GIWW
Lake Borgne
HRC
Bayou Bienvenue
CWA
Biloxi Marsh
Violet Canal
MRGO
Bayou St. Malo
Caernarvon Freshwater Diversion Structure
MRGO Closure Structure at LaLoutre Ridge
Mississippi River
River aux Chenes
Bayou Bienvenue Control Structure
HRC Barrier
GIWW
Paris Road
Bayou Dupre Control Structure
Bayou Dupre
Mississippi River
Violet Canal
Violet Siphon Diversion
MRGO
Caernarvon Diversion

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Annex B
Results baseline scenario 1000 cfs

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Water levels

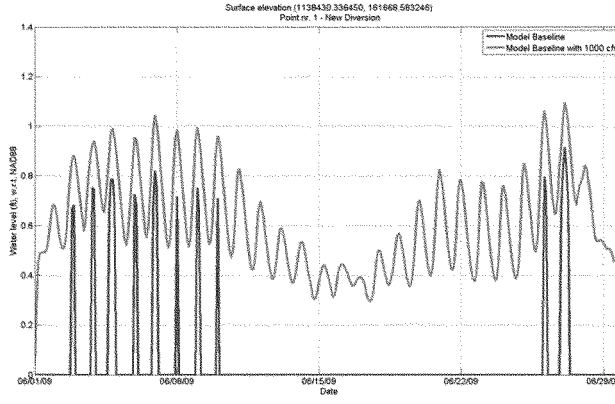

Figure B1: Water levels at point nr 1, New Diversion, for the baseline (blue) and baseline with 1000 cfs (red) scenarios.

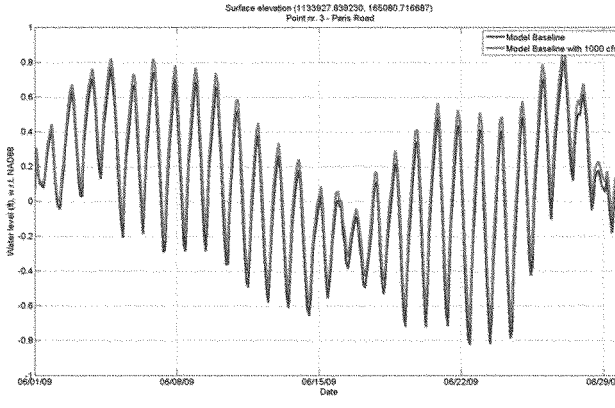

Figure B2: Water levels at point nr 3, Paris Road, for the baseline (blue) and baseline with 1000 cfs (red) scenarios.

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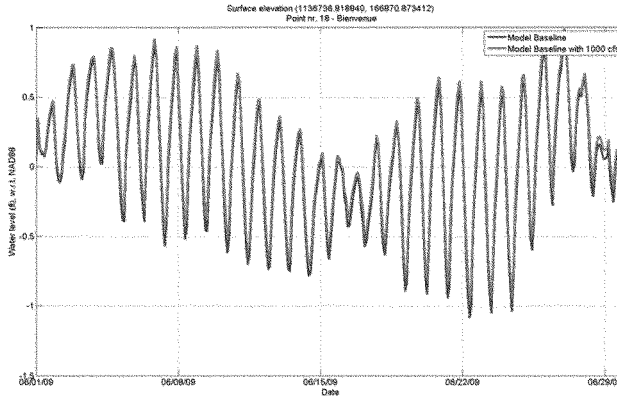

Figure B3: Water levels at point nr 18, Bayou Bienvenue, for the baseline (blue) and baseline with 1000 cfs (red) scenarios.

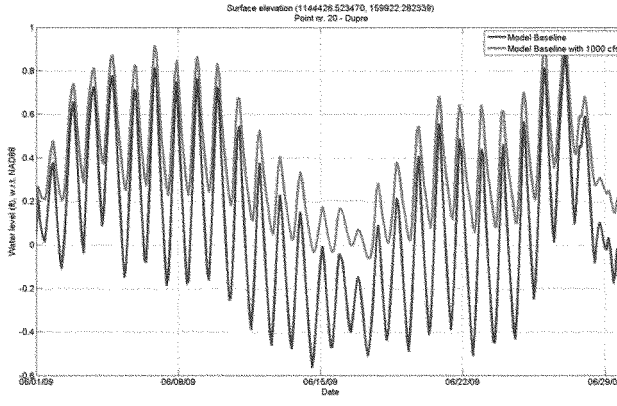

Figure B4: Water levels at point nr 20, Bayou Dupre, for the baseline (blue) and baseline with 1000 cfs (red) scenarios.

ROYAL HASKONING

Current velocities

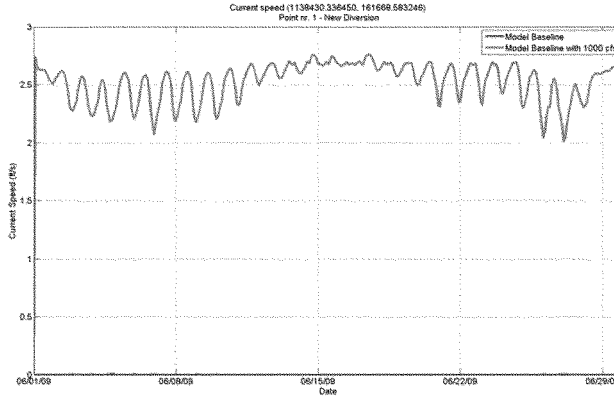

Figure B5: Current velocities at point nr 1, New Diversion, for the baseline (blue) and baseline with 1000 cfs (red) scenarios.

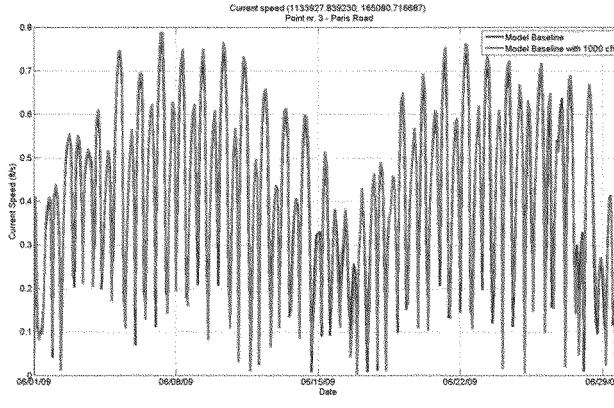

Figure B6: Current velocities at point nr 3, Paris Road, for the baseline (blue) and baseline with 1000 cfs (red) scenarios.

ROYAL HASKONING

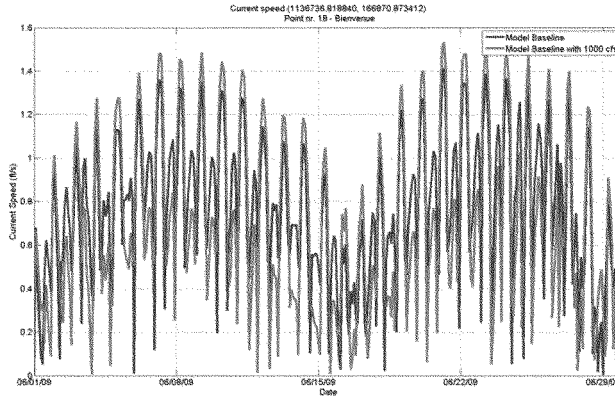

Figure B7: Current velocities at point nr 18, Bayou Bienvenue, for the baseline (blue) and baseline with 1000 cfs (red) scenarios.

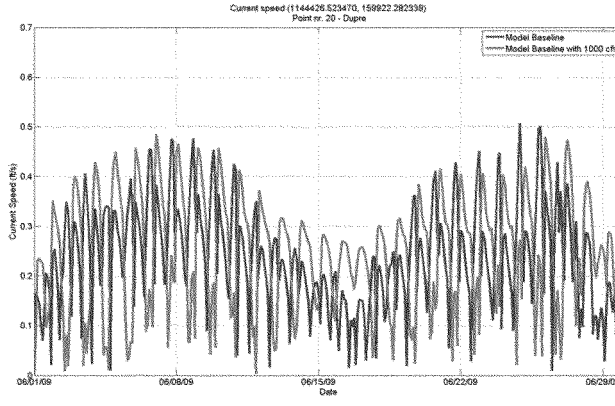

Figure B8: Current velocities at point nr 20, Bayou Dupre, for the baseline (blue) and baseline with 1000 cfs (red) scenarios.

ROYAL HASKONING

Salinity

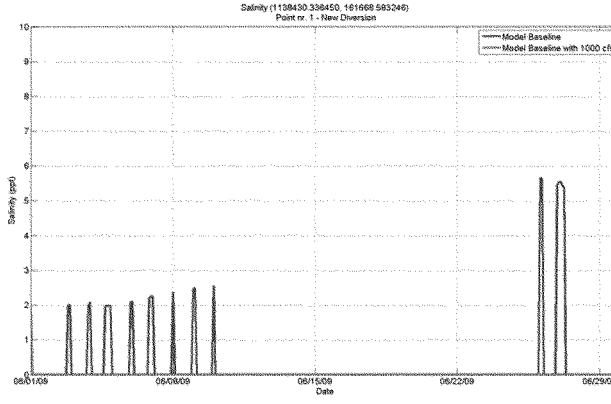

Figure B9: Salinity at point nr 1, New Diversion, for the baseline (blue) and baseline with 1000 cfs (red) scenarios.

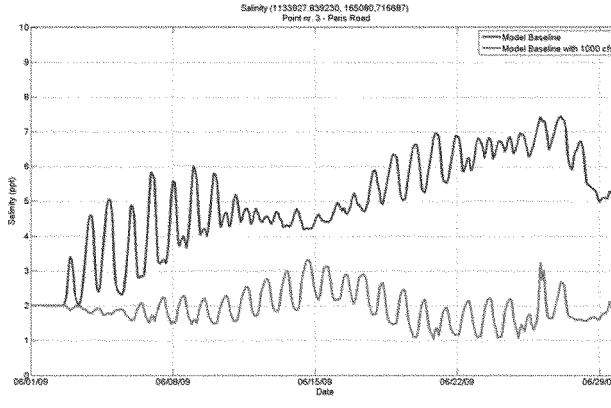

Figure B10: Salinity at point nr 3, Paris Road, for the baseline (blue) and baseline with 1000 cfs (red) scenarios.

ROYAL HASKONING

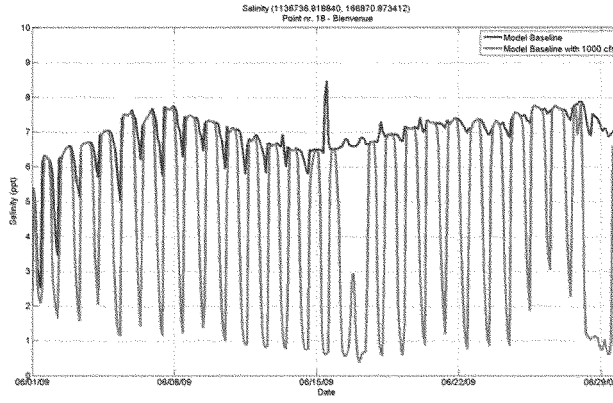

Figure B11: Salinity at point nr 18, Bayou Bienvenue, for the baseline (blue) and baseline with 1000 cfs (red) scenarios.

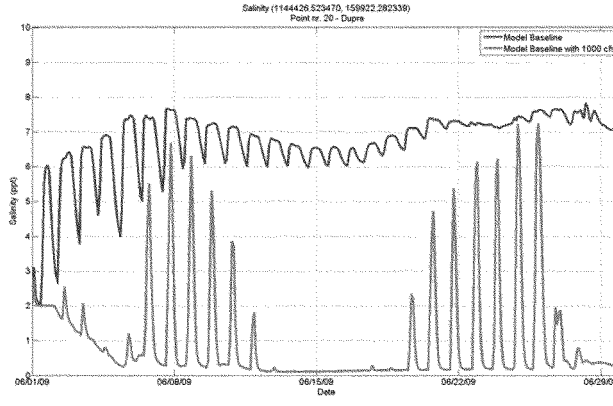

Figure B12: Salinity at point nr 20, Bayou Dupre, for the baseline (blue) and baseline with 1000 cfs (red) scenarios.

ROYAL HASKONING

Annex C
Results restored scenario 1000 cfs

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ROYAL HASKONING

Water levels

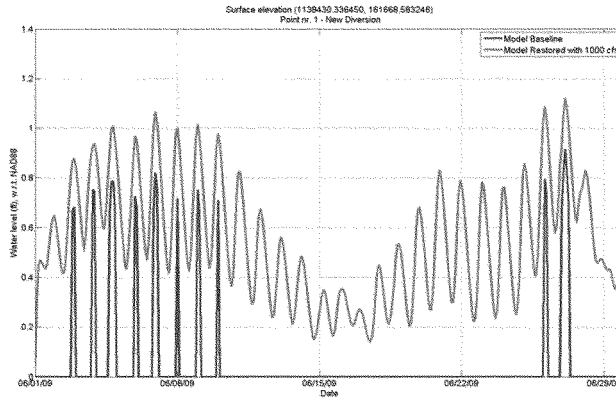

Figure C1: Water levels at point nr 1, New Diversion, for the baseline (blue) and restored with 1000 cfs (red) scenarios.

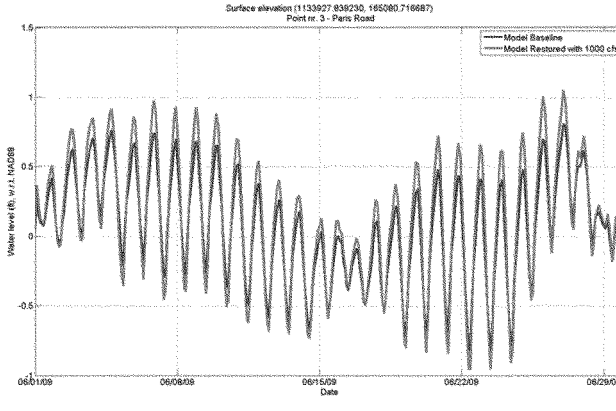

Figure C2: Water levels at point nr 3, Paris Road, for the baseline (blue) and restored with 1000 cfs (red) scenarios.

ROYAL HASKONING

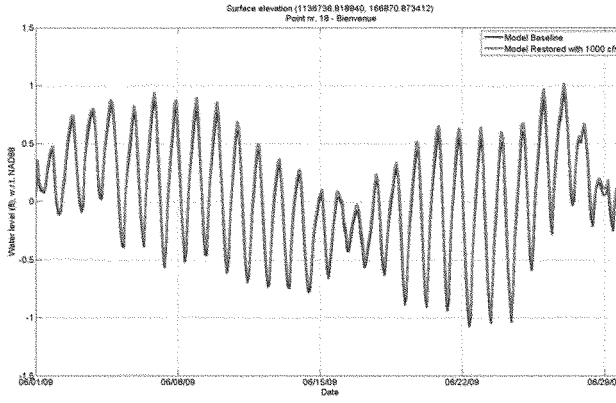

Figure C3: Water levels at point nr 18, Bayou Bienvenue, for the baseline (blue) and restored with 1000 cfs (red) scenarios.

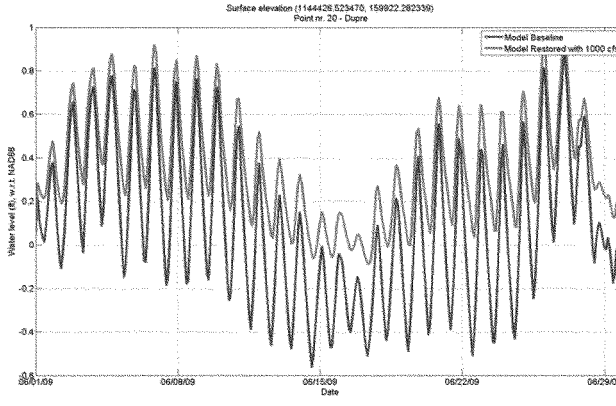

Figure C4: Water levels at point nr 20, Bayou Dupre, for the baseline (blue) and restored with 1000 cfs (red) scenarios.

ROYAL HASKONING

Current Velocities

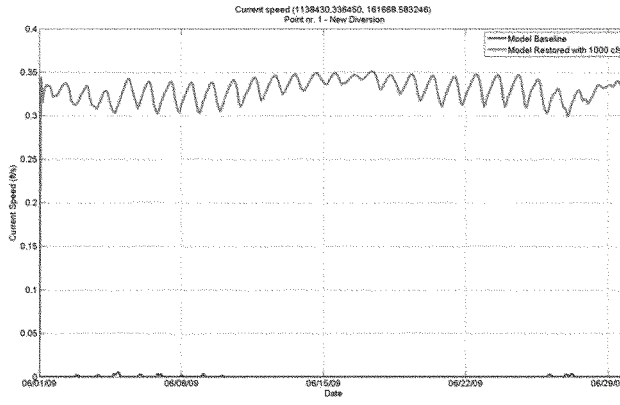

Figure C5: Current velocities at point nr 1, New Diversion, for the baseline (blue) and restored with 1000 cfs (red) scenarios.

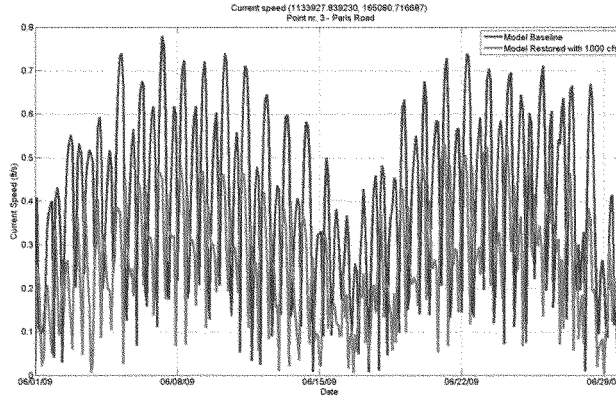

Figure C6: Current velocities at point nr 3, Paris Road, for the baseline (blue) and restored with 1000 cfs (red) scenarios.

ROYAL HASKONING

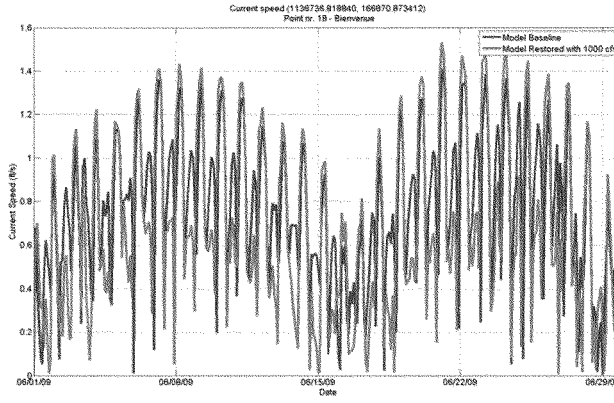

Figure C7: Current velocities at point nr 18, Bayou Bienvenue, for the baseline (blue) and restored with 1000 cfs (red) scenarios.

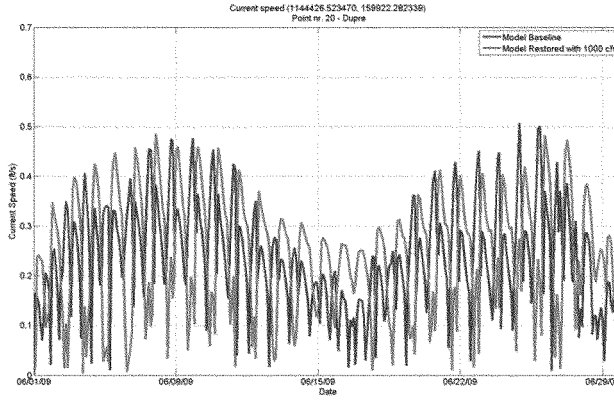

Figure C8: Current velocities at point nr 20, Bayou Dupre, for the baseline (blue) and restored with 1000 cfs (red) scenarios.

ROYAL HASKONING

Salinity

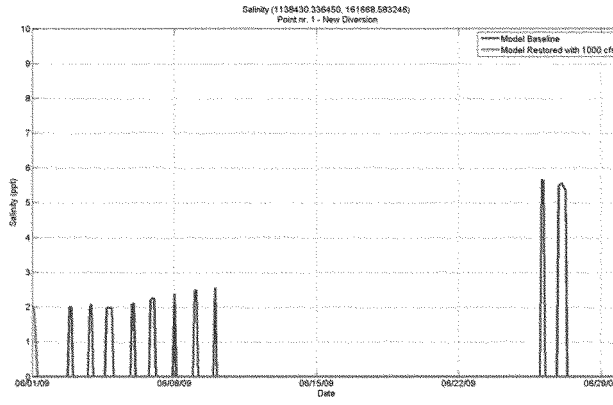

Figure C9: Salinity at point nr 1, New Diversion, for the baseline (blue) and restored with 1000 cfs (red) scenarios.

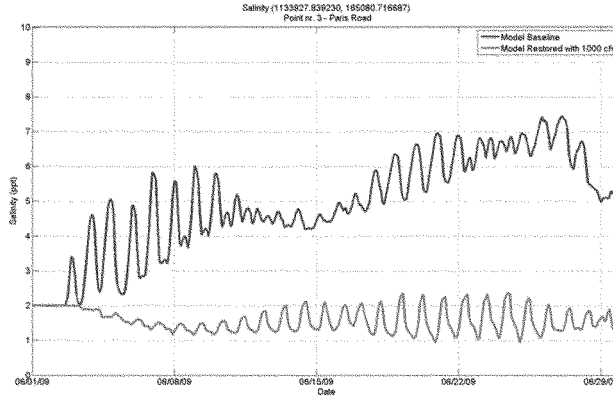

Figure C10: Salinity at point nr 3, Paris Road, for the baseline (blue) and restored with 1000 cfs (red) scenarios.

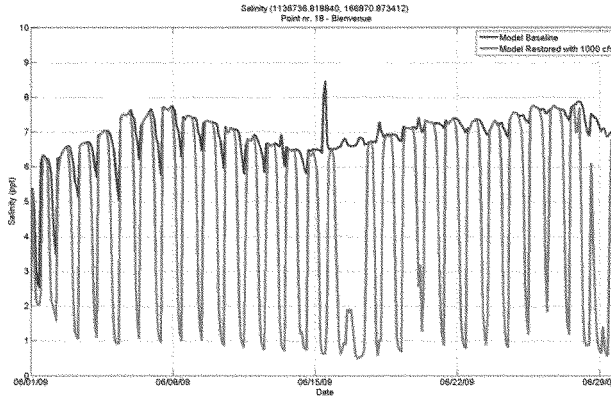

Figure C11: Salinity at point nr 18, Bayou Bienvenue, for the baseline (blue) and restored with 1000 cfs (red) scenarios.

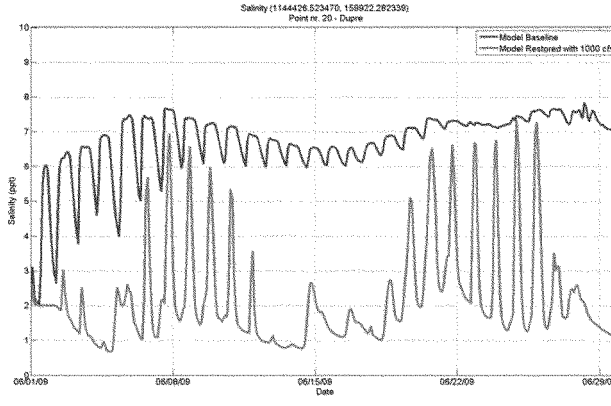

Figure C12: Salinity at point nr 20, Bayou Dupre, for the baseline (blue) and restored with 1000 cfs (red) scenarios.

ROYAL HASKONING

Annex D
Results restored scenario 7000 cfs

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ROYAL HASKONING

Water levels

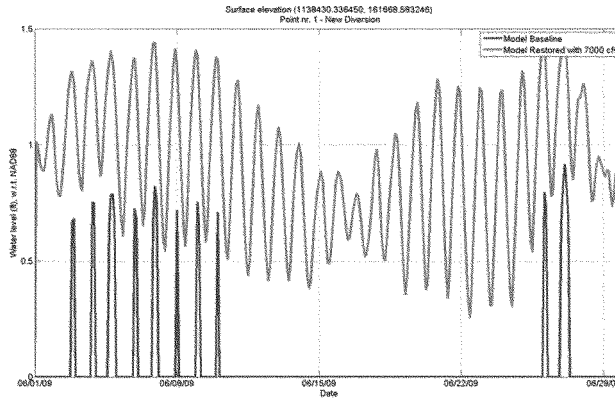

Figure D1: Water levels at point nr 1, New Diversion, for the baseline (blue) and restored with 7000 cfs (red) scenarios.

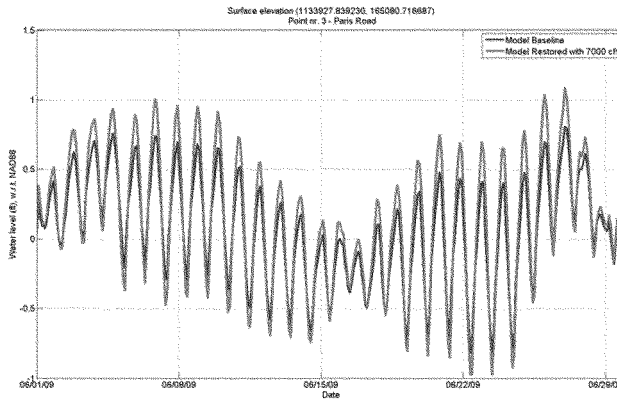

Figure D2: Water levels at point nr 3, Paris Road, for the baseline (blue) and restored with 7000 cfs (red) scenarios.

ROYAL HASKONING

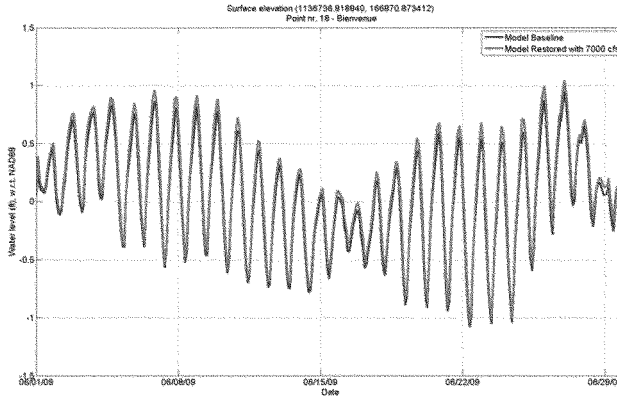

Figure D3: Water levels at point nr 18, Bayou Bienvenue, for the baseline (blue) and restored with 7000 cfs (red) scenarios.

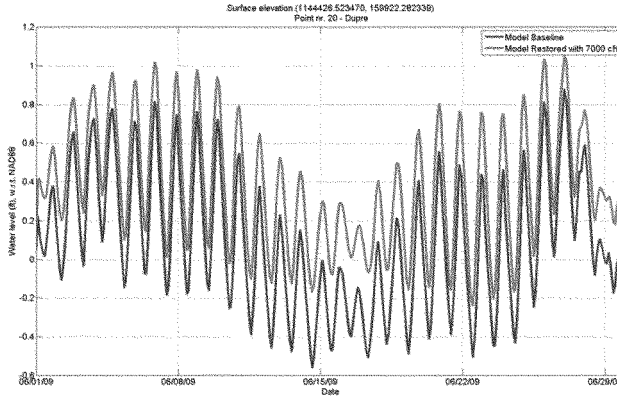

Figure D4: Water levels at point nr 20, Bayou Dupre, for the baseline (blue) and restored with 7000 cfs (red) scenarios.

ROYAL HASKONING

Current Velocities

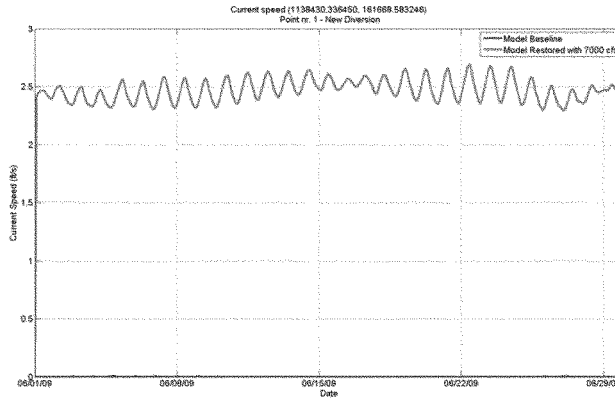

Figure D5: Current velocities at point nr 1, New Diversion, for the baseline (blue) and restored with 7000 cfs (red) scenarios.

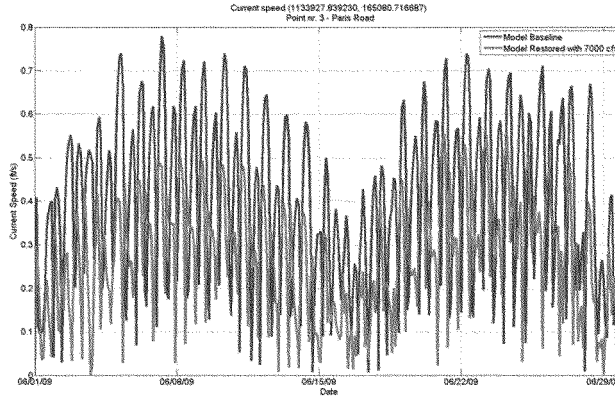

Figure D6: Current velocities at point nr 3, Paris Road, for the baseline (blue) and restored with 7000 cfs (red) scenarios.

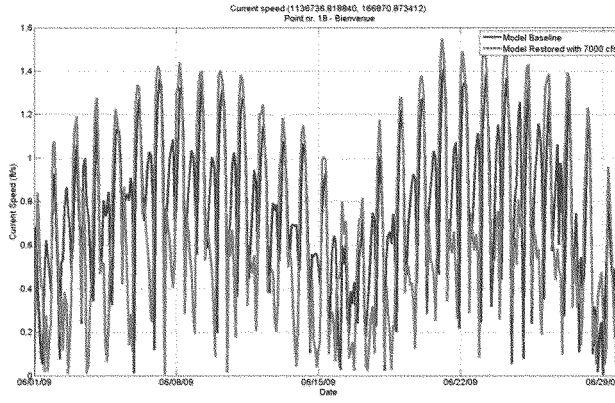

Figure D7: Current velocities at point nr 18, Bayou Bienvenue, for the baseline (blue) and restored with 7000 cfs (red) scenarios.

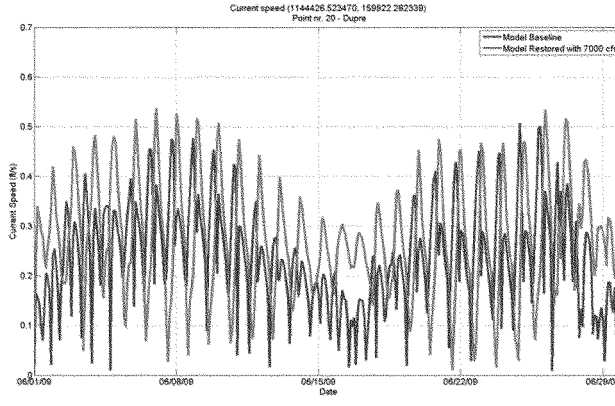

Figure D8: Current velocities at point nr 20, Bayou Dupre, for the baseline (blue) and restored with 7000 cfs (red) scenarios.

ROYAL HASKONING

Salinity

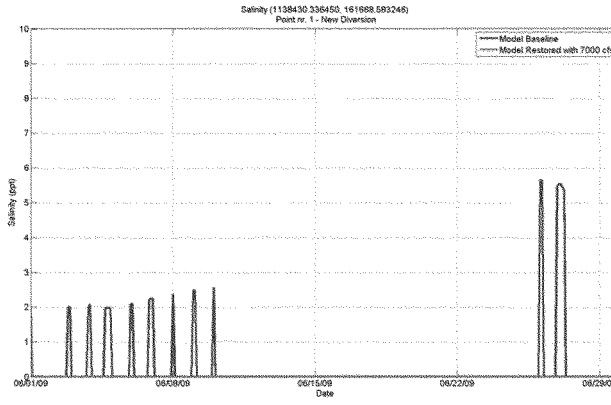

Figure D9: Salinity at point nr 1, New Diversion, for the baseline (blue) and restored with 7000 cfs (red) scenarios.

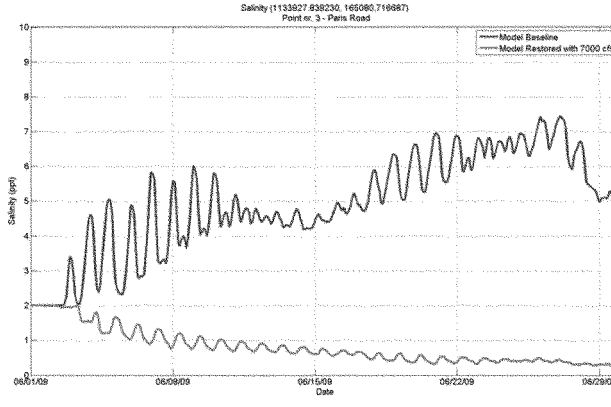

Figure D10: Salinity at point nr 3, Paris Road, for the baseline (blue) and restored with 7000 cfs (red) scenarios.

ROYAL HASKONING

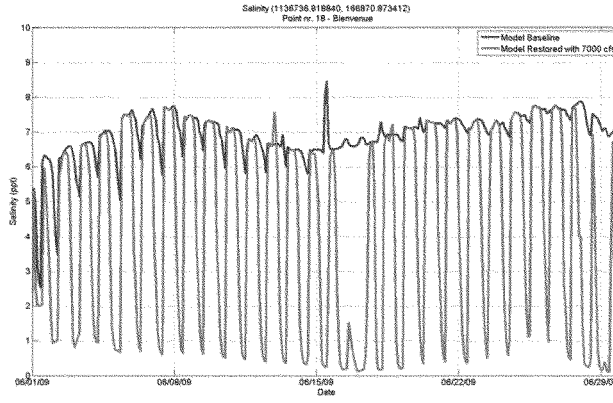

Figure D11: Salinity at point nr 18, Bayou Bienvenue, for the baseline (blue) and restored with 7000 cfs (red) scenarios.

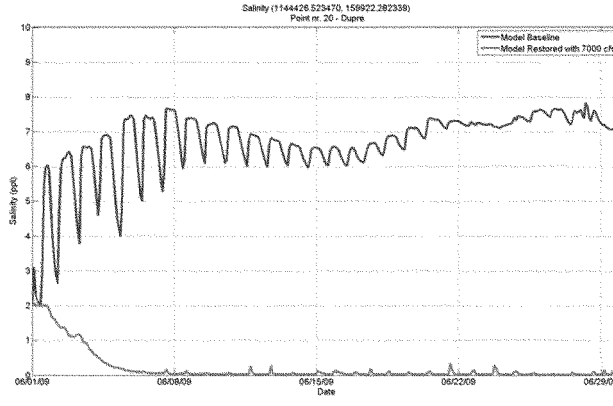

Figure D12: Salinity at point nr 20, Bayou Dupre, for the baseline (blue) and restored with 7000 cfs (red) scenarios.

ROYAL HASKONING

Annex E
Results Sea Level Rise – restored scenario 1000 cfs

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ROYAL HASKONING

Water levels

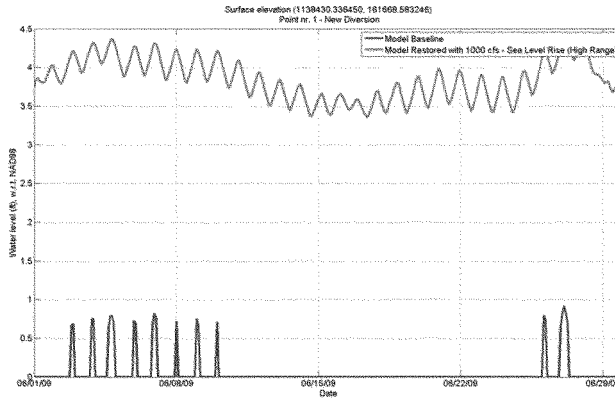

Figure E1: Water levels at point nr 1, New Diversion, for the baseline (blue) and restored with 1000 cfs with Sea level rise (red) scenarios.

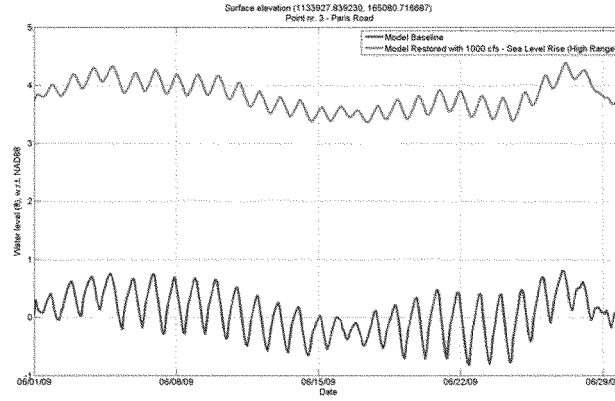

Figure E2: Water levels at point nr 3, Paris Road, for the baseline (blue) and restored with 1000 cfs with Sea level rise (red) scenarios.

ROYAL HASKONING

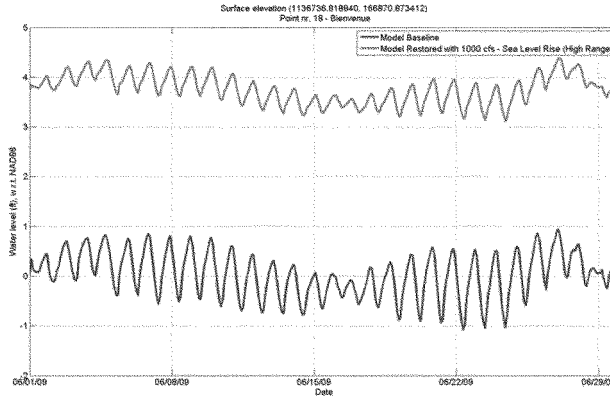

Figure E3: Water levels at point nr 18, Bayou Bienvenue, for the baseline (blue) and restored with 1000 cfs with Sea level rise (red) scenarios.

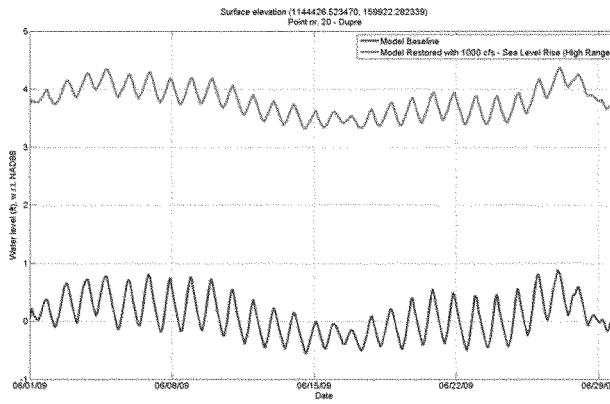

Figure E4: Water levels at point nr 20, Bayou Dupre, for the baseline (blue) and restored with 1000 cfs with Sea level rise (red) scenarios.

ROYAL HASKONING

Current Velocities

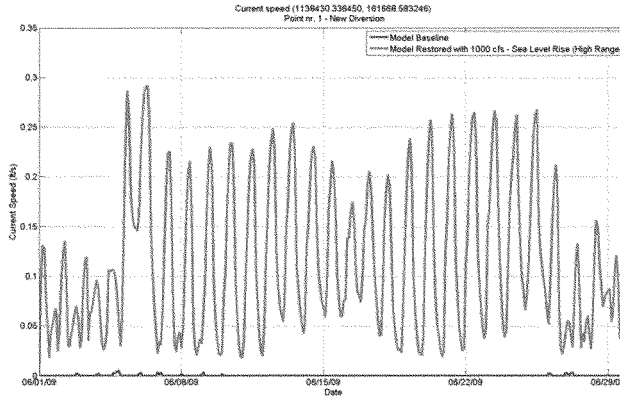

Figure E5: Current velocities at point nr 1, New Diversion, for the baseline (blue) and restored with 1000 cfs with Sea level rise (red) scenarios.

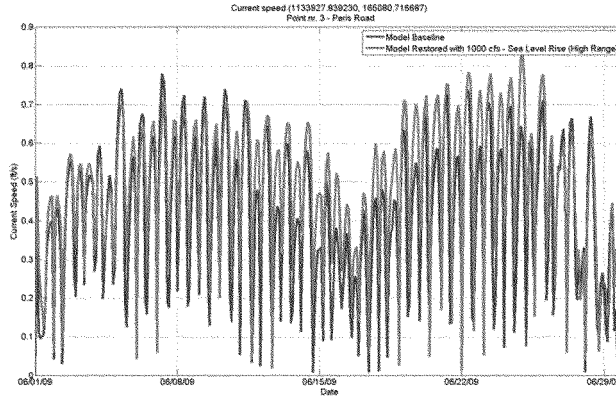

Figure E6: Current velocities at point nr 3, Paris Road, for the baseline (blue) and restored with 1000 cfs with Sea level rise (red) scenarios.

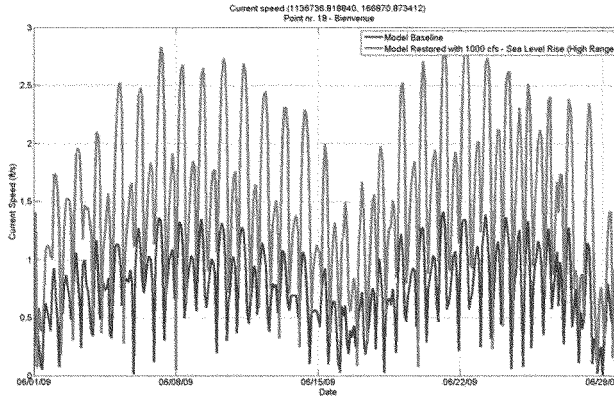

Figure E7: Current velocities at point nr 18, Bayou Bienvenue, for the baseline (blue) and restored with 1000 cfs with Sea level rise (red) scenarios.

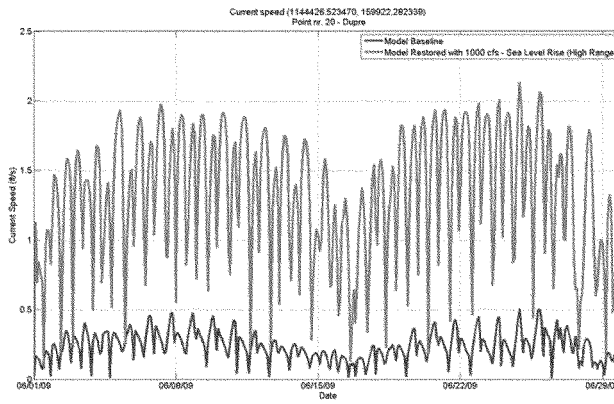

Figure E8: Current velocities at point nr 20, Bayou Dupre, for the baseline (blue) and restored with 1000 cfs with Sea level rise (red) scenarios.

ROYAL HASKONING

Salinity

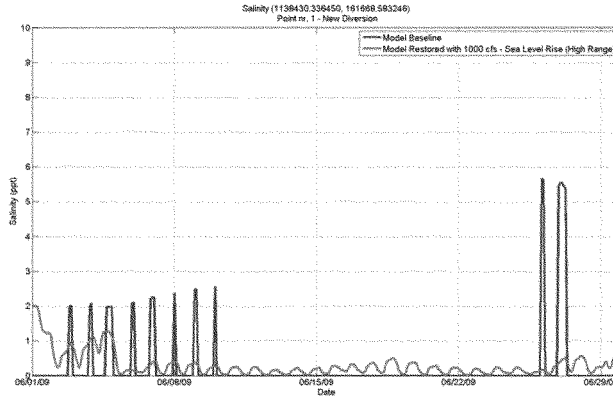

Figure E9: Salinity at point nr 1, New Diversion, for the baseline (blue) and restored with 1000 cfs with Sea level rise (red) scenarios.

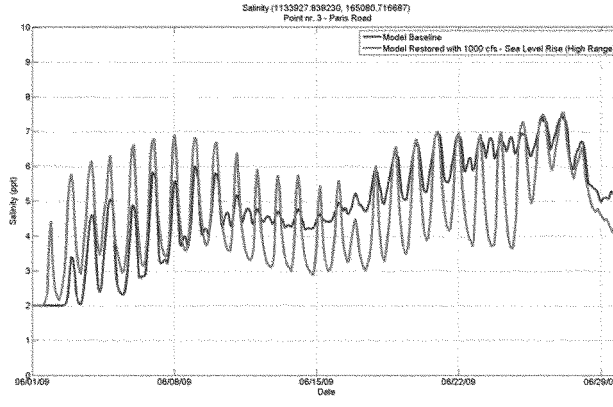

Figure E10: Salinity at point nr 3, Paris Road, for the baseline (blue) and restored with 1000 cfs (red) with Sea level rise scenarios.

ROYAL HASKONING

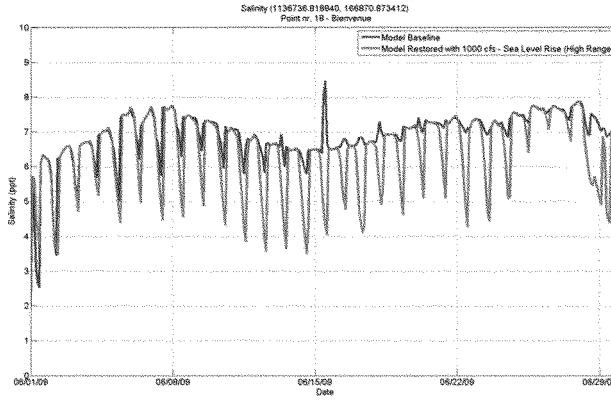

Figure E11: Salinity at point nr 18, Bayou Bienvenue, for the baseline (blue) and restored with 1000 cfs with Sea level rise (red) scenarios.

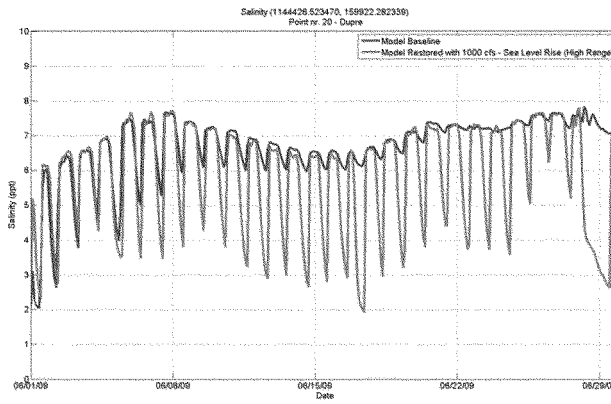

Figure E12: Salinity at point nr 20, Bayou Dupre, for the baseline (blue) and restored with 1000 cfs with Sea level rise (red) scenarios.

ROYAL HASKONING

Annex F
Mean and maximum water levels

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ROYAL HASKONING

Figure F1: Maximum water level, Baseline Scenario: Actual situation

ROYAL HASKONING

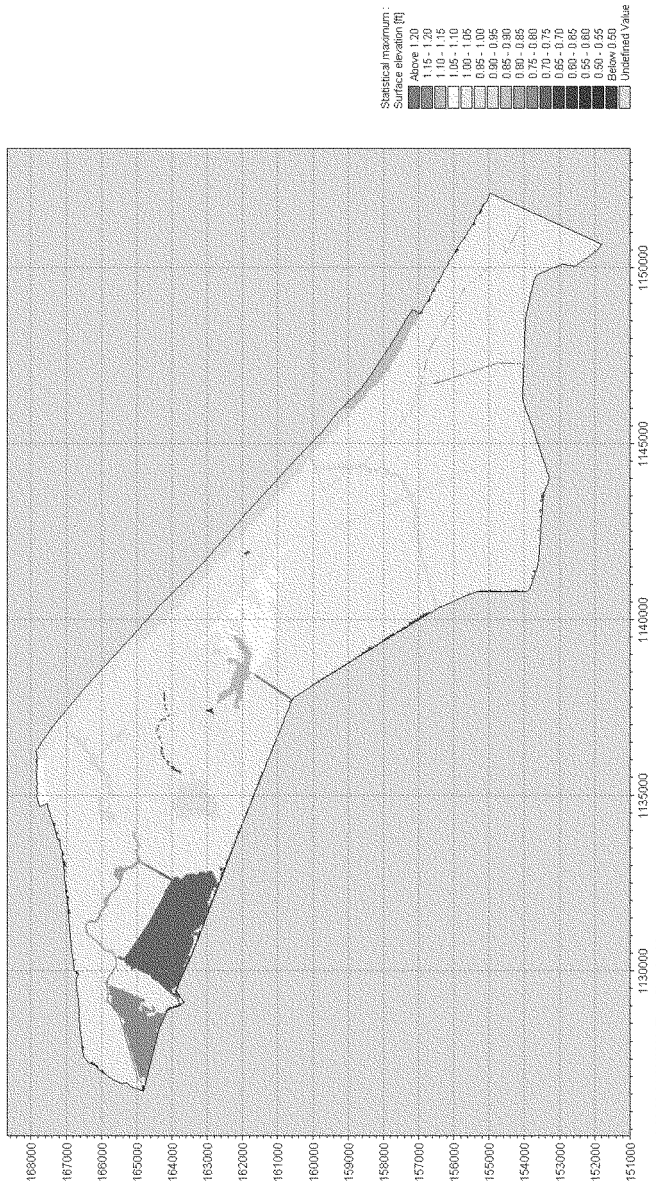

Figure F2: Maximum water level, Baseline Scenario with 1000 cfs

ROYAL HASKONING

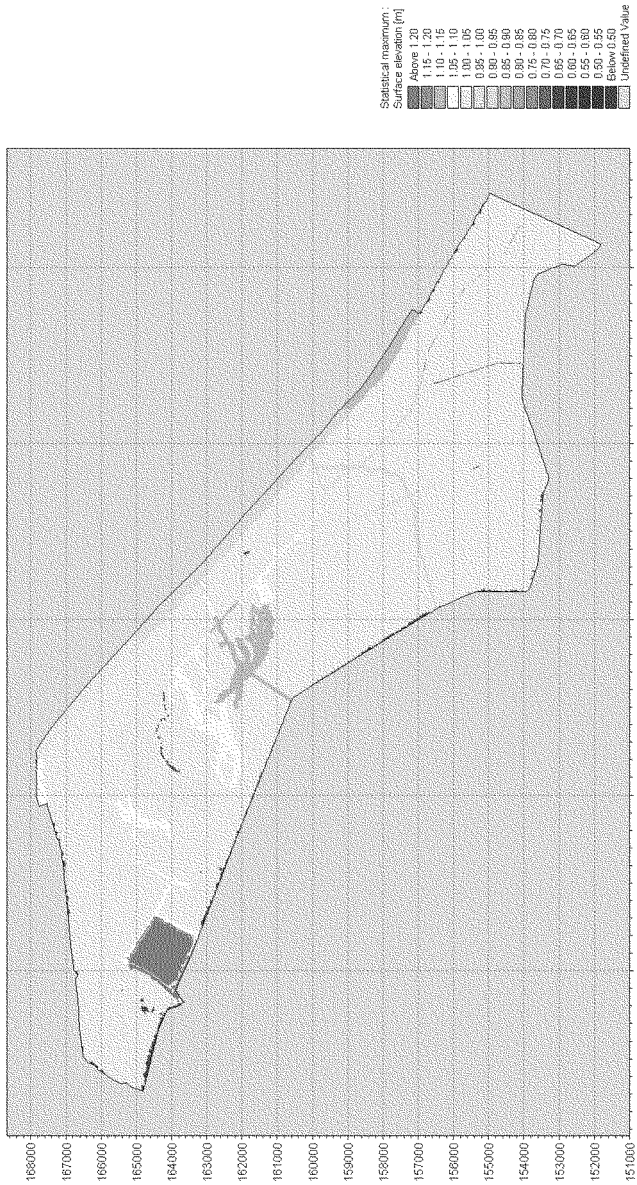

Figure F3: Maximum water level, Restored Scenario with 1000 cfs (error in legend, in ft, not m)

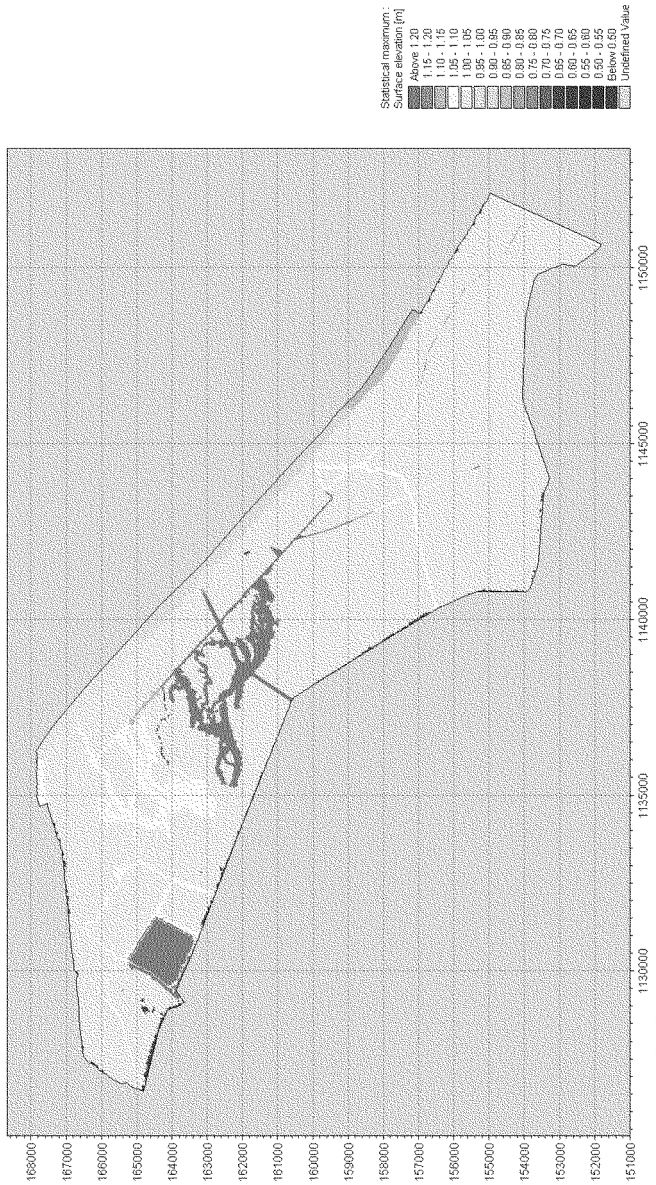

Figure F4: Maximum Water level, Restored Scenario with 7000 cfs (error in legend, in ft, not m)

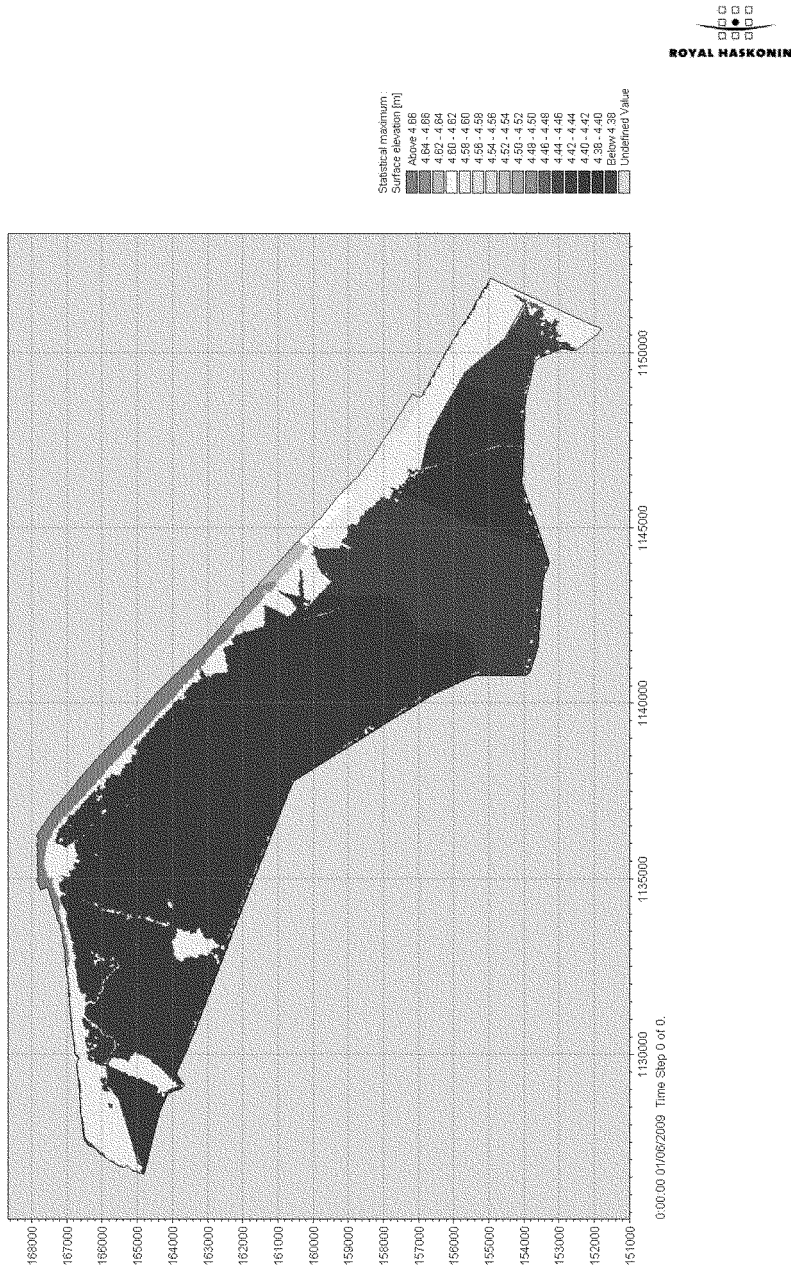

Figure F5: Maximum Water level, Restored Scenario with 1000 cfs and sea level rise (notice: error in legend, in ft, not in m)

ROYAL HASKONING

Mean water levels

Figure F6: Mean water level, Baseline Scenario: Actual situation

ROYAL HASKONING

Figure F7: Mean water level, Baseline Scenario with 1000 cfs (notice: error in legend, in ft, not in m)

ROYAL HASKONING

Figure F8: Mean water level, Restored Scenario with 1000 cfs (notice: error in legend, in ft, not in m)

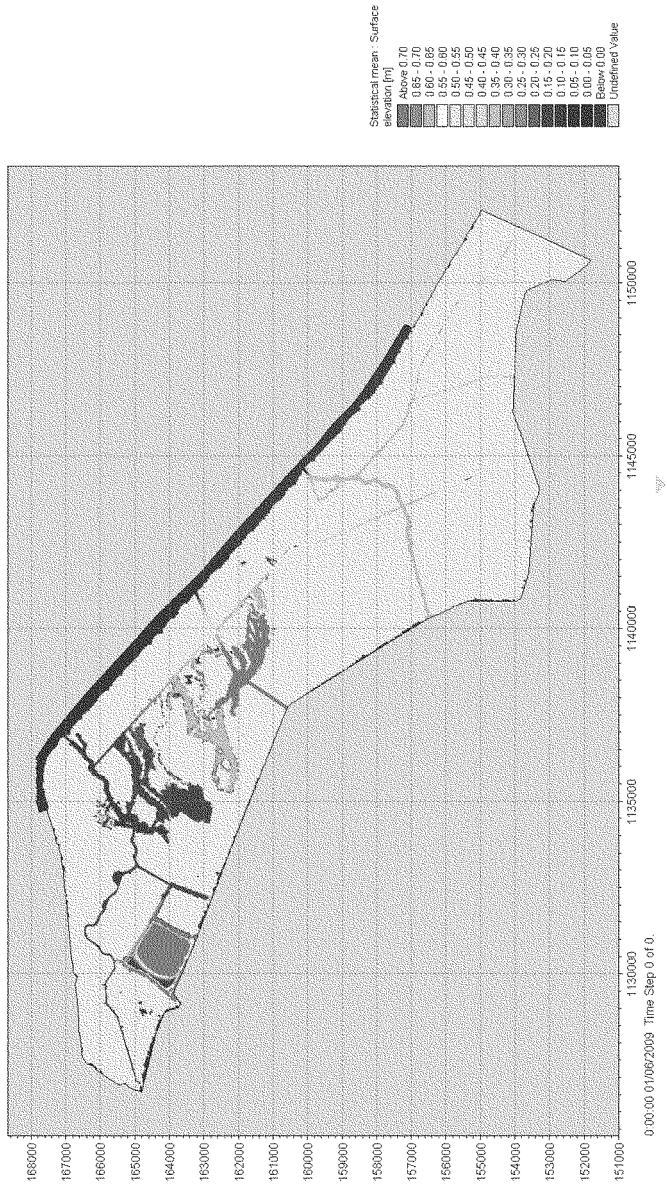

Figure F9: Mean water level, Restored Scenario with 7000 cfs (notice: error in legend, in ft, not in m)

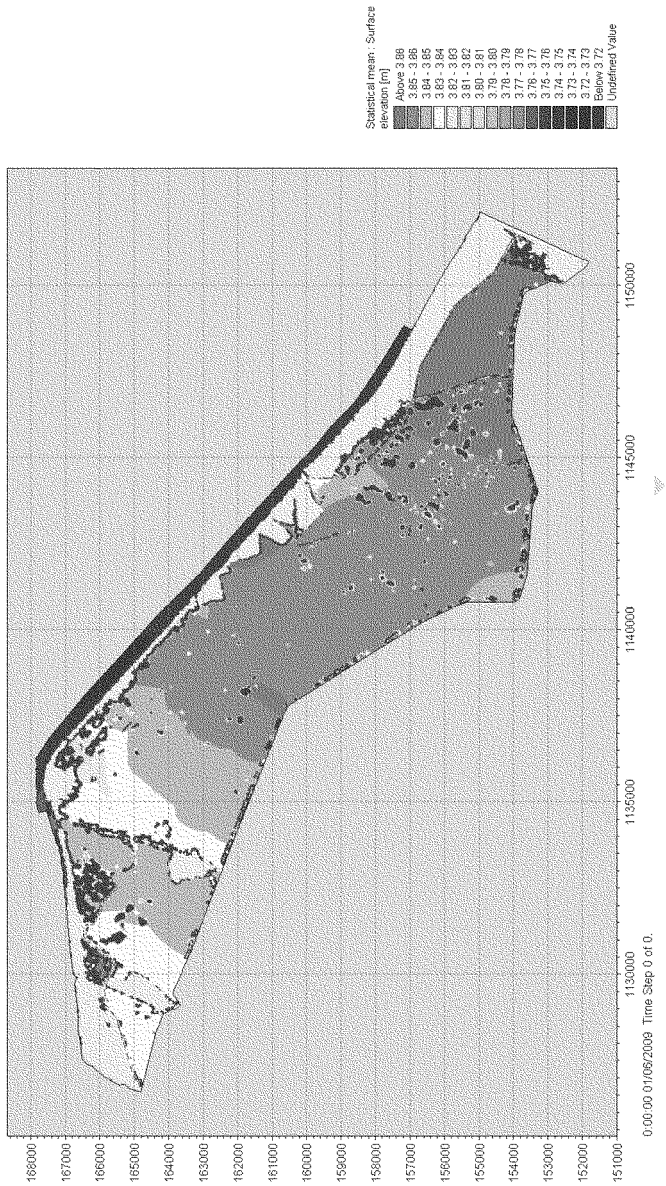

Figure F10: Mean Water level, Restored Scenario with 1000 cfs and sea level rise (notice: error in legend, in ft, not in m)

ROYAL HASKONING

Annex G
Mean salinity values

DRAFT

ROYAL HASKONING

Figure G1: Mean salinity, Baseline Scenario: Actual situation

ROYAL HASKONING

Figure G2: Mean salinity, Baseline Scenario with 1000 cfs

ROYAL HASKONING

Figure G3: Mean salinity, Restored Scenario with 1000 cfs

ROYAL HASKONING

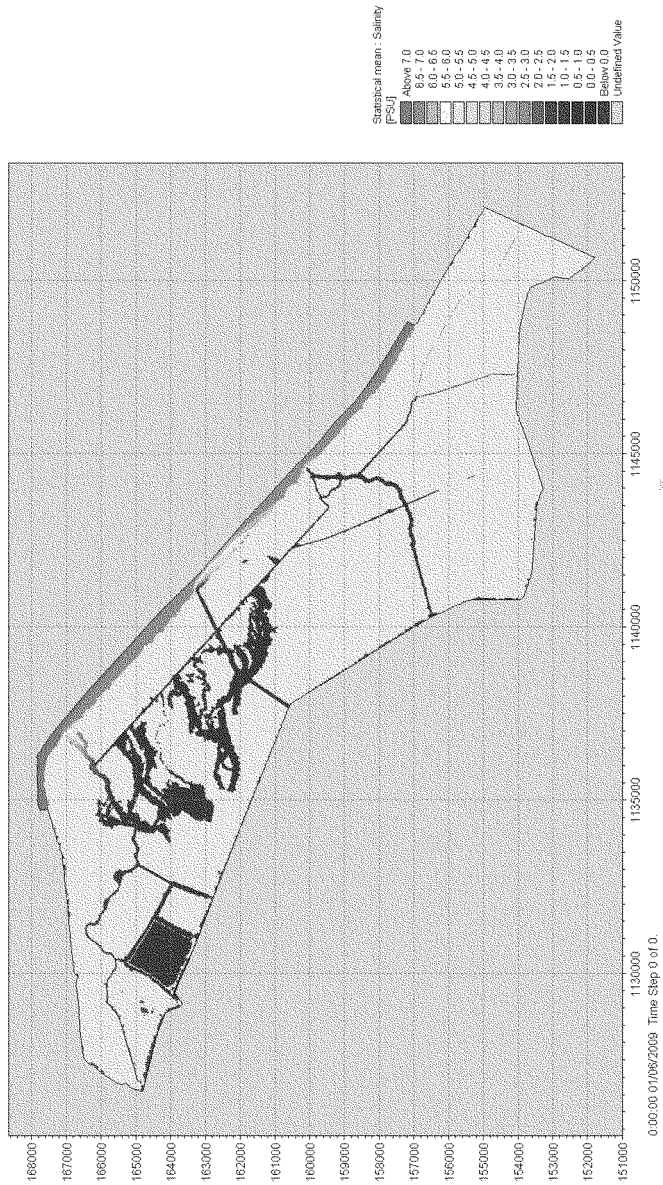

Figure G4: Mean salinity, Restored Scenario with 7000 cfs

ROYAL HASKONING

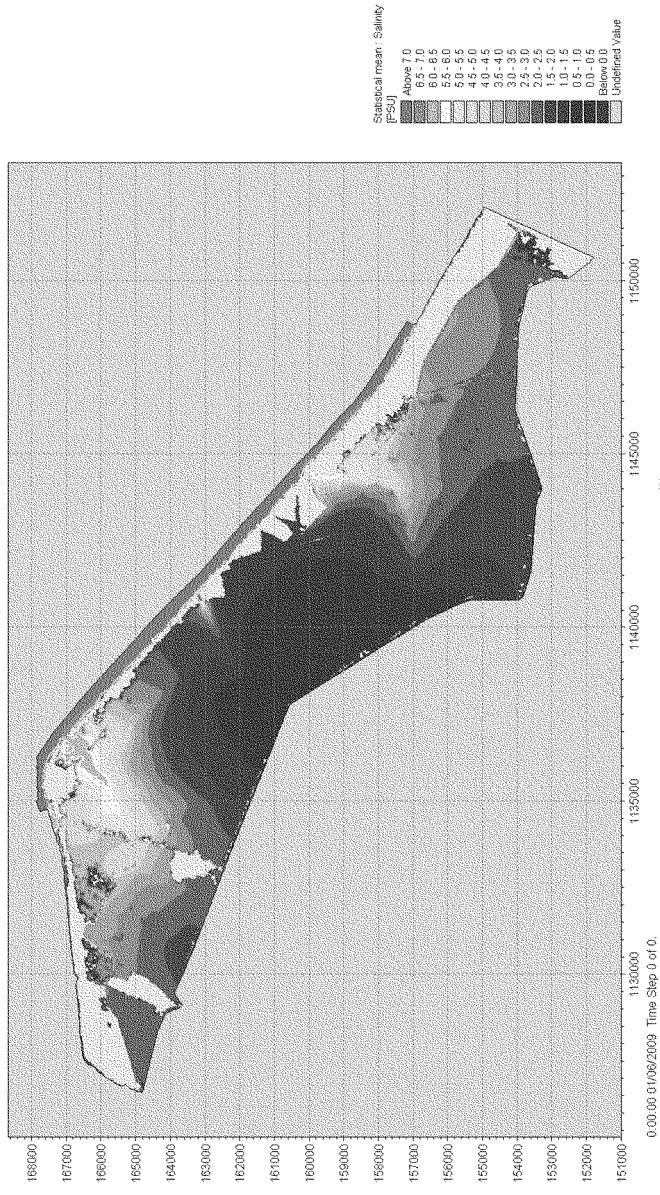

Figure G5: Mean salinity, Restored Scenario with 1000 cfs and sea level rise

ROYAL HASKONING

Annex H
Maximum current velocities

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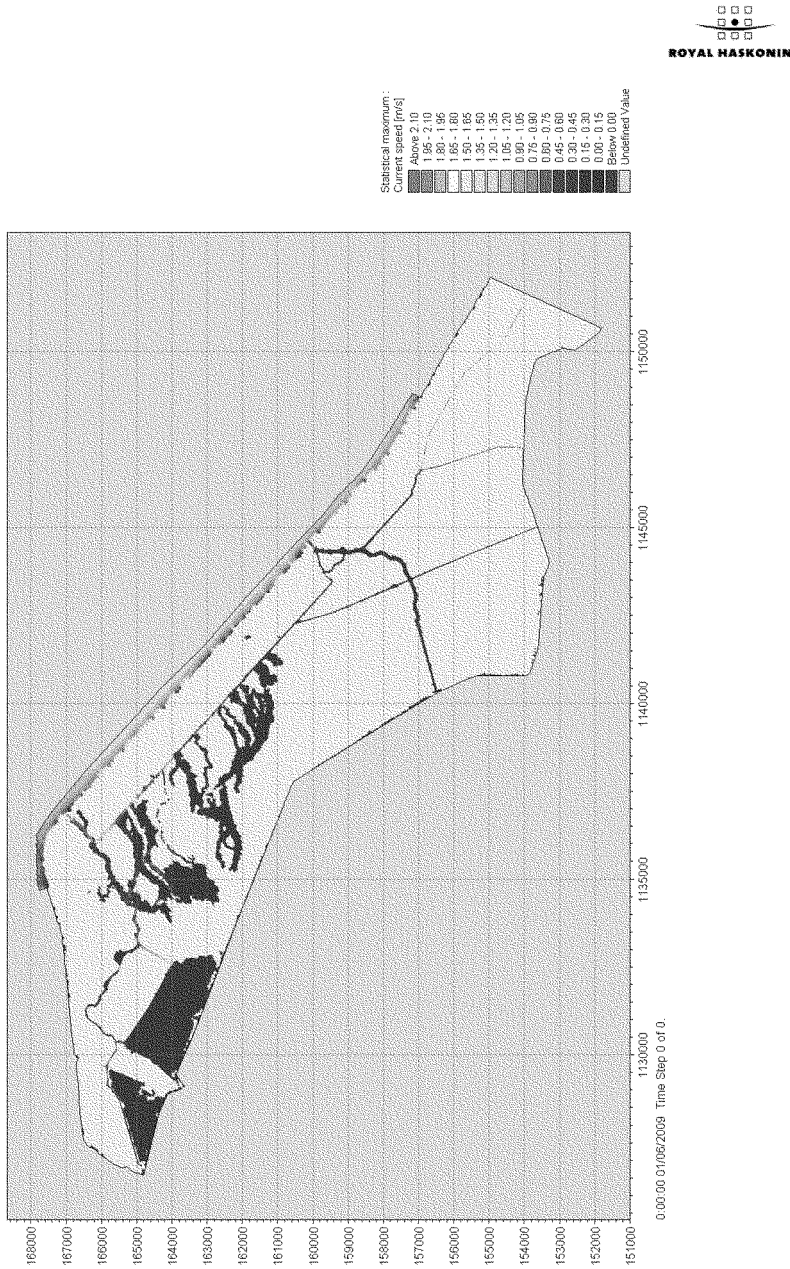

Figure H1: Maximum velocity, Baseline Scenario: Actual situation (notice: error in legend, in ft/s, not in m/s)

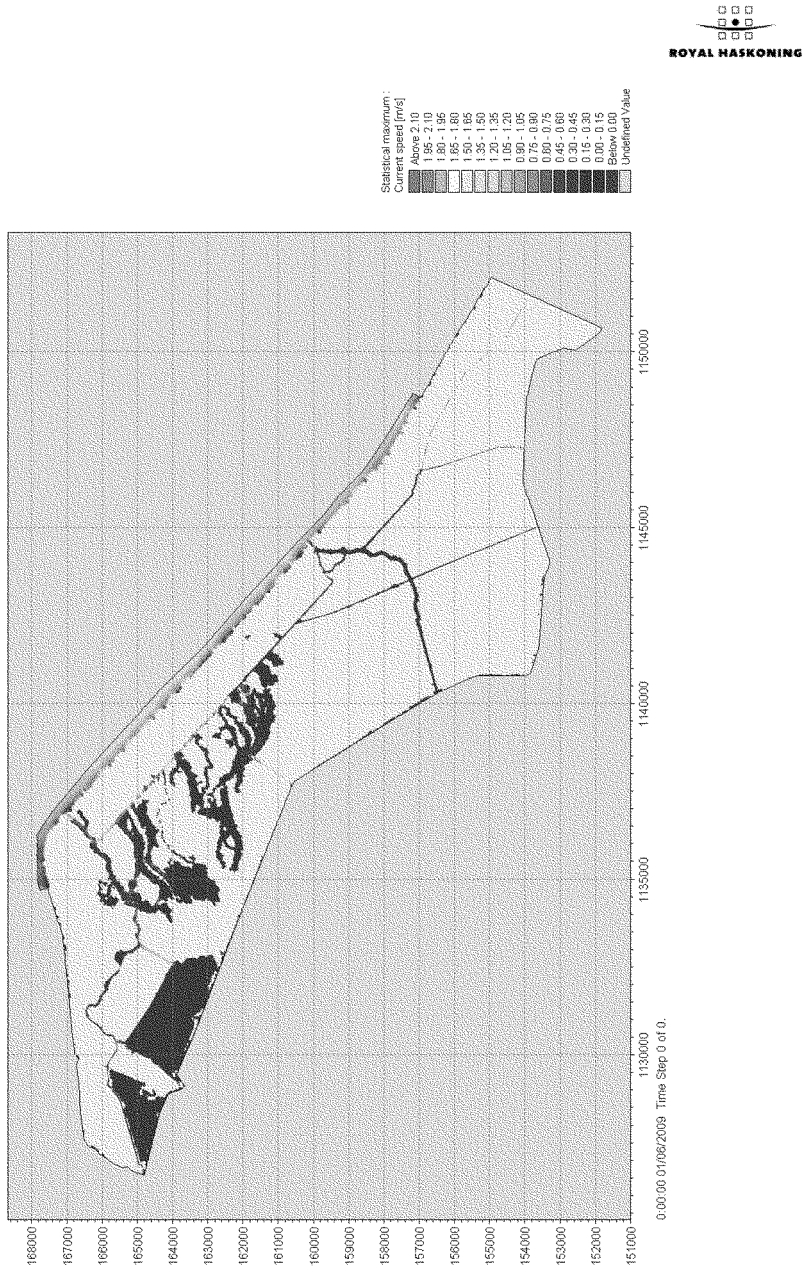

Figure H2: Maximum velocity, Baseline Scenario with 1000 cfs (notice: error in legend, in ft/s, not in m/s)

Figure H3: Maximum velocity, Restored Scenario with 1000 cfs (notice: error in legend, in ft/s, not in m/s)

ROYAL HASKONING

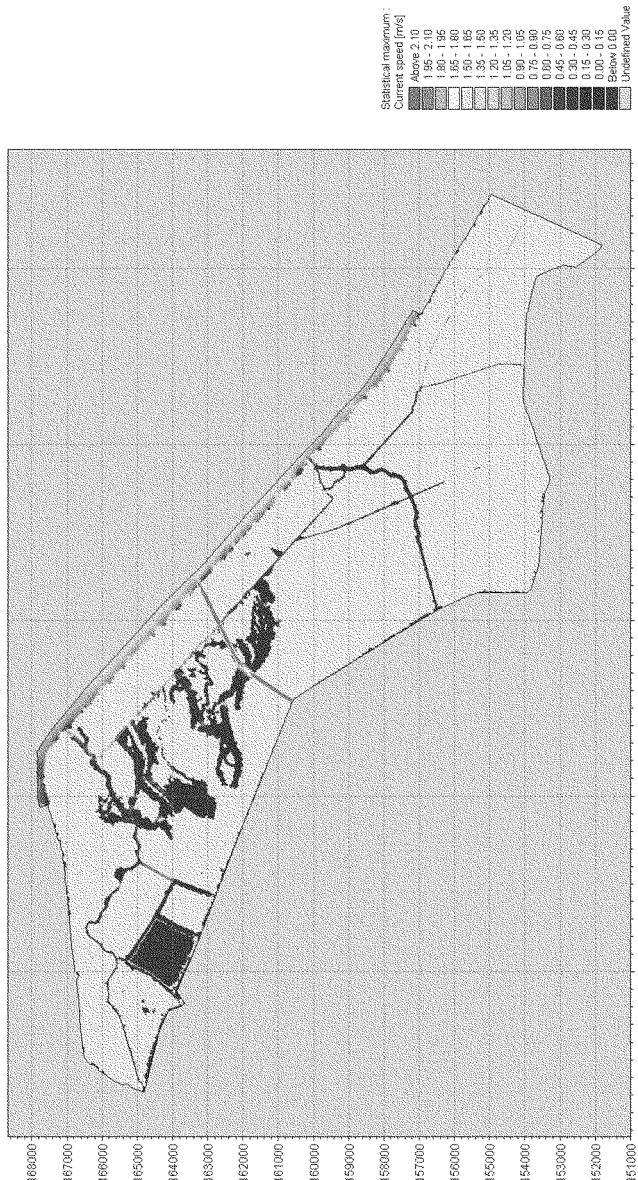

Figure H4: Maximum velocity, Restored Scenario with 7000 cfs (notice: error in legend, in ft/s, not in m/s)

ROYAL HASKONING

Figure H5: Maximum velocity, Restored Scenario with 1000 cfs and sea level rise (notice: error in legend, in ft/s, not in m/s)

APPENDIX H

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High Frequency Response and Transport in the Pontchartrain Basin due to wind stress

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High Frequency Response and Transport in the Pontchartrain Basin due to wind stress

Final Report to:

Post, Buckley, Schuh & Jernigan, Inc. (PBS&J)

Submitted by:

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Draft Final Report

March 12 2010

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INTRODUCTION AND STUDY AREA

The Pontchartrain Estuary is one of the largest estuaries in the northern Gulf of Mexico, covering an area of over 12,000 km^2 on the eastern side of the Mississippi River (Figure 1). The upper Pontchartrain Estuary is composed of three lakes (from west to east - Maurepas, Pontchartrain and Borgne) connected by natural tidal meandering channels and artificial navigation complexes. The estuary occupies a shallow depression between the alluvial ridge of the Mississippi River to the west, the sloping uplands to the north, the Pearl River basin to the east, and Mississippi Sound to the southeast (U.S. Army Corps of Engineers (USACE) 1982). The lakes are connected to the Breton, Chandeleur, and Mississippi Sounds through two natural tidal passes: the Rigolets (opening into Lake Borgne/Western Mississippi Sound) and Chef Menteur (opening into Lake Borgne) and an artificial navigation canal, the Inner Harbor Navigation Canal (IHNC), which is located on the south of the Lake and opens into the Intracoastal Waterway and the Gulf of Mexico through the Mississippi River Gulf Outlet (MRGO). The MRGO, authorized by the River and Harbor Act of 1956 as an alternate navigation route to the port of New Orleans, was constructed in 1958 through 1968 but was de-authorized in 2009 due to a number of impacts including, among others, channel enlargement due to shoreline erosion by tidal currents and vessel wakes, saltwater intrusion, and increased conveyance during storms (LPBF, 2006).

Lake Pontchartrain receives runoff from several rural drainage basins and an urban watershed to the south of the Lake (HARALAMPIDES, 2000), which includes the City of New Orleans. In addition, the estuary receives water from periodic diversions from the Mississippi River through the Bonnet Carré Spillway during times of high stage in the River as a result of high runoff in the Midwest. The return period for floods that require opening of the Spillway has historically been of the order of 10 years. Runoff from the Pearl River basin and other tributaries surrounding the estuary, namely the Amite, Tickfaw, Tangipahoa, and Tchefuncte Rivers, and numerous smaller local streams and bayous provide an additional source of freshwater to the basin. Finally, storm water runoff enters the estuary from the City of New Orleans through pumping via outfall canals along the south shore (CARNELOS et al, 2003).

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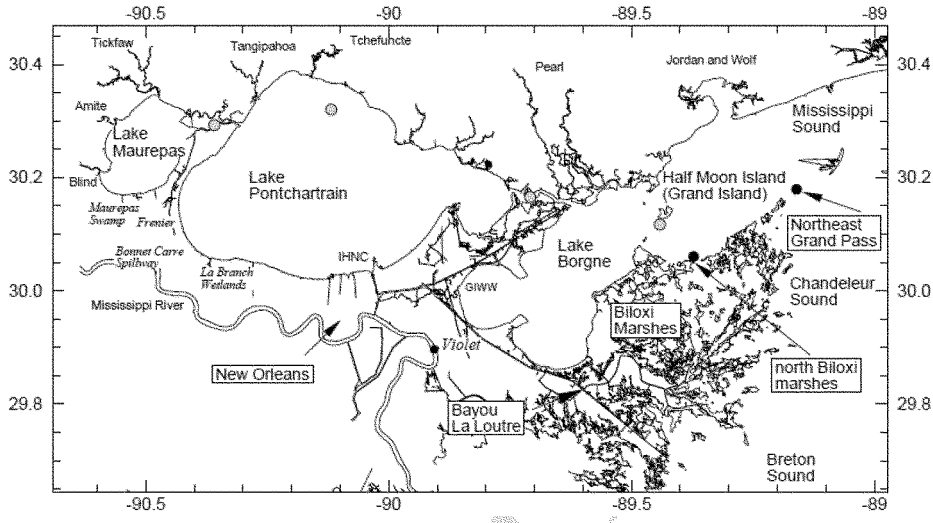

Figure 1 Map of the upper and central Pontchartrain Estuary. Names in italics show the diversion sites. Gray circles show the locations where model tidal validation was compared to observations.

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Hydrodynamics

The Pontchartrain Estuary is shallow and mostly well mixed (HARALAMPIDES, 2000). Circulation currents are largely wind driven and vary in direction and magnitude; typical along-wind magnitudes are approximately 10- 15 cm/s near the lake shorelines and generally much lower in the interior (GEORGIOU, 2002; HARALAMPIDES, 2000; SIGNELL AND LIST, 1997). Tropic tidal range varies along the estuarine axis with typical range in the central portion of the estuary in Lake Pontchartrain of approximately 0.15 m. Total exchange flow during the tropic ebb/flood tides through the tidal passes is approximately 7,800 m^3/s (HARALAMPIDES, 2000), with approximately 1000 m^3/s going through Pass Manchac. Flow distribution among the three main passes (IHNC, Chef Menteur and the Rigolets) is 6%, 30%, and 64% respectively (HARALAMPIDES, 2000).

Hydrodynamics of the upper Pontchartrain Estuary are well modeled. Depth-averaged hydrodynamics were simulated numerically (GAEL, 1980; HAMILTON ET AL., 1985;

HARALAMPIDES, 2000), and three-dimensional hydrodynamics were performed by SIGNELL AND LIST (1997). With the exception of the model developed by Haralampides, these studies were focused on Lake Pontchartrain and did not include the IHNC or thermal and saline gradients. Following the work of SIGNELL AND LIST (1997), three-dimensional hydrodynamics with salinity transport were undertaken by MCANALLY AND BERGER (1996) and BERGER ET AL., (2002) for the entire estuary. GEORGIOU (2002) and GEORGIOU ET AL., (2007;2009) provided similar analysis for Lake Pontchartrain, while CHILMAKURI (2005) added the transport of pathogens and fine sediment transport for a Lake Pontchartrain application.

Previous works have shown that circulation and transport in the estuary is reflective of the geometry, size, and tidal exchange of each part of the estuary. For instance, HAMILTON ET AL. (1985), SIGNELL AND LIST (1997) and HARALAMPIDES (2000) showed that a specific circulation and transport pattern emerges under wind straining, which was present at both a macro (10-15 Km) and a micro scale (2-3 Km). This consisted of downwind currents along the coastline and upwind currents in the center. This pattern was more pronounced in the upper estuary, which is semi-enclosed and includes Lake Maurepas and Lake Pontchartrain. Seasonal shifts in wind could produce the same transport pattern (geometry wise), but net transport within each segment or each Lake is proportional to the wind direction and magnitude (HARALAMPIDES, 2000; RETANA, 2008). SIGNELL AND LIST (1997) also reported that there is an additional forcing to the upper estuary besides the local wind forcing, and that is the tidal forcing. Although tidal forcing produces weaker currents compared to wind straining (GEORGIOU, 2002; SIGNELL AND LIST, 1997), it promotes exchange between the middle and lower estuary (GEORGIOU, 2002), and it is the only mechanism to diffuse higher salinity water up-estuary (RETANA, 2008). Since there are two mechanisms for up-estuary forcing (SIGNELL AND LIST, 1997), mixing and residence time in the estuary could be influenced by both. This could ultimately influence the distribution of salinity in the estuary, especially with additional freshwater input. Since long-term wind distribution in the estuary is uniform for both magnitude and direction (GEORGIOU, 2002), it is expected that while increased mixing and reduced residence time are likely, salinity transport to the upper estuary will be driven by tidal exchange between the upper and lower estuary. Georgiou et al (2009) showed that using a numerical model in the Pontchartrain Basin, and noted that differences in salinity are within demonstrated that although wind stress can impact the

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density field and promote transport and mixing at short scales, for longer simulations they reported that the variance observed in the density field can be explained more by tidal variation rather that wind stress.

OBJECTIVES

The study objectives where to

1. Better understand and quantify high frequency variability of the salinity field in open water using a numerical model, and
2. To understand the transient salinity field during a transition from low to high hypothetical flow magnitude and distribution between sites at Bayou Bienvenue and bayou Dupre in the Central Wetlands Area (CWA).

METHODS

Model description

The Finite Volume Coastal Ocean Model (FVCOM) was selected for this study because it is a prognostic, unstructured-grid, finite-volume, free-surface, 3-D primitive equation coastal ocean circulation model developed by CHEN ET AL., (2003). The model consists of momentum, continuity, temperature, salinity, and density equations and is closed physically and mathematically using turbulence closure sub-models (BURCHARD, 2002; MELLOR AND YAMADA, 1982). The horizontal grid is composed of unstructured triangular cells, and the irregular bottom is represented using generalized terrain-following coordinates (otherwise known as sigma coordinates). The General Ocean Turbulent Model (GOTM) developed by BURCHARD (2002) has been added to FVCOM to provide optional vertical turbulent closure schemes. FVCOM is solved numerically by a second-order accurate, discrete flux calculation in the integral form of the governing equations over an unstructured triangular grid. This approach combines the best features of finite-element methods (grid flexibility) and finite-difference methods (numerical efficiency and code simplicity) and provides a much better numerical representation of both local and global momentum, mass, salt, heat, and tracer conservation. The equations for momentum, continuity, temperature, salinity, and density are as follows:

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$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}-fv=-\frac{1}{\rho_0}\frac{\partial P}{\partial x}+\frac{\partial}{\partial z}\left(K_m\frac{\partial u}{\partial z}\right)+F_u \tag{1}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}+fu=-\frac{1}{\rho_0}\frac{\partial P}{\partial y}+\frac{\partial}{\partial z}\left(K_m\frac{\partial v}{\partial z}\right)+F_v \tag{2}$$

$$\frac{\partial P}{\partial z}=-\rho g \tag{3}$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \tag{4}$$

$$\frac{\partial \theta}{\partial t}+u\frac{\partial \theta}{\partial x}+v\frac{\partial \theta}{\partial y}+w\frac{\partial \theta}{\partial z}=\frac{\partial}{\partial z}\left(K_h\frac{\partial \theta}{\partial z}\right)+F_\theta \tag{5}$$

$$\frac{\partial s}{\partial t}+u\frac{\partial s}{\partial x}+v\frac{\partial s}{\partial y}+w\frac{\partial s}{\partial z}=\frac{\partial}{\partial z}\left(K_h\frac{\partial s}{\partial z}\right)+F_s \tag{6}$$

$$\rho=\rho(\theta,s) \tag{7}$$

where x, y, and z are the east, north, and vertical axes of the Cartesian coordinate; u, v, and w are the x, y, and z velocity components; θ is the potential temperature; s is the salinity; ρ is the density; P is the pressure; f is the Coriolis parameter; g is the gravitational acceleration; K_m is the vertical eddy viscosity coefficient; and K_h is the thermal vertical eddy diffusion coefficient. Here F_u, F_v, and F_s represent the horizontal momentum, thermal, and salt diffusion terms. For a more detailed description of model development and other capabilities the reader is directed to CHEN ET AL. (2003). The model was used in three-dimensional mode due to the episodic and seasonal stratification that the estuary experiences (ABADIE AND POIRRIER, 2000; GEORGIOU, 2002; LI ET AL., 2008) and to capture additional stratification potentially induced near freshwater input sources. Finally, the freely available source code for FVCOM does not readily offer salinity transport under the two-dimensional mode without code modifications.

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Model implementation

The model used in this study was previously developed and validated by Georgiou et al (2007). In that study, the model was set up for an area of the Pontchartrain Basin that includes Lakes Maurepas, Pontchartrain, and Borgne; the Biloxi Marshes; and the Mississippi, Breton, and Chandeleur Sounds. The computational domain consists of 9,306 computational nodes and 15,697 elements (Figure 3). The horizontal grid resolution varies spatially from 40 m in navigation channels and constrictions to approximately 100 m in the tidal passes. The maximum grid resolution is near the open boundary and is more than 1 Km. The vertical resolution of the model includes six vertical layers equally distributed over the water column.

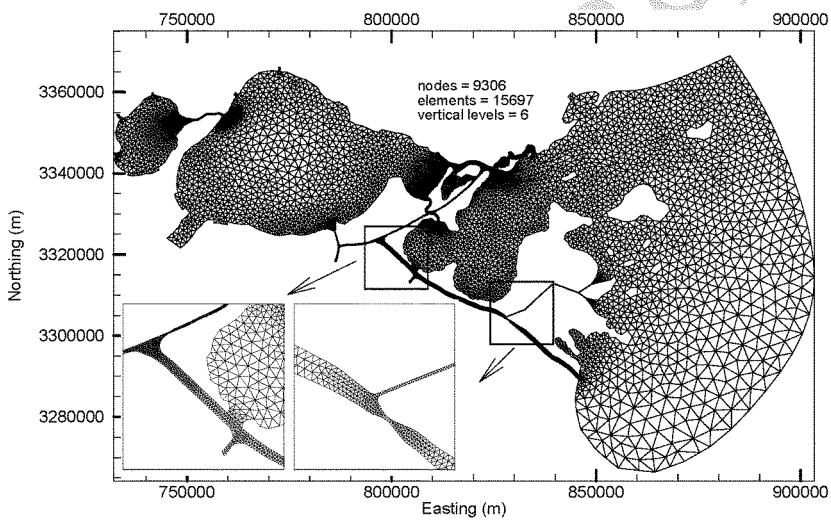

Figure 2 Model computational domain. Resolution varies from more than 1 Km near the open boundary to 100 m in the tidal passes. Bayou La Loutre, ICWW and the IHNC have lower resolution of the order 40 m. Inserts show grid details and resolution at the three locations where closures are taking palce.

This model was subsequently used by Georgiou et al (2009) to study the impact of multiple diversions within the upper and middle parts of the estuary, following recommendations by Federal and State agencies, and additional recommendations proposed by other groups, listed in detail in LPBF (2006). The adopted grid for this study was similar to that of Georgiou et al

(2007; 2009), except for the inclusion of Bayou La Loutré, the full closure of the MRGO at Bayou La Loutre and at another location near bayou Bienvenue, and for some simulations an additional closure at the connection of the MRGO and Lake Borgne.

Initial Conditions

The model bathymetry was obtained from a combination of sources: National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS) hydrographic surveys, and supplements from hydrographic surveys conducted by the United States Geological Survey (USGS) in 1996. Additional data in Breton and Chandeleur Sound were obtained from historic NOAA hydrographic surveys (Figure 4).

Initial salinity conditions were generated using datasets collected from various sources (GEORGIOU, 2002; HARALAMPIDES, 2000; Georgiou et al, 2009). These datasets were used to generate average conditions for a normal year, and were used to populate the model computational grid using spatial interpolation methods, while maintaining the natural estuarine gradient. Once a uniform gradient was generated, the model was executed for 30 days with tidal forcing and mean tributary flows to bring the system to a dynamic equilibrium in the vicinity of freshwater inputs such as tributaries and in areas with dynamic conditions such as those near the tidal passes. For all simulations, initial elevation was set to zero (relative to mean sea level – MSL). The model subsequently started each simulation from rest (still water surface) and the spin-up times for all boundary conditions (tributary flows and tidal elevations at open boundaries) were of the order of two days.

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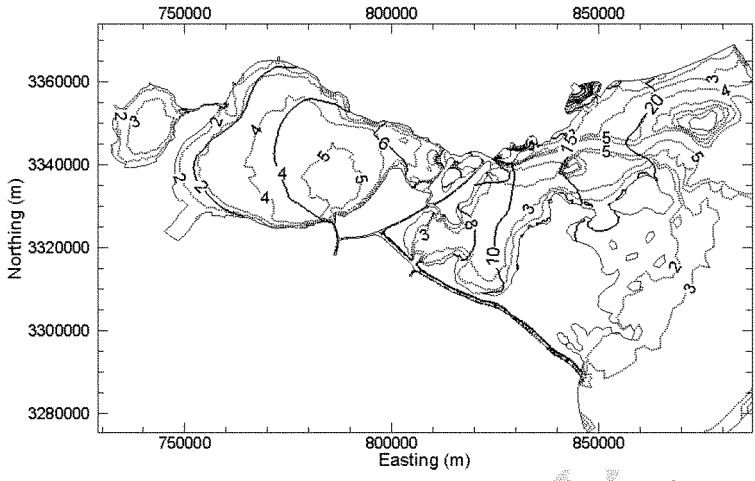

Figure 3 Model Bathymetry (dotted lines) in meters relative to mean sea level, and long-term average isohalines in the Pontchartrain Estuary (solid lines – in ppt). Isohalines were also used as initial condition for the model for most of the simulations (from Georgiou et al, 2009).

Boundary Conditions

At the open boundary, tidal constituents, S_2, M_2, N_2, K_1, and O_1 were derived for each open boundary node using a method after MUKAI ET AL. (2002). Salinity at the open boundary is dynamic and is influenced by the Mississippi River at high flows. For these simulations, the salinity boundary condition was simplified to only reflect seasonal variations during the simulation period due to the lack of observations. The values were generated in part by discrete measurements taken in the vicinity of the boundary as stated in Georgiou et al (2009), and from climatology derived from operational model results maintained by the Naval Research Laboratory, Ocean Dynamics and Prediction Branch. Salinities at the open boundary varied from 28 ppt at the ends of open boundary near coastlines to 34 ppt in the central portion of the open boundary. The open boundary was assumed to be fully mixed (i.e. no stratification was applied) and was constant in time. The same boundary condition was used for all simulations. For the longer simulation (45 days), boundary conditions for salinity and tributary flows were the same as those used in the link-node model. Time dependent daily salinity at the open boundary obtained from the link-node model was used to drive salinity at the open boundary. In space, these daily values were linearly interpolated across the 43 open boundary nodes.

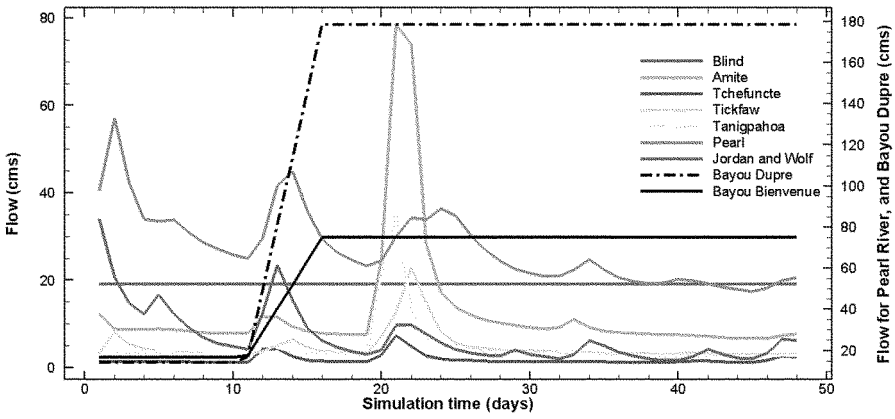

Figure 4 Tributary and diversion flows used in the model for all simulations. Flows are the same as those used in the link-node model.

Tributary discharges for all major rivers flowing into the Pontchartrain Basin including the Amite, Blind, and Tickfaw in Lake Maurepas; the Tangipahoa and Tchefuncte Rivers in Lake Pontchartrain; the Pearl River near the Louisiana and Mississippi State line; and the Wolf and Jordan Rivers in Bay St. Louis. Additionally diversions were included in the model. All flows for tributaries and for diversions were identical as those used in the link-node model. This included daily tributary flows for all simulations, including the longer simulation during spring. The flows for the longer simulation are shown in Figure 4.

Frontal weather and wind input

Extra-tropical storms associated with cold fronts form above the tropics (above the Tropic of Cancer in the Northern Hemisphere) and occur more frequently regardless of their lower intensity than hurricanes or tropical storms. For example, in an average year 20 to 30 cold fronts will pass through coastal Louisiana (Chaney, 1998).

Cold-fronts are defined as narrow transition zones (25 – 250 Km) between two air masses of different densities; polar air from Canada moves south meeting the warm, often moist, air mass

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of the southwestern and southeastern regions. Cold-fronts move west to east and commonly extend to the Gulf of Mexico. They are characterized by spatial and temporal changes in wind speed, direction, barometric pressure, temperature and humidity (Mossa and Roberts, 1990). The pressure gradient at the front controls the intensity of the system and the transfer of energy to the coast. This energy is manifested in the form of strong winds, large waves, low water levels, and abnormal rates of shoreline erosion and sediment transport and deposition (Pepper and Stone, 2002; 2004). The frontal system can be oriented oblique or parallel to the east-west trend of the coast depending upon the initial position of the air masses and how the weather system evolves. An eastward migrating low pressure system will generate an oblique frontal system, and alternatively, when a deep arctic air mass descends toward the Gulf of Mexico a frontal system parallel to the coast develops. The type of cold front controls the duration of the storm and magnitude of the resulting wind fields.

Typically, cold fronts have duration of 12 – 24 hours depending on the storm speed. Studies by scientists at Louisiana State University's Coastal Studies Institute characterized the cold-fronts passage in three phases, the pre-frontal, frontal passage, and post-frontal (Roberts et al, 1987). Initially, a pre-frontal phase occurs during which, strong, warm, moist winds blow from the southerly quadrant. The resulting frontal phase is characterized by a sudden drop in air pressure, erratic winds, and short-lived, but occasionally intense, rain squalls. Finally, a post-frontal phase occurs, during which time temperature and humidity drop, air pressure rises, and winds are strong and northwesterly to northeasterly.

Model input for wind was prepared by use of a combination of realistic wind fields obtained from gauges in the vicinity of the Basin, as well as reconstructed wind field to represent those produced during frontal weather. For instance, rotary type winds, which mimic the pre-frontal-frontal and post-frontal conditions, were also prepared. An example input file for the short simulations used is shown in Figure 5. This is the realistic frontal weather file, and includes the pre-frontal phase with southeast winds gusting at slowly at 10 m/s or more during the peak of the storm, followed by a slow rise in pressure, a slow reduction in wind gusts, and then the switch to northerly winds sustained at slightly lower speeds until the storm passes through.

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For the constructed rotary winds, the following methodology was employed. Low magnitude winds were first kept constant at near 2 m/s, while the direction was slowly changing from east to southeast, followed by a more abrupt change to a north-westerly direction. During this switch the wind speed changed from 2 m/s to 9 m/s, and the direction and magnitude was subsequently held constant for the remaining of the simulation period. This is shown in Figure 6.

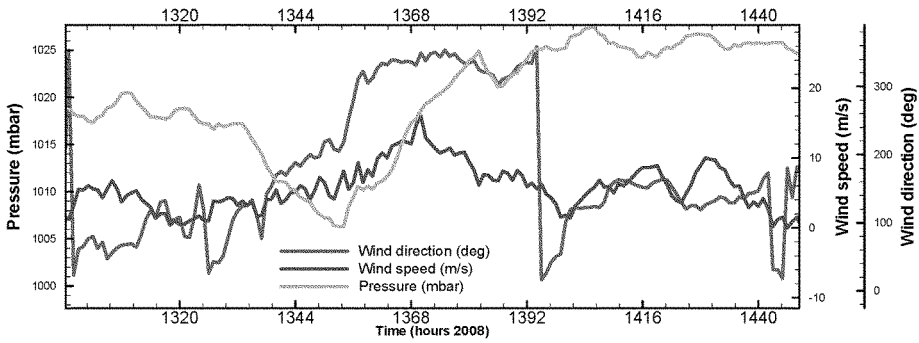

Figure 5 Wind dynamics during frontal weather in Mississippi Sound; Data obtained from NOAA buoy 42007 in 2008.

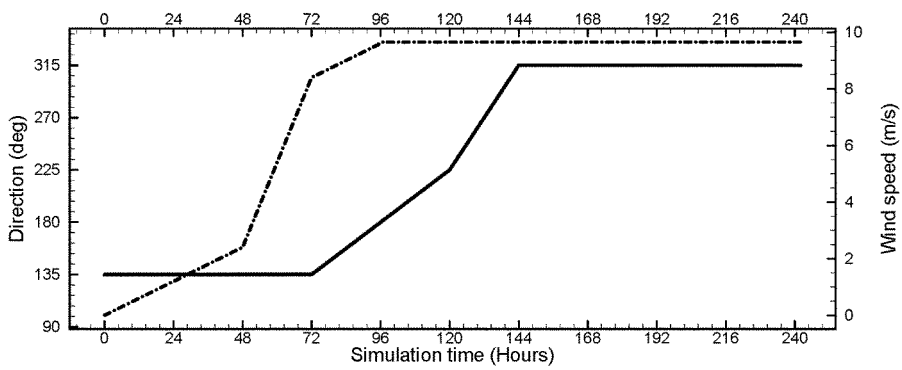

Figure 6 Reconstructed rotary winds used in some of the model simulations; note how the wind speed increase in lagging the direction switch, typically observed during frontal weather.

Simulation Matrix

The following simulation matrix was considered to address the objectives of this study. First, two simulations, one with wind and one without wind were conducted to compare the high frequency variability in the open water areas of the Basin such as Lake Borgne and Mississippi Sound in the vicinity of the Biloxi marshes. These simulations were conducted with the realistic winds, and did not include a closure at the connection between Lake Borgne and the MRGO and without a diversion. The second set of simulations, were performed using reconstructed winds as shown in Figure 6, included a diversion of a constant flow of 7,000 cfs, and an active connection between Lake Borgne and the MRGO. Finally, a longer simulation of 45 days was performed, to investigate the time-dependent evolution of the salinity field resulting from a diversion of 1,000 cfs (split at 50/50 between Bayou Bienvenue and Bayou Dupre) to 7,000 cfs (with a split of 10/90 respectively). During this simulation, the MRGO channel was closed at two locations, and so was the connection between MRGO and Lake Borgne. Table 3 shows a summary of the simulations performed.

Table 1 Casename and initial and boundary conditions for each simulation performed.

casename	simulation time (days)	MRGO closure La Loutre	MRGO closure Bienvenue	MRGO and Lake Borgne	Wind stress	Diversion flow	Open BC (salinity)
OPT1	5	yes	No	open	Yes, realistic	no	Gaussian/marine
OPT2	5	yes	No	open	No wind	no	Gaussian/marine
OPT3	5	yes	yes	open	Yes, realistic	yes	Gaussian/marine
OPT5	10	yes	yes	closed	Yes, constructed	yes/7,000	Gaussian/marine
OPT6	10	yes	yes	closed	No wind	yes/7,000	Gaussian/marine
OPT7	45	yes	yes	closed	No wind	yes/(1,000-7,000)	Gaussian/marine
OPTF	45	yes	yes	closed	No wind	yes/(1,000-7,000)	from link-node model

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MODEL CALIBRATION AND VALIDATION

The model was calibrated previously by Georgiou et al, (2007; 2009), to reproduce observed tidal variations at selected locations in the estuary and to reproduce observed tidal flow through the main tidal passes and the navigation complex connecting Lake Pontchartrain and Lake Borgne (ICWW, IHNC). The model was not re-calibrated for this study and was used as is, following a re-validation of the tidal range in Lake Pontchartrain after the addition of the La Loutre channel. The results from the previous validation of the model performed by Georgiou et al, (2007; 2009) are shown in Tables 2. Discharge measurements in the tidal passes performed in August 1997 by the U.S. Geological Survey and the University of New Orleans were used to validate the model (HARALAMPIDES, 2000). The measurements were conducted using a vessel-towed Acoustic Doppler Current Profiler (ADCP), which was used to collect synoptic flow data across all tidal channels (IHNC, Pass Manchac, Rigolets, and Chef Menteur) over a 2 day period (Table 3). Local depth, water surface elevation, and velocities were extracted from the model every hour to compute tidal flows through the passes.

Table 2 Simulated and observed tidal ranges and phases for the spring tide

		Lake Pontchartrain	Rigolets	Half Moon Island	Pass Manchac
Simulated	Range (m)	0.16	0.43	0.66	0.15
	Phase* (hours)	23.5	23.5	24.2	23.3
Observed	Range (m)	0.17	0.31	0.65	0.16
	Phase* (hours)	24	25	25	26

* Phase is measured relative to the previous maxima during spring tides

Table 3 Simulated and observed flows for August 1997

	Flows in (m^3/s)	IHNC	Chef Menteur	Pass Manchac	Rigolets	Total
Simulated	Flood/Ebb	439 (15,500)	2322 (82,000)	1034 (36,500)	4955 (175,000)	8764 (309,500)
Observed	Flood/Ebb	368 (13,000)	2407 (85,000)	991 (35,000)	5097.03 (180,000)	8863 (313,000)

* Measured and simulated flow is the maximum during the tidal cycle and is averaged for Flood and Ebb. Flows in cfs are shown in parentheses.

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MODEL RESULTS AND DISCUSSION

Tidal variation in the Pontchartrain Basin

During the equatorial cycle, tidal range in the upper estuary can be as low as 0.01 – 0.03 m, while during the tropic tides tidal range can reach 0.23 m. Tidal currents in the Pontchartrain Estuary vary in time and space. Depth averaged tidal currents in Lakes Pontchartrain and Borgne and generally in open and non-constricted watercourses are of the order of 0.01 – 0.02 m/s during equatorial tides and reach 0.10 – 0.15 m/s during tropic tides or when strong wind forcing is present (wind speed in excess of 5 m/s). In navigation channels and tidal passes, currents are swift and can reach magnitudes of more than 1 m/s. Lunar-averaged currents achieved magnitudes of 0.8 m/s in the IHNC, and vary from 0.2 – 0.4 m/s in the remaining passes. The currents, once entering interior water bodies, decrease rapidly to magnitudes typically of the order of 0.02 – 0.1 m/s. Strong tidal currents also occurred in the northern region of Lake Borgne near the Pearl River, the area near Half Moon islands, and the waterway between Grand Pass and Chandeleur Sound. It is noted here that this is the main corridor for tidal propagation to the middle and upper estuary, with average tidal velocities varying from 0.15 to 0.2 m/s.

Simulated salinity distribution under wind stress

Initially the model was used to investigate the short term high frequency variability in open water (in Lake Borgne and Mississippi Sound). This was accomplished by use of realistic wind fields (Figure 5). Two simulations were performed, one with wind as shown in Figure 5 (opt1) and one without (opt2). Figure 7 shows the depth-integrated distribution of salinity averaged over the 5 day simulation period for the case with wind, and Figure 8 sows the same solution without wind. By comparison these two simulations look very similar, and an initial conclusion would be to infer that there are negligible changes between the two simulations. When we compare the variance or dispersion in the system however, by means of calculating he standard deviation of each node (in time), and plot the results in two dimensions we see a different pattern emerge. Figure 9 shows that wind induced circulation within Lake Pontchartrain will cause variation in the salinity near the coastlines where currents are larger. Similarly, higher variability is observed in Mississippi Sound, although small, near half moon island, and the interaction of the Pearl River freshwater plume in that vicinity, as well as within the Biloxi Marsh area.

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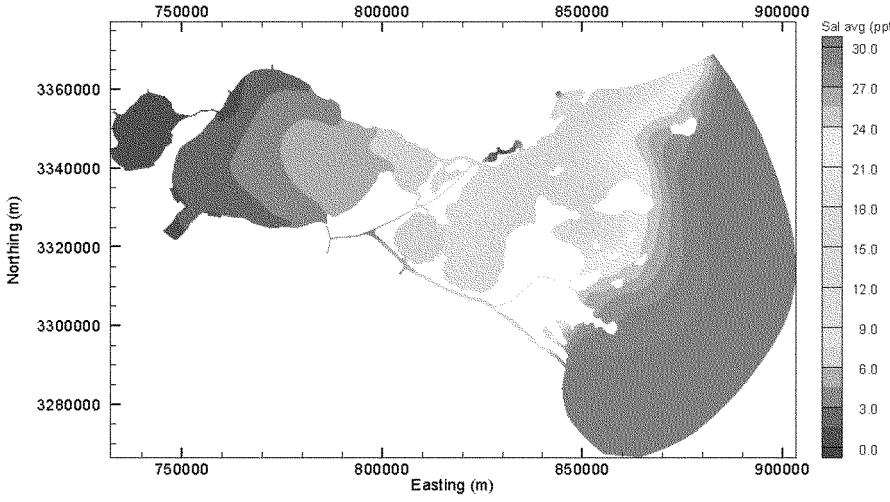

Figure 7 Model simulated depth-integrated salinity distribution averaged over 5 days (case opt1; frontal wind).

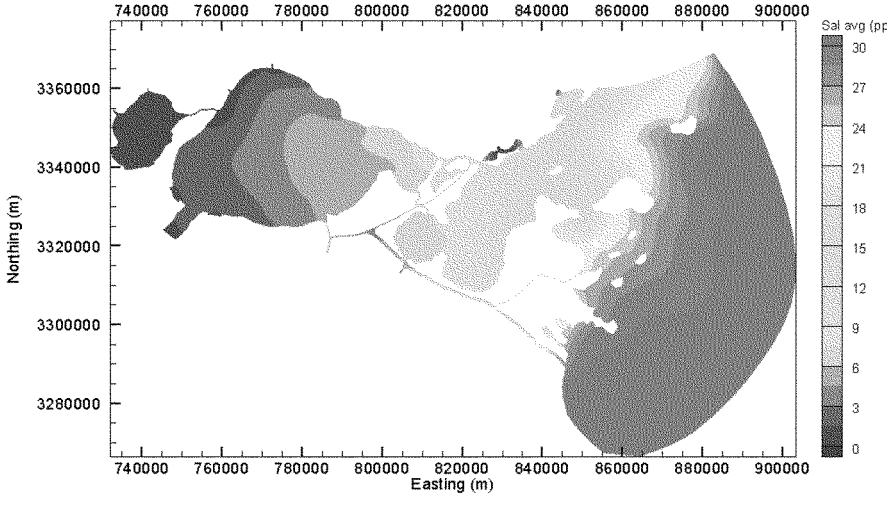

Figure 8 Model simulated depth-integrated salinity distribution averaged over 5 days (case opt2; no wind).

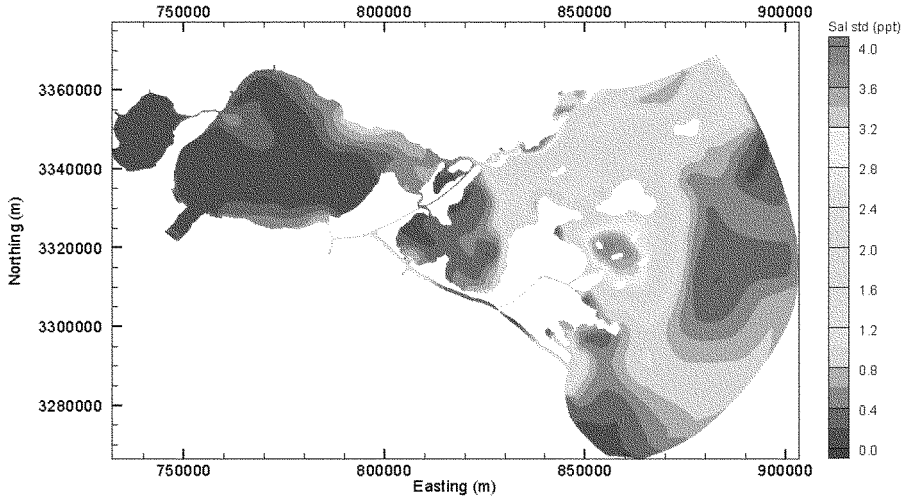

Figure 9 Model simulated depth-integrated standard deviation distribution for 5 days (case opt1; frontal wind).

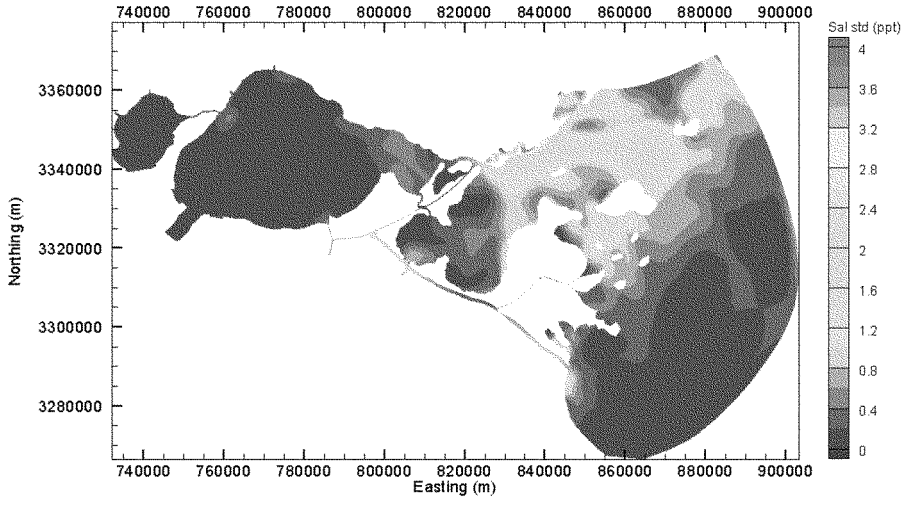

Figure 10 Model simulated depth-integrated standard deviation distribution for 5 days (case opt2; no wind).

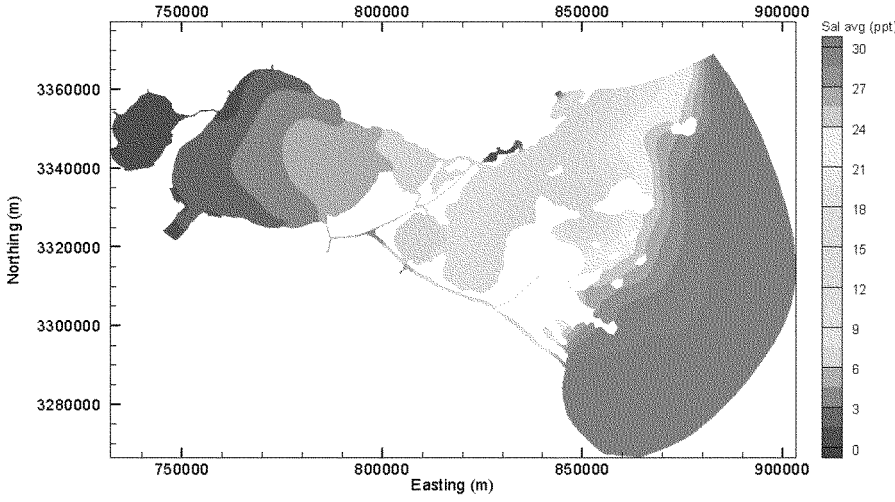

Figure 11 Model simulated depth-integrated salinity distribution averaged over 5 days (case opt1; frontal wind).

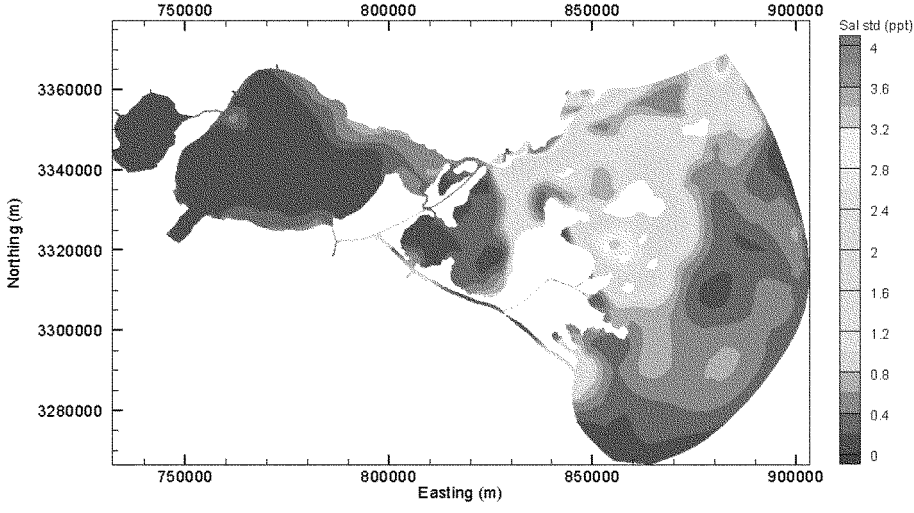

Figure 12 Model simulated depth-integrated standard deviation distribution for 5 days (case opt3; frontal wind).

Because in simulations opt1 and opt2 the Bayou Bienvenue closure of the MRGO was not implemented, in an attempt to investigate intermittent or transient conditions, another simulation was performed (opt3), which was similar to opt1 (i.e., with frontal actual winds, and other boundary conditions), except this time the second closure at the MRGO near Bienvenue gates was implemented. Figure 11 shows that the average depth-integrated salinity for this simulation looks identical to that of opt1. Moreover, the distribution of the standard deviation for scenario opt3, shown in Figure 12, very closely compares to that of the simulation without the closure. Some obvious and expcted differences exist between the two simulations and are largely in the MRGO itself, and as a result additional rather small difference in Breton Sound, and within the Biloxi Marshes. The differences however outside the navigation complex are rather small and insignificant.

A second set of simulations with and without winds wee conducted, this time however, with constructed and more persistent duration of the west and northwest winds during the post frontal phase of the storm. This wind pattern would have the tendency to push or force water seaward of the Basin, and in the process help spread and disperse the salinity. As a subsequent result, targets in Mississippi Sound, Biloxi Marshes and other areas of interest could be met faster than anticipated. These simulations, namely opt5, and opt6, have the same initial and boundary conditions as opt1-opt3, with the exception of the winds which are constructed as shown in Figure 6, rather than those in Figure 5. An additional difference between these simulations is that there is a diversion at Violet with a constant flow of 7,000 cfs throughout the simulation. These simulations are slightly longer and last for 10 days. Comparatively, Figures 13 and 14 look again very similar, with average depth-integrated salinities fairly similar through the computational domain. When inspect closely, we notice that there is small wind induced variability that shows even in the averaged salinity field. This can be seen in Lake Pontchartrain, where again the wind induced currents produce more mixing and hence more variability near the coast. Additional differences include small deviations in Mississippi and Chandeleur sounds, however when looking at the average salinity field these initially do not appear to be large.

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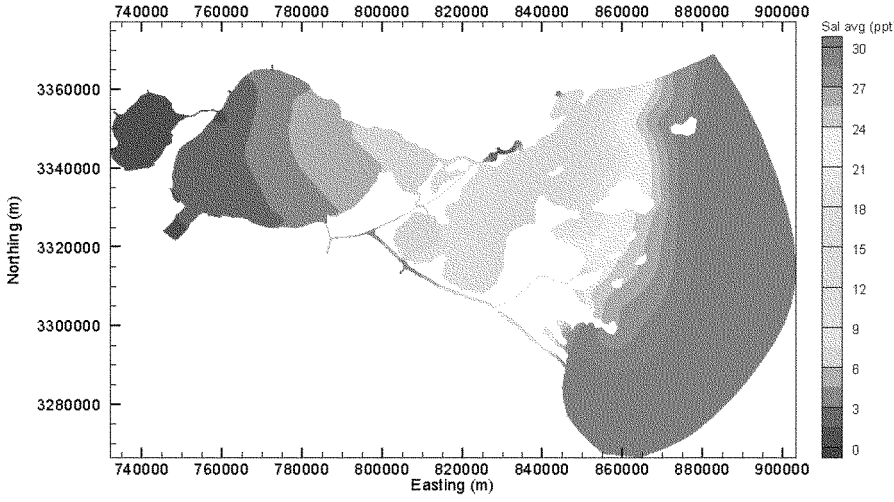

Figure 13 Model simulated depth-integrated salinity distribution averaged over 5 days (case opt5; frontal wind).

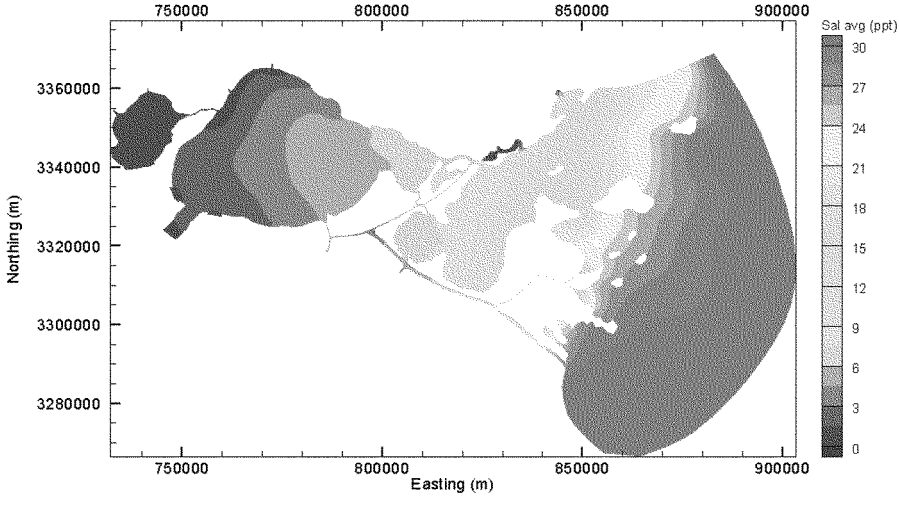

Figure 14 Model simulated depth-integrated salinity distribution averaged over 5 days (case opt6; no wind).

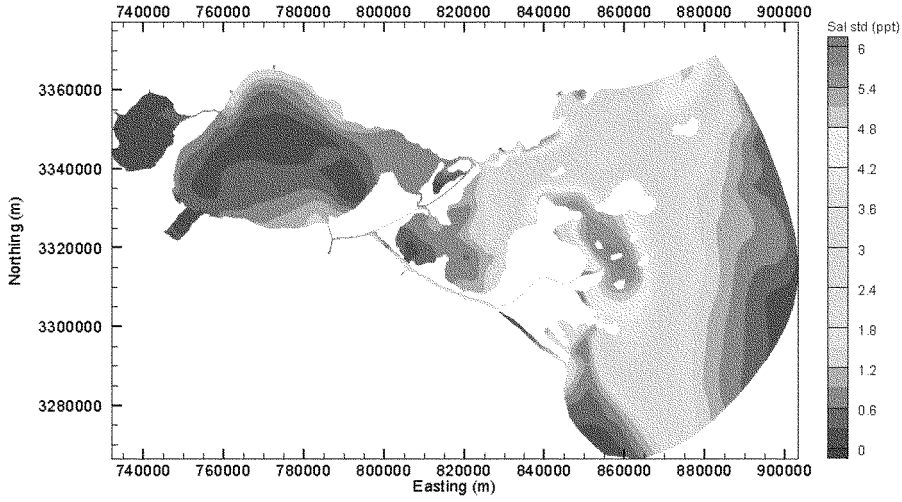

Figure 15 Model simulated depth-integrated standard deviation distribution for 5 days (case opt6; frontal wind).

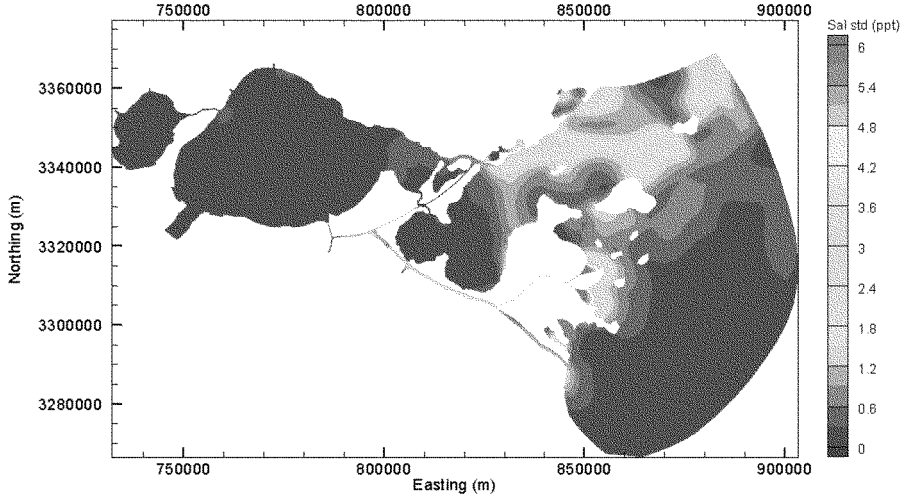

Figure 16 Model simulated depth-integrated standard deviation distribution for 5 days (case opt6; no wind).

When we examine the variance by looking at the standard deviation in time for every node (Figure 15 and 16), the variability due to wind stress is profound. Up-estuary, in Lake Pontchartrain there appears to be very small variability due to tidal forcing alone (Figure 16). Moreover, in Mississippi Sound standard deviations are of the order of 3 ppt, and are largely in areas where tidal range is high. In the area of interest, and within the Biloxi Marsh area, we see evident change, although most of this change can de attributed to freshwater input at Violet, which naturally flows seaward through bayou La Loutre. When we compare Figure 16 to Figure 16 (frontal constructed wind stress), we notice that there is additional variability explained only by high frequency response to wind stress. Wind incuded currents within Lake Pontchartrain cause as previously observed, to cause salinity to respond along the coastline. Furthermore, within the Biloxi Marsh area, the standard deviations appear to rise to 6 ppt or more. Similarly, Figure 15 also shows that open water bodies such as Breton, Chandeleur, and Mississippi Sound respond to wind stress rapidly. The areas, when compared to no wind simulations, showed double the variability in the present of wind stress.

Transient Salinity response to a Diversion

The second objective of the study was to investigate the transient response of the salinity field from the 1,000 cfs to the 7,000 cfs during spring, with three closures implemented; namely, (1) MRGO at Bayou La Loutre, (2) MRGO at Bayou Bienvenue, and (3) the connection between Lake Borgne and the MRGO. The same model was used for this simulation as well, with the exception of a variation from previous simulations (Table 1). For these two simulations, the first included the same boundary condition for salinity as the one used in all previous simulations which included Gaussian distribution mainly of marine salinity conditions, while another simulation with a open boundary obtained and forced from the link-node simulations during spring was used. The intention for this second simulation was to indirectly simulate a diversion within the Caernarvon basin which would ultimately bring water into Breton Sound. However, due to the fact that model domain does not cover the entire Breton Sound, or Caernarvon, the possible and expected reduction in salinity was forced at the boundary as simulated by the link-node model. This way, tidal constituents forced at the boundary are expected to advect this lower salinity water within the model domain. No wind was considered for this longer 45 day simulation.

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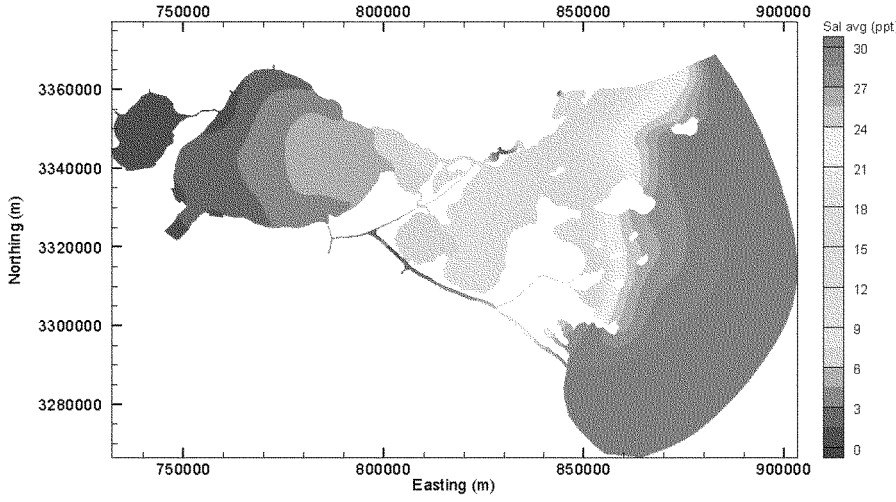

Figure 17 Model simulated depth-integrated distribution for 45 days (case opt7; no wind)

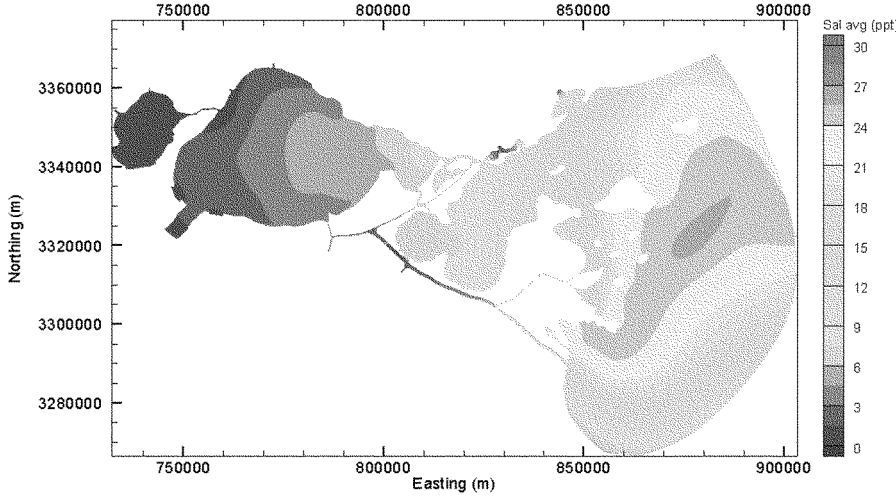

Figure 18 Model simulated depth-integrated distribution for 45 days (case optf; no wind)

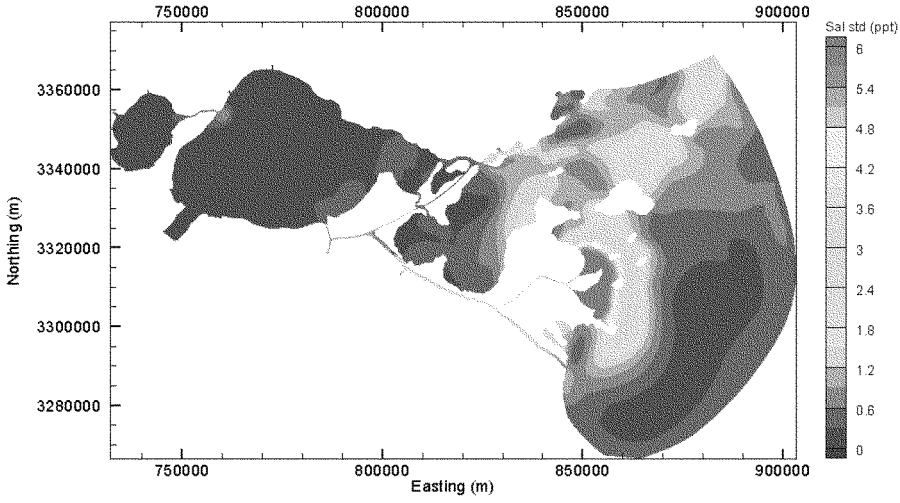

Figure 19 Model simulated depth-integrated standard deviation distribution for 45 days (case opt7; no wind).

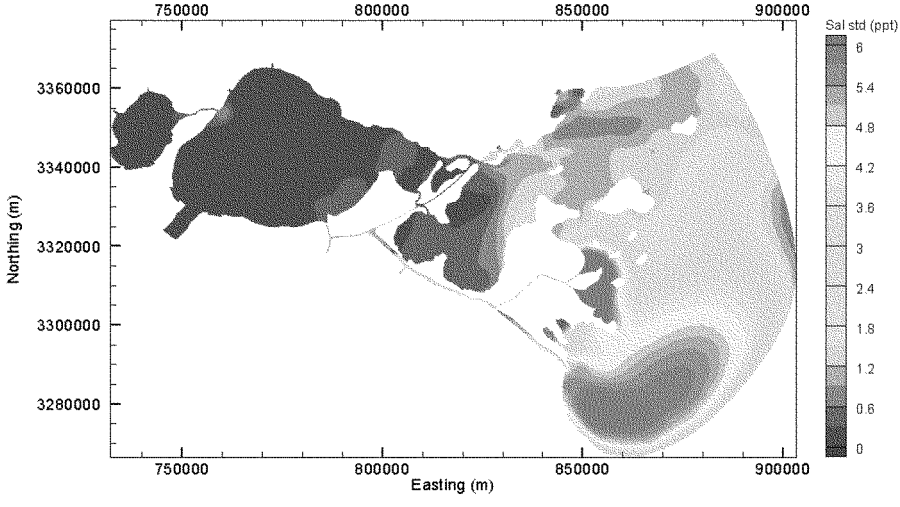

Figure 20 Model simulated depth-integrated standard deviation distribution for 45 days (case optf; no wind)

Figure 17 and Figure 18 show the average depth-integrated distribution of salinity over the period of the simulation (45 days). Similar to previous statistical estimated, the average value for every node (in time) is computed based on the hourly output. It is evident from the average salinity field that up-estuary (such as within Lake Pontchartrain), lower salinities in Breton Sound as a result of diversions in the Caernarvon Basin have little or no impact. This is the same for Lake Borgne and for parts of Biloxi Marsh and Mississippi Sound. Average salinities however start to be considerably different within Breton Sound (as expected), and within Chandeleur Sound and the eastern part of Mississippi Sound. Within the Biloxi Marsh however, the change is rather small, perhaps due to the short simulation period.

Looking at Figures 19 and 20, on the other hand, we see large differences in eh standard deviation, which can explain areas that are more dynamic. For instance, the small and rather insignificant change up-estuary as a result of diversion in Breton sound directly can be explained easily by direct comparison of Figure 19 and 20, where we see that these two images are very similar. Similarly, the freshwater diversion at Violet (through Bayou Dupre) shows to be unaffected by additional input into Breton Sound. This is explained by the similar standard deviation within the Biloxi Marsh area between Figure 19 and 20. Finally, as expected, and as shown to some extend in the average salinity field from the Figure 17 and 18, the eastern portion of Mississippi Sound, as well as Breton and Chandeleur Sound, and the eastern portion of the Biloxi Marsh, can be affected by lower salinity in Breton Sound as shown in Figure 20.

Although most of this change and variability can be explained by either tidal induced circulation, or freshwater induced circulation as a result of diversion, the large variation we see in Figure 20, can also be explained relative to the initial condition. Since the initial condition is somewhat higher in salt than the future and imposed boundary condition, this part of the domain responds to the forcing by rapidly mixing the forced salinity inside the domain. This maybe somewhat unrealistic, and will be largely a function of the initial condition. However, the model predicts that this area will respond to a lower salinity in Breton sound, and would in fact given sufficient time reach within the area of interest.

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Time-series results of the evolution of the salinity field during the longer simulation of 45 days, starting from 1,000 cfs and going through 7,000 cfs is shown in sequential plots in the Appendix as Figure 22 through Figure 27. The figures show the evolution of the salinity field as a function of time. Figure 21, on the other hand, shows the evolution of an instantaneous surface salinity at two locations, one in the MRGO channel upstream of Bayou La Loutre, and the other in the center of the Biloxi Marsh. The figure shows that initially, when the diversion in the system is of the order of 1,000 cfs using a 50/50 split between Bayou Bienvenue and Bayou Dupre, the instantaneous salinity at both locations is dominated by tidal induced circulation. Both signals respond to tidal forcing by showing diurnal oscillations. The salinity within the MRGO (green solid line) although small, shows some response to diurnal oscillation. Since this is so small and cannot be seen with the salinity time-series, we demonstrate this by showing the gradient term. This is demonstrated by the use of the time-derivative for salinity, DS/Dt, shown in the figure as blue solid line. As we can see, the gradient term does respond to diurnal oscillations during the low diversion flow but they are rather negligible. The gradient term however, shows a rather rapid response once the flow starts to rise to 7,000 cfs, and the majority of the flow at this point flows down this area. This rapid decline in the gradient term DS/Dt, is also reflected in the actually instantaneous salinity by a slow reduction to nearly freshwater values. The continuing slow reduction of salinity then makes this term smaller with time, to an eventual zero value when the salinity no longer changes when it reaches a 0.2 value. The absence of the diurnal oscillation in this term also deems this area now dominated by river-water rather than tides.

In the Biloxi Marshes however, despite the obvious decline in instantaneous salinity as a result of the diversion (black trend line, Figure 21), there seems to be a slightly different response. There is an obvious phase or lag in the system. For instance, during the early part of the simulation, the area is responding only to tidal forcing, as the local average or trend is rather a horizontal line up to hour 240 and above. By this time, the diversion has already been operating and is fully rampd to 7,000 cfs, but has not produced a measurable change in this area. Subsequently, and coinciding with a neap cycle, the system responds with a sudden reduction in the salinity, verifying the small dominance of river-induced circulation in the absence of strong tidal induced flow. By this time, the diversion flow is fully developed, and has reached this area, hence form this point onwards, the declining trend in the salinity appears to be linear in time.

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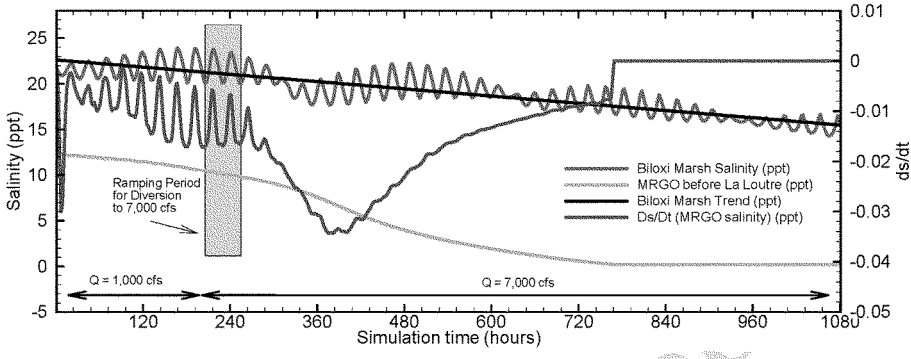

Figure 21 Instantaneous surface salinity for simulation optf, showing the salinity in the central Biloxi Marsh)red line) and within the MRGO channel upstream of Bayou La Loutre (green solid line).

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CONCLUDING REMARKS

The model simulations showed that wind stress resulting from frontal weather can produce high frequency variability in the Pontchartrain Basin within just three days of the application of the wind. In simulations of only 5 days with half a day of spin up time, the model predicted double the variability as measured by the standard deviation evaluated at each node based on the hourly model output. The model also predicted that when only using the averaged salinity field, one would tend to underestimate this variability and high frequency response, primarily because the response is rapid. The model also predicted that in longer simulations, the high frequency response would tend to be smaller due to the natural tendency of wind to cancel this response. This is largely a function of wind climate, basin geometry, duration and intensity of each event, and he relaxation scale of the basin.

Finally, a longer simulation of a diversion from 1,000 cfs to 7,000 cfs showed that the MRGO-La Loutre pathway is largely dominated by tidal currents when the flow is near the low 1,000 cfs magnitude, but when the flow is near the 7,000 cfs, the basin in this area is dominated by the diversion flow. Furthermore, the model predicted a lag time of the order 4-7 days for this flow to reach the Biloxi Marsh area through this direct route. It is emphasized that for this simulation the Lake Borgne connection to the MRGO was closed, which further ensures that the conveyance is maximum through this pathway. The model also showed that the Biloxi Marsh area is largely tidally influenced when the flow at Violet is near 1,000 cfs. Although tidal flows continue to cause strong siurnal oscillations in the salinity, when the flow reaches 7,000 cfs and dynamic equilibrium after the lag period, there is a steady decline in the salinity (Figure 21, solid black line).

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APPENDIX

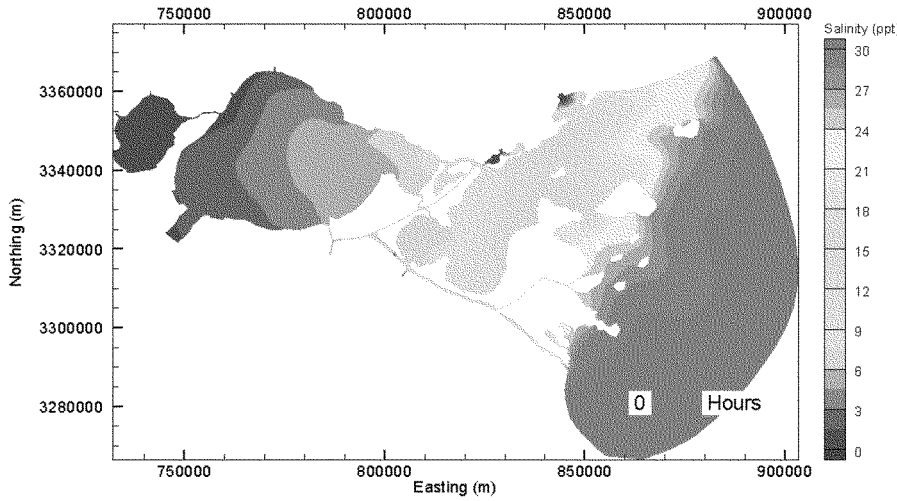


Figure 22 Model simulated depth-integrated salinity at day zero (case optf)

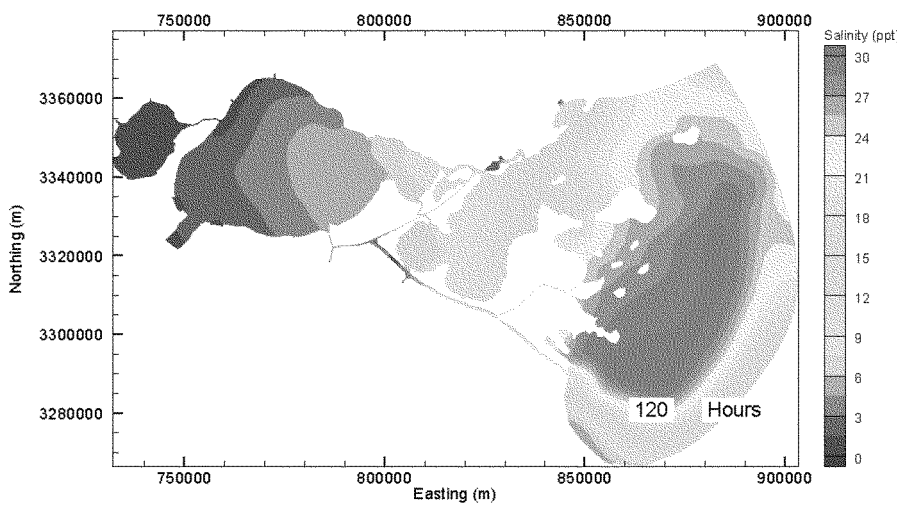


Figure 23 Model simulated depth-integrated salinity at day 10 (case optf)

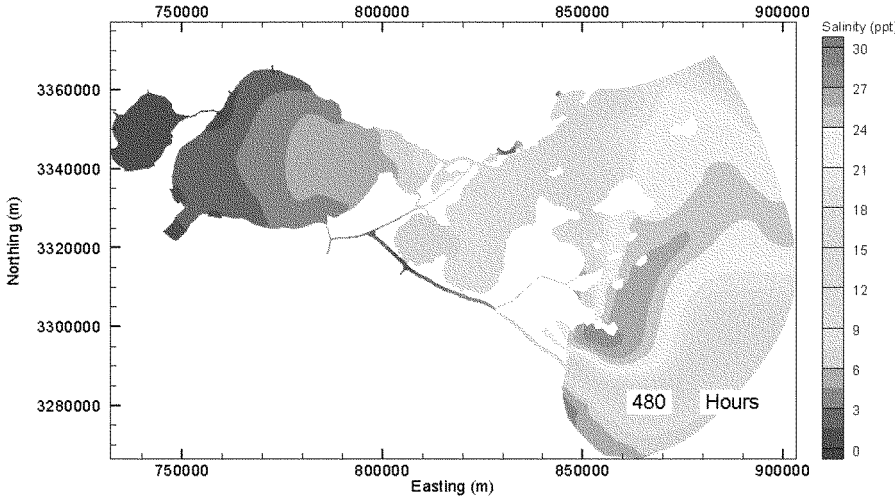


Figure 24 Model simulated depth-integrated salinity at day 20 (case optf)

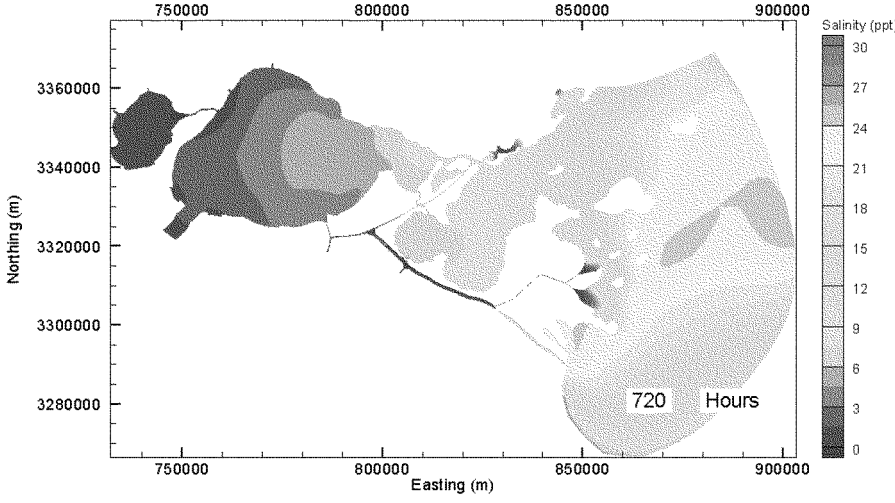


Figure 25 Model simulated depth-integrated salinity at day 30 (case optf)

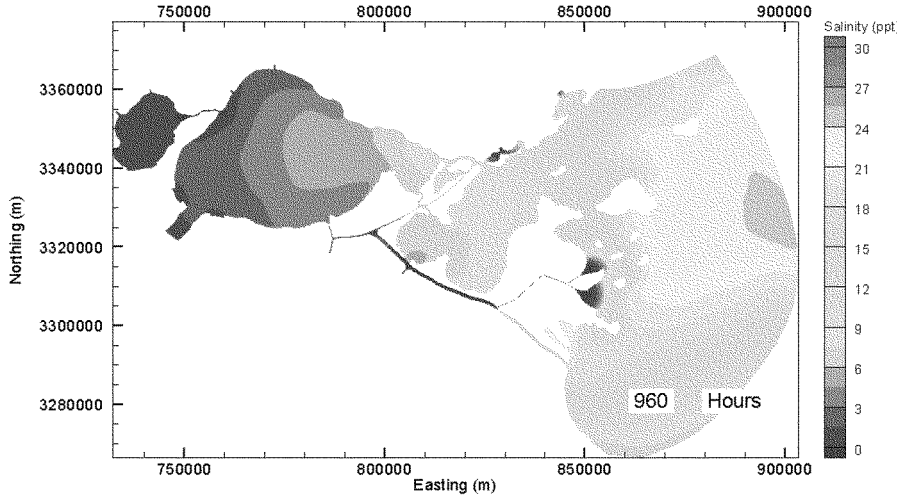


Figure 26 Model simulated depth-integrated salinity at day 40 (case optf)

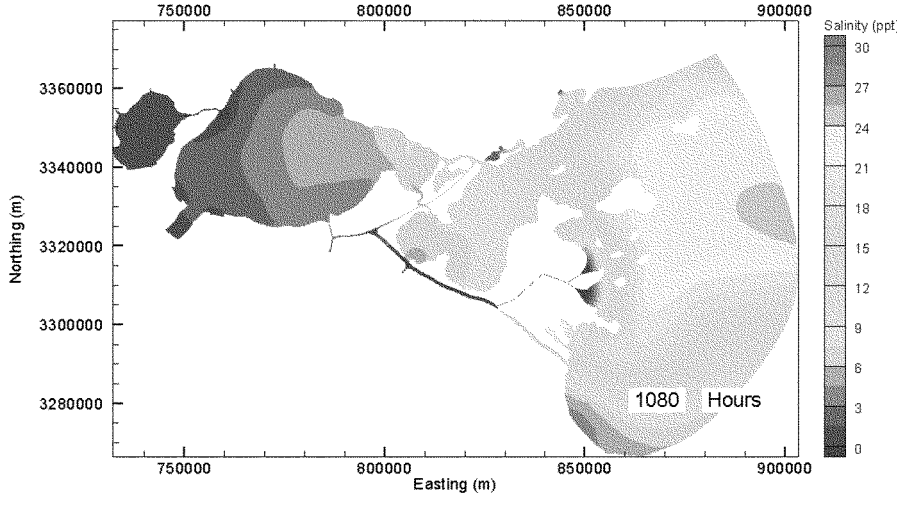


Figure 27 Model simulated depth-integrated salinity at day 45 (case optf).

Appendix I

Preliminary Design of Structures and Channel for Diversion near Violet

Preliminary Considerations and Design

In terms of channel configuration, diversions into and through the CWA will require four components. First, there must be a structure through the Mississippi River Levee; second, a sediment basin will trap particulates from the water; third, there must be sufficient conveyance through the CWA; and fourth, exit structures in the Chalmette levee must be capable of passing the diversion to the MRGO within acceptable impacts to the CWA and infrastructure. These four components will be addressed from the downstream end of the system.

There are two existing structures in the Chalmette levee adjacent to the MRGO. These are the Bayou Bienvenue Control Structure and the Bayou Dupre Control Structure. Both of these structures are 56 feet wide with a sill depth of 10 feet. The Violet Canal and Bayou Dupre connect the Violet Siphon location directly to the Bayou Dupre Control Structure. There is a small hydraulic connection via the back levee canal between Bayou Dupre and Bayou Bienvenue, such that some water introduced into the Violet Canal will make its way out the Bayou Bienvenue structure. Water in the Violet Canal can also migrate into small channels and low points in the CWA.

The size of the two control structures limits the amount of flow that can be diverted. A Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) study conducted by EA Engineering, Science, and Technology for the National Marine Fisheries Service (EA Engineering) showed that increased diversion amounts using the existing channels and openings in the Chalmette levee could raise stages in the CWA to where the marsh would be inundated and potentially impact infrastructure.

Preliminary calculations to understand the size of structure and canal necessary to move various flows through a near Violet Canal diversion were performed. A river stage of 5.35, which is the 25% exceedence stage value for this segment of the river, is assumed for the following calculations. Various marsh surface water elevations are provided to give a range of channel configuration and estimated structure requirements. For this estimate box culverts are used and the channel is estimated at 12 ft deep with 3:1 side slopes. Table 1 provides relative information on various configurations.

Table 1. Hydraulic Design Estimated Values.

River Stage = 5.35				
Flow (cfs)	**River Levee Culverts**	**Channel Width (ft)**	**Chalmette Levee Culverts**	**Marsh Surface Elevation**
5,000	3 – 12' x 12'	225	4 – 13' x 15'	1.8
5,000	3 – 13' x 13'	250	3 – 13' x 13'	2.8
6,000	4 – 11' x 13'	225	4 – 13' x 15'	2.0
6,000	4 – 12' x 13'	275	4 – 12' x 13'	2.8
7,000	4 – 12' x 13'	300	5 – 13' x 15'	2.0
7,000	4 – 13' x 14'	300	5 – 13' x 14'	2.8
10,000	6 – 15' x 15'	275	6 – 13' x 15'	1.0
10,000	6 – 15' x 15'	275	6 – 13' x 15'	2.4
15,000	9 – 15' x 15'	400	9 – 13' x 15'	2.4
20,000	12 – 15' x 15'	550	12 – 13' x 15'	2.4

Channel Design for 7,000 cfs Flow

The channel and structures for the diversion are designed to deliver 7,000 cfs during the months of April and May. This design uses a head elevation in the River that could be reasonably expected during those months. The 25% non- exceedence stage in the river is reasonable design criterion for preliminary design computations. This equates to the river stage being at or above that value 75% of the time. An analysis of the last fifty years of flow and stage data showed that the 25% non-exceedence value of the monthly average stage at the Algiers lock for the month of May was a value of 5.35 feet (NAVD88 2004.65). Assuming the marsh elevation outside of the back levee at the MRGO is plus one foot (NAVD88 2004.65), there is 4.35 feet of head loss presently available to drive the flow through the structures and channels.

There are numerous ways to route the design flow of 7,000 cfs through the Central Wetlands. As a first approximation, a straight channel with confined flow was investigated using the following assumptions: culverts at the river would be 500 feet in length (i.e. long enough so that the Mississippi River levee as well as the river road and the railroad could pass over them); the culverts under the back levee would be 200 feet in length (i.e. long enough to allow them to pass under the levee); and the length of the direct channel between the two culverts is approximately 21,000 feet. It is further assumed that the velocity head (energy) through the culverts is lost due to using a settling basin downstream of the culvert at the Mississippi River and again with the deep water of the MRGO downstream of the second set of culverts. The channel size was manipulated so as to maintain a velocity of two feet per second with a 7,000 cfs flow. The channel design is a twelve foot deep channel with one on three side slopes; a 250 foot bottom

width; and an almost imperceptible gradient of one foot over the 21,000 foot length of the channel. The five culverts at the River are sized as 13 feet by 13 feet gated concrete box culverts. The culverts at the east end of the channel will be five 13 feet by 12 feet gated culverts. The head loss through the MRGO culvert would be 1.58 feet.

This configuration will satisfy the need to route the proposed amount of water through the Central Wetlands. The channel dredging for this proposed configuration will involve the removal of an estimated 2.7 million cubic yards of material.

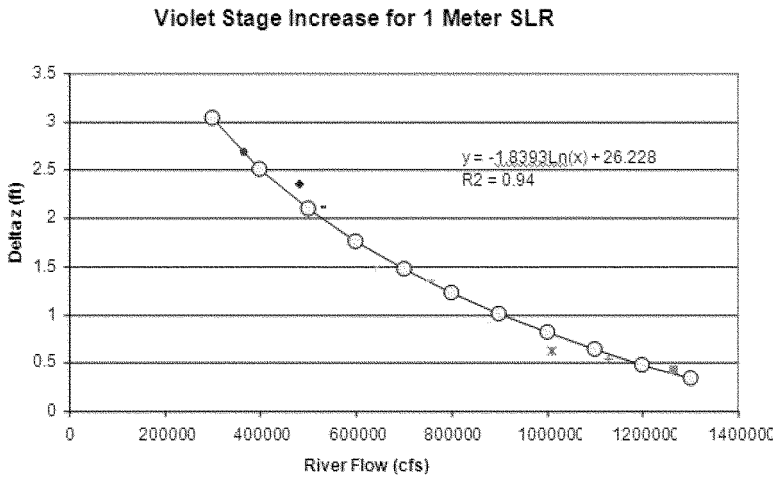
The design configuration given above uses a relatively small width channel so that the velocity for the 7,000 cfs would be slightly greater than 2 feet per second, thus reducing the potential for sedimentation. The calculations also assume a sedimentation basin at the head of the channel (i.e. the velocity head through the River culverts is entirely lost in the sedimentation basin). This channel could be constructed so that the 12 foot depth is below the marsh elevation and thus dikes confining the flow would not be required. By slightly throttling the exit culverts the water elevation in the channel could be adjusted to where it overflowed onto the marsh.

For the background flow of 1,000 cfs, the gates at the back would be adjusted (or totally closed) so that flow is forced to go overland toward the Bayou Dupre and Bayou Bienvenue structures. If all of the flow were forced to exit through these two structures there would be an average seaward flow of slightly less than one foot per second in the structures (56 feet wide by 10 foot deep).

Channel Design for 7,000 cfs Flow Considering Sea Level Rise

This section considers Sea-level rise as a component of the design. With one meter of relative sea level rise, the receiving waters' level in the Central Wetlands would increase by one meter. The stages in the Mississippi River at the diversion site would not increase by the same amount due to variations of the backwater response with different flow rates.

A HEC-RAS model of the river from Tarbert Landing to the Gulf including all of the passes was used to determine the increase in stage at the project site with a one meter increase in the Gulf of Mexico water level. Figure 1 shows the modeled increase in stage in the River at the project site as a function of river flow. To use this plot it is necessary to determine the flow that corresponds to a stage of 5.35 feet. Since a stage discharge rating curve is not available, the best option is to determine the 25% non-exceedence flow and make the assumption that this flow corresponds to the 25% non-exceedence stage. The month of May is the critical month since flows in the River are generally less in May than in April.



Using the DSSMATH statistical analysis package to analyze 50 years of river flow data from January 1, 1959 to December 31, 2008, the monthly average 25% non-exceedence flow for the month of May is 503,000 cfs. Using this flow value in the equation for the curve in Figure 1, the stage increase at the project site is 2.09 feet or a water level of 7.44 feet and the receiving waters are now 4.28 feet generating a head of 3.16.which is a 1.19 foot difference from the one meter increase in the receiving area outside of the Central Wetlands area. Thus, 3.16 feet of head is the design criteria to drive the 7,000 cfs flow in the month of May.

By considering sea level rise, the design for future conditions would be five 14 feet by 14 feet gated concrete box culverts at the River and seven 12 feet by 12 feet gated culverts under the MRGO levee.

Sediment Basin Design

Incorporating a sediment basin into the design of the conveyance channel reduces the velocity head and allows for deposition of sediments at a convenient location for removal and maintenance. This feature would decrease shoaling in the conveyance channel which could negatively impact flow. Sediment can be removed from the basin once filled. The design of a sediment basin balances the need for the basin to be large enough to reduce incoming velocities and the need to minimize the cost of construction.

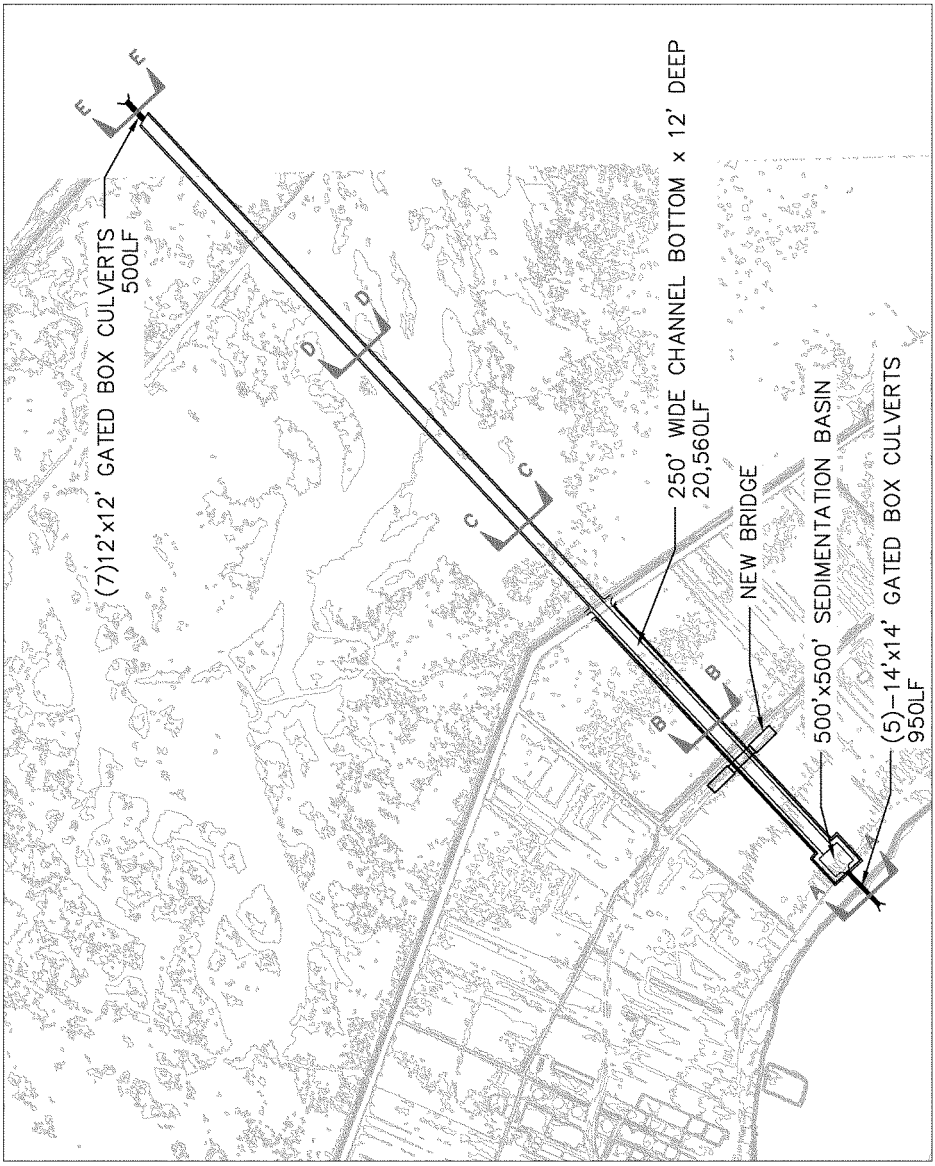
A sediment basin is planned immediately downstream from the culverts at the Mississippi River levee, with a short transition channel flaring out from the Culvert to the basin. As a first approximation, a basin width was chosen by doubling the conveyance channel bottom width of 250 ft. The basin length was selected to be equal to the width. The basin depth was selected as one foot deeper than the 12 ft deep conveyance channel. Thus the sedimentation basin dimensions are a 500 foot bottom width, 500 ft length, and 13 ft depth. Assuming one on three side slopes, the cross sectional area of the basin would be approximately 7,000 sq ft yielding a velocity nearly 1.0 ft/sec per second through the sediment basin. With a length of 500 ft, it would take 500 sec for the 7,000 cfs flow entering the basin to traverse the

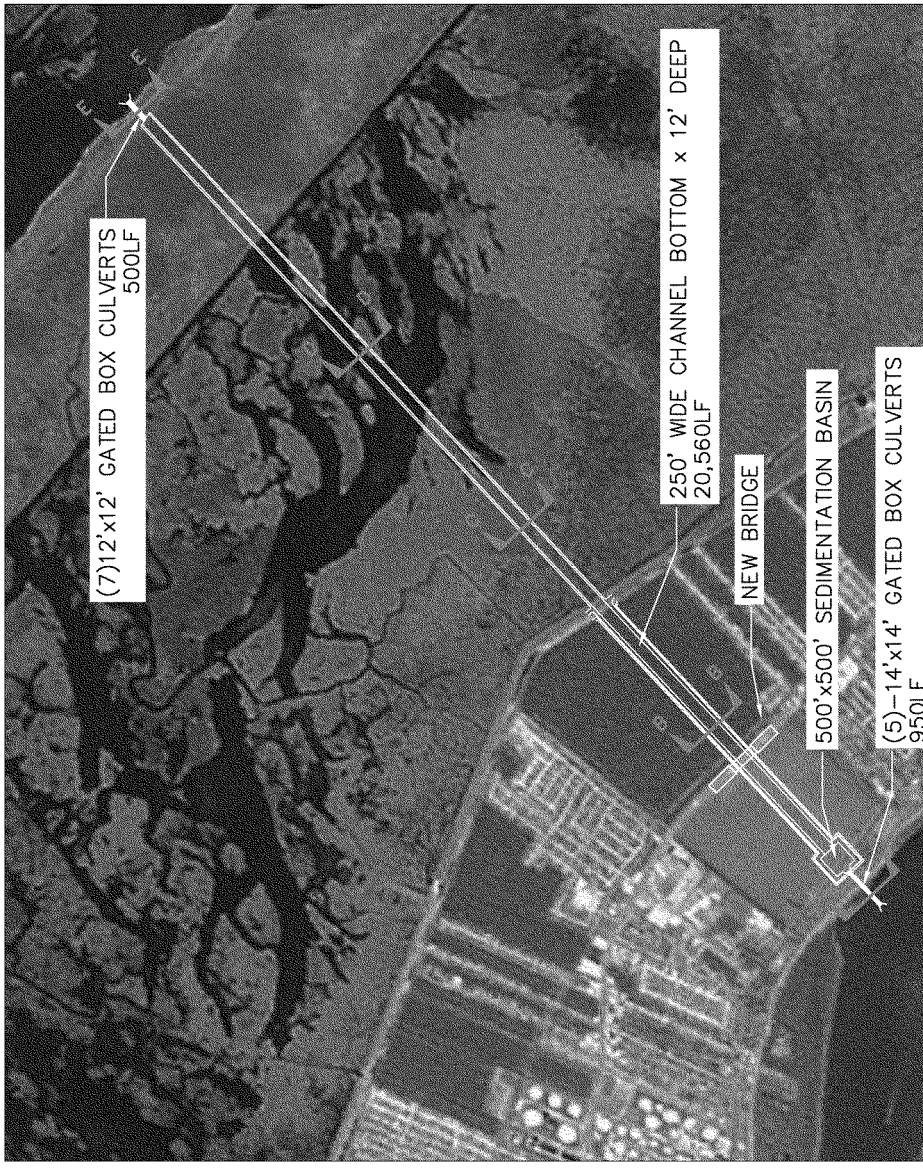
length of the basin and would allow for settling of particles with a diameter greater than 0.09 mm to 0.15 mm or those particles with a settling velocity greater than 0.8 cm/sec.

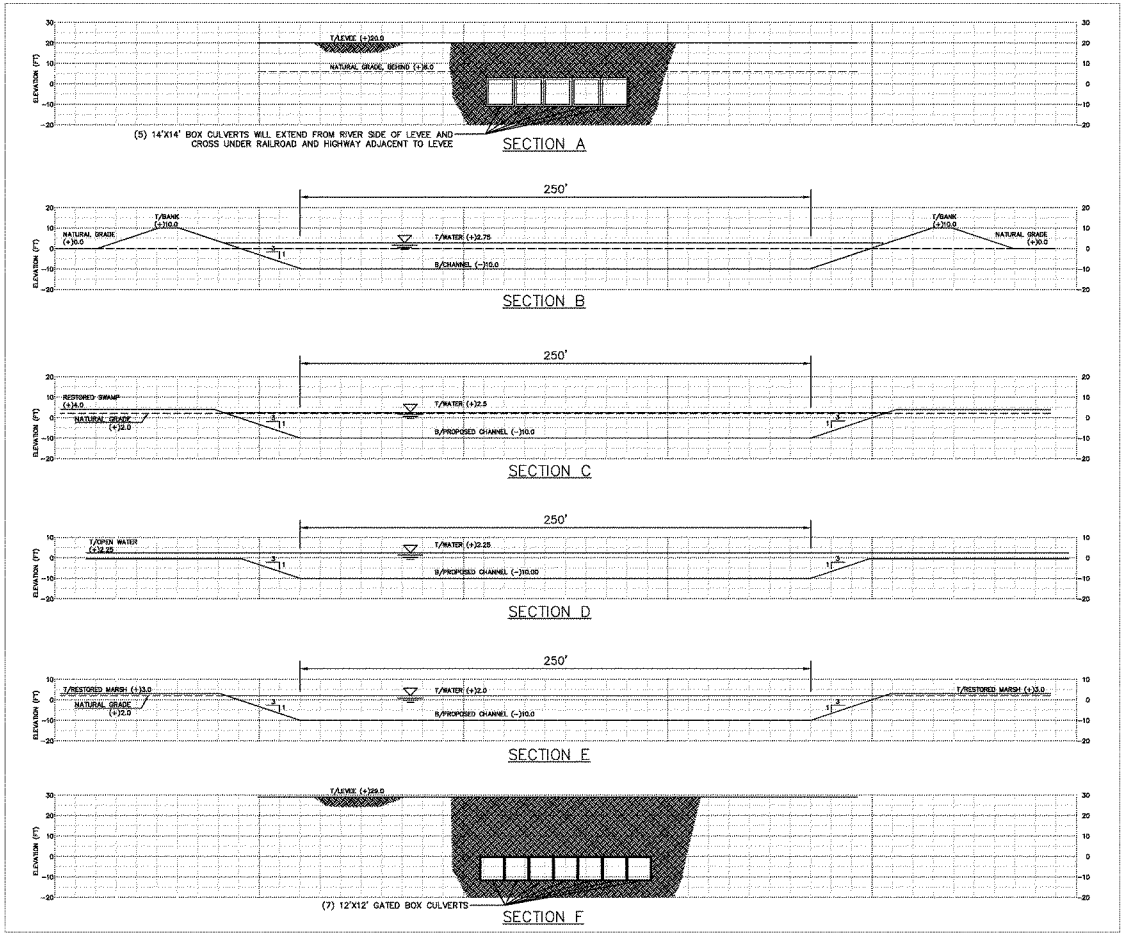
The UNO mass balance modeling effort indicates that approximately 600 tons of sand would be diverted per year. If this sand is assumed to be 108 pounds per cubic foot, then the 600 tons spread evenly over the 500 by 550 foot sedimentation basin would represent a deposition rate of 0.53 inches per year. At this rate, the basin would be filled in approximately 22.5 years.

Reference:

EM 1110-2-1100. Coastal Engineering Manual. U.S. Army Corps of Engineers. 2002.


(7)12'x12' GATED BOX CULVERTS
500LF
250' WIDE CHANNEL BOTTOM x 12' DEEP
20,560LF
NEW BRIDGE
500'x500' SEDIMENTATION BASIN
(5)-14'x14' GATED BOX CULVERTS
950LF
A
B
C
D
E


(7)12'x12' GATED BOX CULVERTS
500LF
250' WIDE CHANNEL BOTTOM x 12' DEEP
20,560LF
NEW BRIDGE
500'x500' SEDIMENTATION BASIN
(5)–14'x14' GATED BOX CULVERTS
950LF


T/LEVEE (+)20.0
NATURAL GRADE, BEHIND (+)14.0
ELEVATION (FT)
(5) 14'X14' BOX CULVERTS WILL EXTEND FROM RIVER SIDE OF LEVEE AND CROSS UNDER RAILROAD AND HIGHWAY ADJACENT TO LEVEE
SECTION A
250'
T/BANK (+)10.0
NATURAL GRADE (+)9.0
T/WATER (+)2.75
B/CHANNEL (-)10.0
SECTION B
250'
RESTORED SWAMP (+)4.0
NATURAL GRADE (+)2.0
T/WATER (+)2.5
B/PROPOSED CHANNEL (-)10.0
SECTION C
250'
T/OPEN WATER (+)2.25
T/WATER (+)2.25
B/PROPOSED CHANNEL (-)10.00
SECTION D
250'
T/RESTORED MARSH (+)3.0
NATURAL GRADE (+)2.0
T/WATER (+)2.0
B/PROPOSED CHANNEL (-)10.0
SECTION E
T/LEVEE (+)29.0
(7) 12'X12' GATED BOX CULVERTS
SECTION F

Appendix J

Impacts to Navigation and Potential for Shoaling

The MRGO Ecosystem Restoration Plan Feasibility Study is being conducted to comply with the Water Resources Development Act (WRDA) of 2007 (P.L. 110-114) Section 7013 to develop a plan to "restore the areas affected by the navigation channel" that considers "diversions of fresh water to restore the Lake Borgne ecosystem." Investigations under Section 7013 have identified that a freshwater diversion at or near Violet, Louisiana is needed to achieve ecosystem restoration goals. Section 3083 of the 2007 Water Resources Development Act (WRDA) authorizes the diversion of freshwater at or near the Violet Canal, Louisiana, for the purposes of reducing salinity in the western Mississippi Sound, enhancing oyster production, and promoting the sustainability of coastal wetlands. Section 3083 states that the freshwater diversion must be designed to meet, or maximize the ability to meet, the salinity levels identified by Chatry et. al, 1982. A Salinity Working Group for the MRGO Ecosystem Restoration Plan validated the use of the Chatry targets for ecosystem restoration in the study area. As part of the MRGO Restoration Feasibility Study, the potential of impacts to navigation and shoaling as a consequence of the proposed freshwater diversion in the vicinity of Violet, Louisiana were evaluated.

Impacts to Navigation

No impacts to the Mississippi River Deep Draft Navigation Channel are anticipated from the proposed diversion. The river is approximately 2,250 feet in width at the location of the proposed diversion. The authorized width of the navigation channel is 750 feet. Thus, 1500 feet of the river is outside of the authorized navigation channel. Assuming that the channel is twice as far from the inside of the bend as from the outside of the bend, the channel is at a minimum of 500 feet from the diversion location. When the diversion is operated at peak flow, currents would be expected on or near the batture but not in the deep draft navigation channel. Further assuming radial flow into the diversion structure and an average flow depth of 20 feet for out of channel locations, the average current contribution 500 feet from the structure would not exceed 0.2 feet per second. This current magnitude is insignificant in a river that has mean currents up to 7 or 8 feet per second. In addition, the peak flow proposed is slightly less than the peak flows for the Davis Pond and Caernarvon diversions. Neither of these two projects has reported impacts to the navigation channel.

Shoaling in the River

The concern is that by diverting flow, the flow in the main channel of the River will be reduced and thus the equilibrium cross-section in the River will become smaller to accommodate the smaller flow. This cross section adjustment could result in shoaling. To better assess the issue of flow reduction, fifty years of Tarbert Landing flow records were averaged for each day of the year and are presented in Figure 1 below.

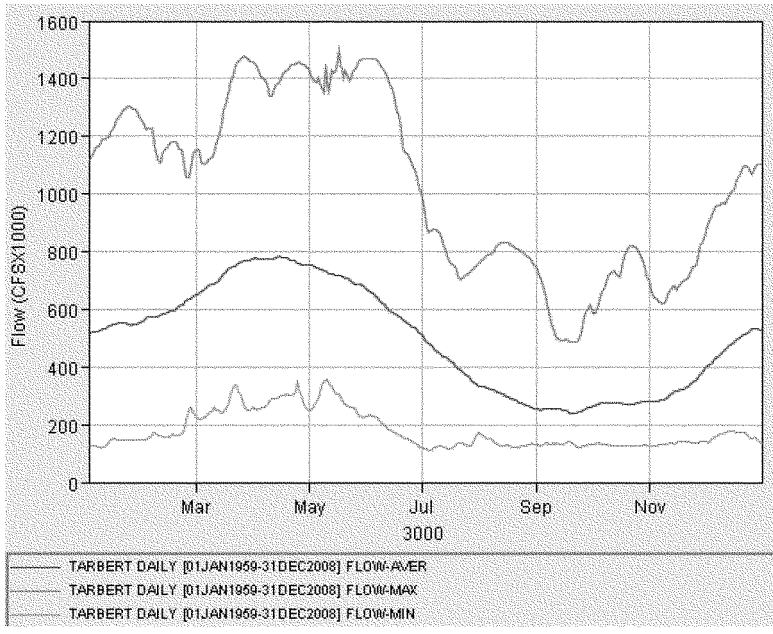


Figure 1: Average, maximum, and minimum flows in the lower Mississippi River from fifty years of daily flow data (Note that 3,000 is a dummy date)

The river cross section is generally shaped by extreme flows and the reduction in flow due to the diversion is extremely small. The proposed operation scheme selected to meet the salinity target in May is a diversion of 7000 cfs in the months of April and May. This proposed diversion flow is about one percent of the average river flow of 700 to 800 thousand cfs. However, diversion flow in the months of March and June immediately preceding and after the 7000 cfs flows will be 1000 cfs when the average flow in the river is around 600 thousand cfs. This represents less than 0.2% of the average river flow and is much less than the percentage error in the measurement of flow in the river.

The maximum flow for this proposed diversion is less than the maximum flows for the existing Davis Pond Diversion (10460 cfs) and the Caernarvon Diversion (8000 cfs). Neither of these projects has reported any perceived shoaling impacts due to their operation.

Based on the small percentage of river flow being diverted and the similarity with the existing Davis Pond and Caernarvon diversions, it is safe to conclude that there will be an imperceptible changes in the river cross section and minimal, in any, shoaling.

ANNEX 2

BORROW PIT ASSESSMENT

An Assessment of the Impacts of Borrow Pits Proposed in Lake Borgne on Local Wave Climate Using ADCIRC and SWAN Hydraulic Modeling

DRAFT

Max Agnew
DRAFT 1-24-2012

Executive Summary

A wave model of Lake Borgne was developed to determine the impact on wave climate due to the excavation of several borrow pits. The material dredged from the borrow pits is to be used for marsh and swamp restoration and nourishment for the MRGO Ecosystem Restoration Plan (USACE, 2011). An unstructured SWAN model was chosen to provide high resolution wave calculations in the area of interest. For the with and with-out borrow pit scenarios, simulations were performed for 24 wind directions, with 4 different windspeeds, and two water levels. This set of simulations is meant to provide an estimate of the impact for "normal" or "non-storm" conditions, where waves are locally generated by wind. A total of 120 simulations were performed for the with and without borrow pit scenarios.

Simulation Set	Wind Speed (mph)	24 Wind Directions (Nautical deg.)	Water Level (ft. NAVD88)	Number of Simulations
W20	20	[0:15:345]	0.92	24
W30	30	[0:15:345]	0.92	24
W40	40	[0:15:345]	0.92	24
W50	50	[0:15:345]	0.92	24
W30H	30	[0:15:345]	2.50	24

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An additional ADCIRC+SWAN simulation of Hurricane Gustav was conducted to show the impact of the borrow pits for a recent high impact storm. Gustav has been chosen due to the unprecedented amount of observational data, and strong validation of the modeling. Peak water level, water velocity, significant wave height were determined for the with and without project conditions.

Very little difference in significant wave height and mean wave period was attributed to the proposed borrow pits along the Lake Borgne shoreline for the simulated "non-storm" conditions. We have calculated a 0 to 4% increase in significant wave height, and a 0 to 3% increase in mean wave period along the shoreline. Within the borrow pits, there can be substantial increases: 3 to 39% increase to significant wave height and up to a 10% increase in mean wave period.

With the full-scale ADCIRC+SWAN simulation of hurricane Gustav, very little change in peak surge elevation was observed. The perturbation to the bottom bathymetry is not enough to significantly alter surge levels in the region of interest. However, the change in peak velocity surrounding the borrow pits is significant. We see a change of up to 0.7 ft/s at the Lake Borgne shoreline, which could be significant in terms of erosion and deposition patterns. The simulation of hurricane Gustav shows relatively large significant wave heights forming in Lake Borgne, at about 5.5 ft with a depth of about 18.0 ft. When we add the borrow pits and re-run the simulations, we see a relatively large increase in significant wave height within the borrow pit areas, at about 10 to 20%, or almost 1.0 ft higher. For this simulation, the larger waves that are developing within the borrow pit areas do not propagate far from the borrow pit areas, apparently due to depth limitation. The largest increase is about 0.2 ft, a 3% increase, at point LB15. Figure 2.6 displays the location of the model output locations.

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1 Introduction

1.1 Objective

The objective of the modeling is to determine impact of the Lake Borgne borrow pits on wave climate for normal and storm conditions.

2 Methodology

2.1 Models

To assess normal conditions (non-hurricane), the numerical model SWAN (Simulating WAves Nearshore) has been implemented. SWAN is the most widely used computer model to compute irregular waves in coastal environments, based on deep water wave conditions, wind, bottom topography, currents, and tides. SWAN explicitly accounts for all relevant processes of propagation, generation by wind, interactions between waves and decay by breaking and bottom friction. To assess normal conditions, we have assigned a static global mean water surface value, and assumed zero velocity throughout the domain. Twenty four different wind directions, 4 different wind-speeds, and two global water surface elevations have been modeled for the with and with-out project condition.

To access hurricane conditions, the coupled version of ADCIRC+SWAN has been implemented. The coupled version of ADCIRC+SWAN solves for the free surface water elevation, currents, and wave conditions. One ADCIRC+SWAN simulation of hurricane Gustav has been conducted to show the impact on surge and waves for a high impact storm. Gustav has been simulated with and without the proposed borrow pits. Gustav has been chosen due to the unprecedented amount of observational data, and strong validation of the ADCIRC+SWAN hindcast modeling (Dietrich, 2010).

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2.2 Bathymetry

The SL16 ADCIRC mesh was used as the base condition for the SWAN mesh. The bathymetric information in the SL16 mesh comes from a variety of sources, including USACE and NOAA surveys. Figure 2-1 displays the SL16 bathymetry for the entire mesh domain, which includes all of the Gulf of Mexico, Caribbean, and the Atlantic Ocean to longitude -60. With over 5 million nodes, SL16 is one of the more recent ADCIRC meshes developed at the University of Notre Dame for hurricane hindcasting.

Unstructured meshes allow high resolution in areas of interest, thereby decreasing the overall number of computational elements. Unstructured meshes also provide better representation of irregularly shaped boundaries than do conventional regular grids. Adcirc pre-processing software know as Gridscope was used to extract a mesh for the area of interest. This extracted mesh can also be interpreted by SWAN for simulation of waves only. Running SWAN on the extracted mesh improves efficiency because we are only modeling the area of interest. The extracted mesh covers all of Lake Borgne out to the Mississippi Sound. Figure 2-2 displays the SL16 bathymetry for the area of interest. The proposed borrow pit bathymetry was incorporated into the extracted mesh. Figure 2-3 displays the modified bathymetry that includes the proposed borrow pits. The borrow pits will be 12 to 17 feet below the existing condition mudline.

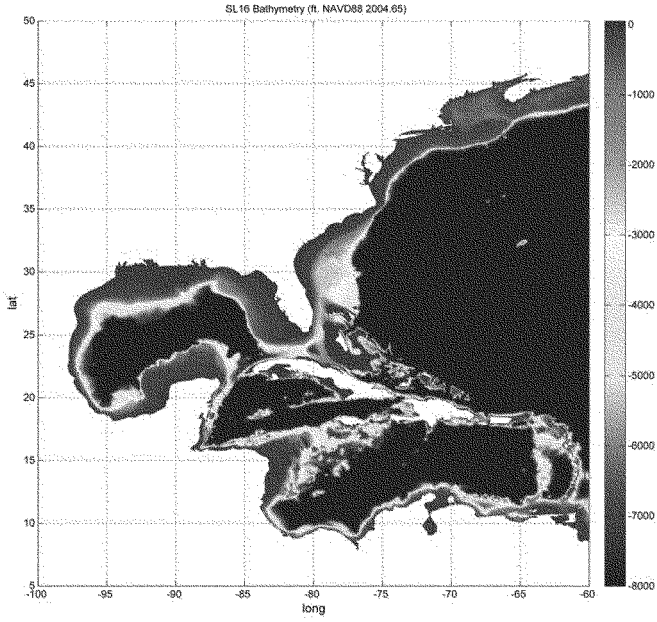

Figure 2-1 SL16 Full Scale Bathymetry (ft. NAVD88 2004.65)

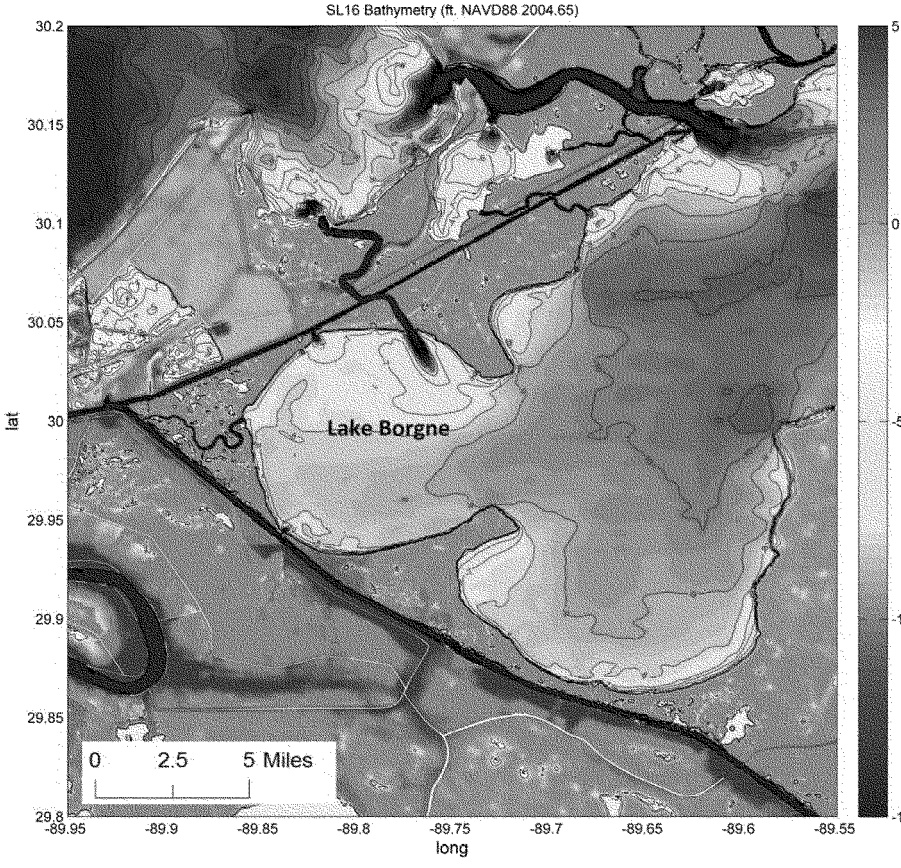

Figure 2-2 SL16 Bathymetry in Lake Borgne

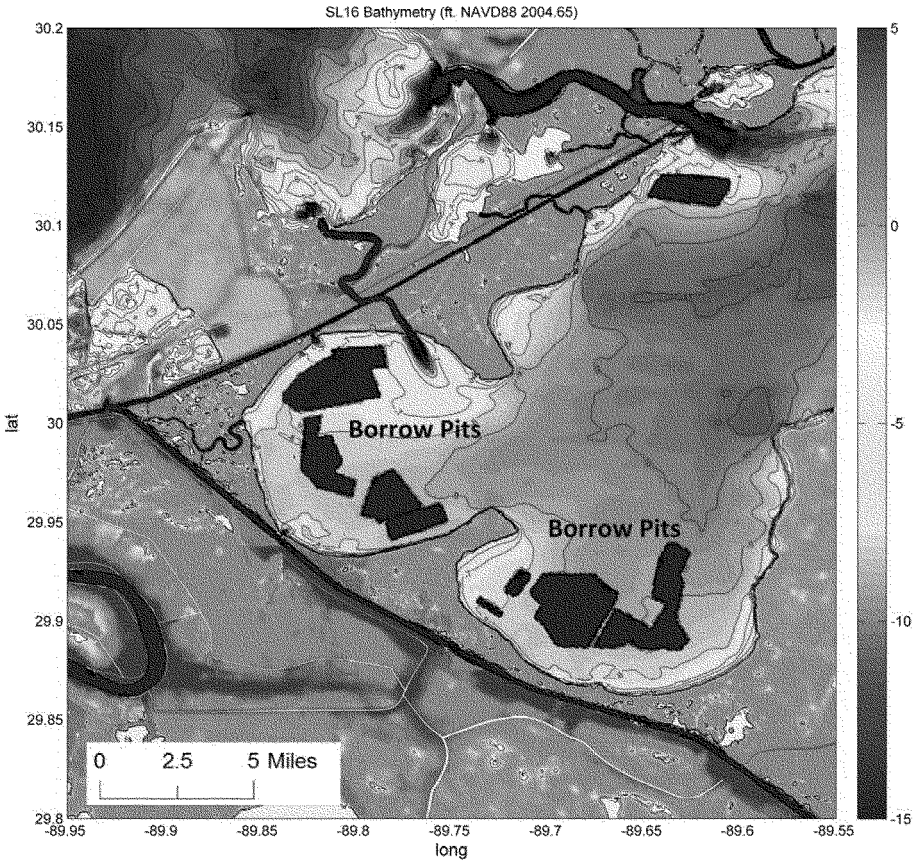

Figure 2-3 SL16 Bathymetry in Lake Borgne with Borrow Pits Bathymetry.

2.3 Boundary conditions

Boundary conditions were not applied to the extracted mesh because waves are assumed to develop locally during normal non-storm conditions.

2.4 Friction

Friction was not applied in the SWAN modeling for non-hurricane swan modeling. However, for the simulation of Hurricane Gustav, the coupled version of ADCIRC+SWAN utilizes friction from the ADCIRC fort.13 nodal attribute file.

2.5 Numerical settings

The solution of the equations in SWAN requires an iterative approach. The model was set to stop iterating when wave heights and peak wave periods in 98% of the active nodes do not change with more than 2%, when compared to the previous iteration. Due to time constraints, all simulations were set up to conduct a maximum of 25 iterations. However, the model runs met the stopping criterion before 25 iterations.

2.6 Points of Interest

SWAN allows the user to define a set of points within the mesh domain at which to record and tabulate detailed model output. Figure 2-4 shows the locations of the selected output locations. A series of points, designated LB1 to LB40, were assigned outside of the borrow pits along the Lake Borgne shoreline to capture the impact of waves that propagate out of the borrow pit areas. A separate series of points, designated as P41 to P66, were assigned to show the impact to wave climate within the borrow pits. Table 2-1 contains the longitude and latitude of each point, as well as the bathymetric elevation for the with and without-borrow pit scenarios.

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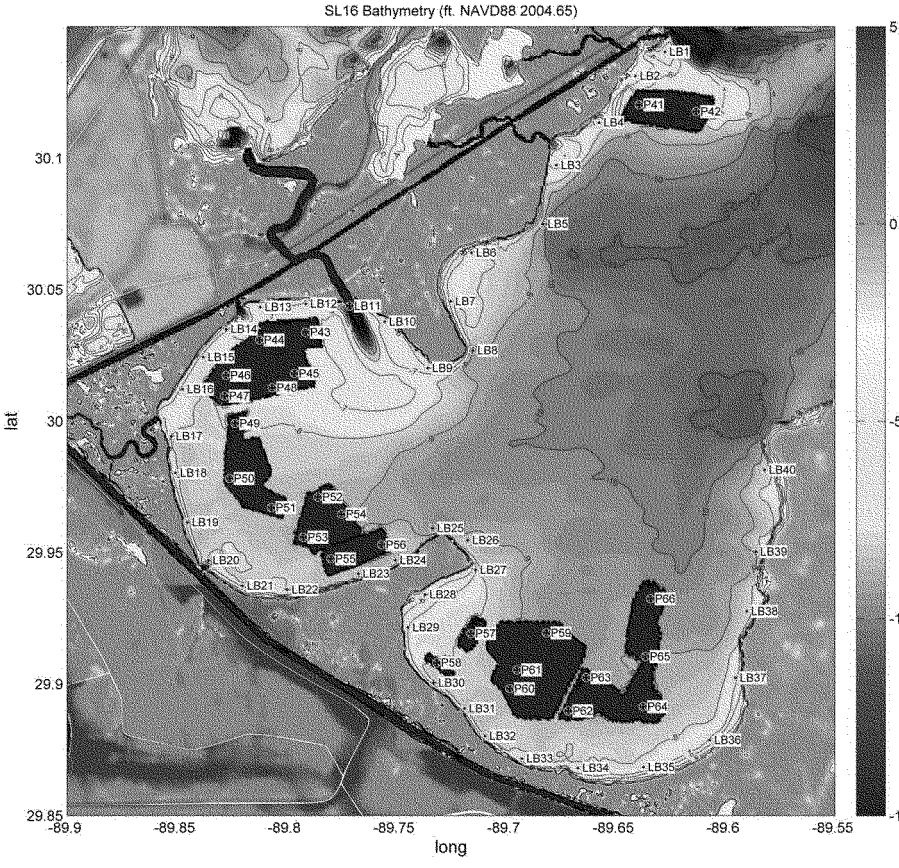

Figure 2-4 SWAN and ADCIRC+SWAN Model Output Locations

Point ID	Longitude	Latitude	Bathymetric Elevation (ft. NAVD88)	Bathymetric Elevation with Borrow Pits (ft. NAVD88)
LB1	-89.6276	30.14044	-6.73	-6.73
LB2	-89.6411	30.13132	-4.53	-4.53
LB3	-89.677	30.09734	-6.77	-6.77
LB4	-89.6576	30.11357	-7.17	-7.17
LB5	-89.683	30.07503	-9.22	-9.22
LB6	-89.7157	30.06412	-7.39	-7.39
LB7	-89.7252	30.04558	-7.56	-7.56
LB8	-89.7151	30.02692	-9.18	-9.18
LB9	-89.7357	30.02022	-6.13	-6.13
LB10	-89.7553	30.03782	-6.48	-6.48
LB11	-89.7712	30.04384	-34.35	-34.35
LB12	-89.7912	30.04465	-7.25	-7.25
LB13	-89.812	30.04338	-6.87	-6.87
LB14	-89.8276	30.03507	-6.66	-6.66
LB15	-89.8381	30.02439	-7.59	-7.59
LB16	-89.8475	30.01219	-7.41	-7.41
LB17	-89.8525	29.9943	-8.13	-8.13
LB18	-89.8506	29.98033	-7.60	-7.60
LB19	-89.8453	29.96157	-7.45	-7.45
LB20	-89.8358	29.94709	-8.82	-8.82
LB21	-89.8201	29.93744	-7.24	-7.24
LB22	-89.7998	29.93594	-8.10	-8.10
LB23	-89.7673	29.94199	-8.59	-8.59
LB24	-89.7504	29.94711	-8.70	-8.70
LB25	-89.7335	29.95933	-9.64	-9.64
LB26	-89.7175	29.95472	-8.69	-8.69
LB27	-89.7139	29.94343	-6.84	-6.84
LB28	-89.737	29.93411	-5.86	-5.86
LB29	-89.7447	29.92158	-6.97	-6.97
LB30	-89.733	29.90054	-7.58	-7.58
LB31	-89.719	29.89071	-7.94	-7.94
LB32	-89.7096	29.88031	-8.00	-8.00
LB33	-89.6928	29.87174	-7.27	-7.27
LB34	-89.6672	29.86816	-7.40	-7.40
LB35	-89.6373	29.86847	-7.53	-7.53
LB36	-89.6071	29.87878	-7.04	-7.04
LB37	-89.5955	29.90243	-7.19	-7.19
LB38	-89.5903	29.92771	-8.22	-8.22
LB39	-89.5861	29.95035	-8.92	-8.92
LB40	-89.5822	29.98147	-8.22	-8.22
P41	-89.6393	30.12032	-7.67	-19.67
P42	-89.6134	30.11773	-6.88	-18.88
P43	-89.7913	30.03384	-7.31	-19.31
P44	-89.8124	30.03087	-6.88	-23.88
P45	-89.7965	30.01814	-7.30	-19.30
P46	-89.8277	30.01744	-8.18	-25.18
P47	-89.8283	30.00959	-7.97	-24.97
P48	-89.8066	30.01271	-7.76	-19.76

Table continued on following page

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P49	-89.8235	29.99916	-7.82	-19.82
P50	-89.826	29.97823	-8.47	-20.47
P51	-89.807	29.96714	-8.74	-20.74
P52	-89.7858	29.97114	-8.90	-20.90
P53	-89.7924	29.95587	-8.85	-20.85
P54	-89.775	29.96465	-8.96	-20.96
P55	-89.7798	29.94767	-8.72	-15.22
P56	-89.7568	29.95301	-8.64	-15.14
P57	-89.716	29.91925	-8.05	-20.05
P58	-89.7316	29.90814	-8.15	-20.15
P59	-89.6816	29.91946	-9.50	-21.50
P60	-89.6983	29.89827	-8.70	-20.70
P61	-89.6951	29.90538	-8.95	-20.95
P62	-89.6717	29.88981	-8.94	-20.94
P63	-89.6635	29.9025	-9.27	-21.27
P64	-89.6376	29.89145	-8.85	-20.85
P65	-89.6364	29.91051	-8.92	-20.92
P66	-89.6341	29.93246	-9.61	-21.61

Table 2-1 Model Output Coordinates and Bathymetric Elevations

2.7 Modeling Scenarios

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Table 2-2 displays the 5 different modeling scenarios evaluated for non-hurricane conditions. For each scenario, one wind-speed has been selected. Windspeeds of 20, 30, 40 and 50 mph were selected because these values roughly correspond to the 1YR, 5YR, 20YR and 100YR sustained windspeed statistics presented in Table 2-3 (USAF,2011).

Simulation Set	Wind Speed (mph)	24 Wind Directions (Nautical deg.)	Water Level (ft. NAVD88)	Number of Simulations
W20	20	[0:15:345]	0.92	24
W30	30	[0:15:345]	0.92	24
W40	40	[0:15:345]	0.92	24
W50	50	[0:15:345]	0.92	24
W30H	30	[0:15:345]	2.50	24

Table 2-2 Modeling Scenarios for non-hurricane conditions

New Orleans Sustained Winds (mph)										
RETURN PERIOD (YRS)	1.1	1.25	2	5	10	20	50	100	1000	10000
North	20.5	21.6	25.0	30.3	33.9	37.4	41.9	45.3	56.0	66.6
Northeast	19.6	20.3	23.6	30.0	34.9	39.8	46.3	51.2	67.6	84.1
East	18.6	19.5	23.4	31.2	37.2	43.2	51.2	57.2	77.5	97.7
Southeast	19.8	21.2	24.5	29.0	31.7	34.3	37.4	39.7	46.8	53.5
South	21.8	22.3	25.2	32.0	37.5	43.2	50.9	56.8	76.6	96.8
Southwest	20.5	21.1	24.5	32.1	38.2	44.4	52.9	59.3	80.9	102.8
West	21.1	22.1	25.7	32.1	36.9	41.5	47.6	52.1	67.1	82.0
Northwest	20.6	21.6	24.7	29.5	32.8	36.0	40.1	43.2	53.1	62.7
Average	**20.3**	**21.2**	**24.5**	**30.8**	**35.6**	**40.3**	**46.6**	**51.4**	**67.1**	**82.8**

Table 2-3 New Orleans Sustained Windspeed Statistics

3 SWAN Results

3.1 SWAN Results for Scenario W20

Table 6-1 presents the summary of impact to significant wave height and mean wave period. The WOP column is the "Without Project" or "existing condition". The WP column is the "With Project" or with borrow pit scenario. The WP column represents the maximum wave height /wave period calculated for the 24 different wind directions. We have modeled 24 different wind directions, and extracted the maximum value from these 24 simulations for the WOP and WP conditions.

The difference and % difference have been calculated for the change in significant wave height (Hs) and mean wave period (Tm10). Very little difference in Hs and Tm10, about 0 to 2%, is observed along the Lake Borgne shoreline LB points. However we see a 3 to 9% increase in Hs, and a 0 to 4% increase in Tm10, within the borrow pits themselves. Appendix A displays 2D results for the W20 scenario.

3.2 SWAN Results for Scenario W30

Table 6-2 presents the summary of impacts for the W30 scenario. Differences and percent differences have been calculated for significant wave height (Hs) and mean wave period (Tm10). We see a 0 to 4% increase in Hs, and a 0 to 3% increase in Tm10, along the Lake Borgne shoreline. A 4 to 16% increase in Hs, and a -1 to 7% change in Tm10, within the borrow pits themselves. Appendix A displays 2D results for the W30 scenario.

3.3 SWAN Results for Scenario W40

Table 6-3 presents the summary of impacts for the W40 scenario. Differences and percent differences have been calculated for significant wave height (Hs) and mean wave period (Tm10). We see a 0 to 4% increase in Hs, and a 0 to 3% increase in Tm10, along the Lake Borgne shoreline. A 9 to 24% increase in Hs, and a -2 to 7% change in Tm10, within the borrow pits themselves. Appendix A displays 2D results for the W40 scenario.

3.4 SWAN Results for Scenario W50

Table 6-4 presents the summary of impacts for the W50 scenario. Differences and percent differences have been calculated for significant wave height (Hs) and mean wave period (Tm10). We see a 0 to 2% increase in Hs, and a -1 to 3% change in Tm10, along the Lake Borgne shoreline. A 14 to 39% increase in Hs, and a -2 to 10% change in Tm10, within the borrow pits themselves. Appendix A displays 2D results for the W50 scenario.

3.5 SWAN Results for Scenario W30H

Table 6-5 presents the summary of impacts for the W30H scenario. Differences and percent differences have been calculated for significant wave height (Hs) and mean wave period (Tm10). We see a 0 to 3% increase in Hs, and a 0 to 2% increase in Tm10, along the Lake Borgne shoreline. A 4 to 13% increase in Hs, and a 0 to 7% increase in Tm10, within the borrow pits themselves. Appendix A displays 2D results for the W50 scenario.

4 ADCIRC+SWAN Simulation of Hurricane Gustav

Table 4-1 contains the summary of impacts of the borrow pits on peak surge and peak velocity for the full scale ADCIRC+SWAN simulation of Hurricane Gustav. Very little difference is observed in peak surge. A substantial decrease in velocity is observed within the borrow pits, and a substantial increase in velocity is observed immediately outside the borrow pits. Figure 4-1 displays the maximum surge velocity for the WOP condition. Figure 4-4 shows the difference in peak surge elevation between the WOP and WP conditions. The difference and percent difference have been labeled at the selected output locations. Figure 4-2 displays the maximum velocity for the WOP condition. Figure 4-5 displays the difference in maximum velocity. The difference and percent difference have been labeled at the selected output locations.

Table 4-2 presents the summary of impacts of the borrow pits on peak significant wave height for the full scale ADCIRC+SWAN Gustav simulation. As seen with the stationary simulations, very little difference in peak significant wave height is observed along the Lake Borgne shoreline. In general, we see about a 0 to 4% increase in significant wave height at the LB points along the Lake Borgne shoreline. Within the borrow pits, at locations P41-P66, we see a substantial increase in significant wave height, at about 5 to 20%. Figure 4-3 displays the peak significant wave height for the WOP condition. Figure 4-6 displays the difference between the WOP and WP condition, with the points of interest labeled with the actual and percent differences.

Summary of Impacts for Hurricane Gustav								
Point ID	Peak Surge Elevation (ft. NAVD88)				Peak Velocity (ft/s)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (ft/s)	WP (ft/s)	Dif. (ft/s)	% Dif
LB1	10.23	10.23	-0.01	-0.06%	2.12	2.15	0.03	1.61%
LB2	10.30	10.29	-0.01	-0.10%	1.62	1.61	-0.01	-0.74%
LB3	10.33	10.33	-0.01	-0.07%	1.26	1.27	0.01	0.97%
LB4	10.33	10.32	-0.01	-0.07%	1.45	1.41	-0.04	-3.01%
LB5	10.27	10.26	-0.01	-0.11%	1.74	1.75	0.01	0.83%
LB6	10.37	10.35	-0.01	-0.13%	1.20	1.22	0.02	1.70%
LB7	10.32	10.30	-0.01	-0.11%	1.07	1.08	0.01	0.64%
LB8	10.18	10.17	-0.02	-0.18%	1.94	2.02	0.08	4.02%
LB9	10.21	10.19	-0.02	-0.21%	2.31	2.30	-0.02	-0.74%
LB10	10.32	10.29	-0.03	-0.31%	1.72	1.69	-0.03	-1.64%
LB11	10.34	10.30	-0.04	-0.35%	4.13	4.12	0.00	-0.05%
LB12	10.42	10.37	-0.05	-0.46%	1.43	1.61	0.18	12.63%
LB13	10.52	10.44	-0.07	-0.70%	1.03	1.38	0.35	34.40%
LB14	10.56	10.47	-0.09	-0.90%	0.69	1.19	0.51	73.76%
LB15	10.56	10.46	-0.11	-1.02%	0.47	1.18	0.71	151.63%
LB16	10.55	10.45	-0.09	-0.90%	0.51	0.89	0.39	75.75%
LB17	10.48	10.40	-0.08	-0.79%	0.56	0.74	0.18	32.03%
LB18	10.40	10.33	-0.07	-0.67%	0.68	0.92	0.24	35.18%
LB19	10.28	10.23	-0.05	-0.52%	0.76	1.03	0.27	36.32%
LB20	10.18	10.14	-0.04	-0.38%	1.28	1.43	0.16	12.23%
LB21	10.07	10.04	-0.03	-0.31%	0.70	0.94	0.23	33.22%
LB22	9.99	9.97	-0.02	-0.21%	0.81	1.15	0.34	42.61%
LB23	9.91	9.92	0.01	0.07%	1.06	1.54	0.47	44.78%
LB24	9.88	9.88	0.00	0.00%	1.14	1.26	0.13	11.14%
LB25	9.89	9.88	-0.01	-0.14%	2.01	2.01	0.00	-0.15%
LB26	9.82	9.80	-0.02	-0.22%	1.73	1.52	-0.20	-11.86%
LB27	9.76	9.73	-0.04	-0.36%	1.36	1.34	-0.02	-1.44%
LB28	9.81	9.77	-0.04	-0.41%	0.91	1.04	0.13	14.19%
LB29	9.78	9.74	-0.04	-0.38%	0.65	0.72	0.06	9.78%
LB30	9.63	9.60	-0.03	-0.28%	0.80	1.16	0.36	44.72%
LB31	9.54	9.52	-0.01	-0.15%	0.90	1.26	0.36	40.38%
LB32	9.46	9.46	0.00	0.03%	0.95	1.30	0.35	37.01%
LB33	9.36	9.38	0.02	0.23%	1.11	1.54	0.44	39.30%
LB34	9.26	9.30	0.04	0.38%	1.32	1.62	0.30	22.71%
LB35	9.17	9.21	0.04	0.48%	1.21	1.37	0.16	13.02%
LB36	9.11	9.16	0.04	0.48%	1.10	1.07	-0.03	-2.82%
LB37	9.19	9.22	0.03	0.36%	1.00	1.18	0.18	18.30%
LB38	9.28	9.29	0.01	0.12%	0.87	0.87	0.00	-0.38%

Table continued on following page

Summary of Impacts for Hurricane Gustav								
Point ID	Peak Surge Elevation (ft. NAVD88)				Peak Velocity (ft/s)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (ft/s)	WP (ft/s)	Dif. (ft/s)	% Dif
LB39	9.36	9.36	0.00	0.02%	1.10	1.02	-0.08	-7.02%
LB40	9.47	9.47	0.00	-0.01%	1.46	1.40	-0.06	-3.78%
P41	10.28	10.28	0.00	0.04%	1.53	0.96	-0.57	-37.12%
P42	10.18	10.20	0.02	0.22%	2.25	1.48	-0.78	-34.44%
P43	10.40	10.36	-0.04	-0.36%	1.35	1.39	0.04	3.07%
P44	10.48	10.40	-0.07	-0.71%	1.10	1.17	0.06	5.74%
P45	10.37	10.34	-0.03	-0.30%	1.22	0.69	-0.53	-43.37%
P46	10.49	10.41	-0.08	-0.78%	0.73	1.31	0.58	79.31%
P47	10.46	10.39	-0.06	-0.61%	0.75	0.88	0.13	17.03%
P48	10.39	10.34	-0.04	-0.40%	1.06	0.67	-0.39	-36.80%
P49	10.38	10.33	-0.06	-0.55%	0.85	1.43	0.58	68.14%
P50	10.29	10.25	-0.04	-0.43%	0.83	0.83	0.00	-0.58%
P51	10.17	10.21	0.04	0.43%	0.83	1.47	0.63	76.10%
P52	10.11	10.09	-0.03	-0.26%	1.05	0.62	-0.43	-40.66%
P53	10.07	10.05	-0.02	-0.17%	0.83	0.60	-0.23	-27.36%
P54	10.05	10.03	-0.02	-0.17%	1.13	0.81	-0.32	-28.49%
P55	9.98	9.98	0.00	0.01%	0.91	0.94	0.03	3.78%
P56	9.93	9.93	0.00	-0.02%	1.27	0.86	-0.41	-32.17%
P57	9.66	9.63	-0.04	-0.37%	0.74	0.79	0.06	7.56%
P58	9.66	9.63	-0.03	-0.28%	0.62	1.18	0.56	90.67%
P59	9.55	9.52	-0.03	-0.36%	0.92	0.61	-0.30	-33.18%
P60	9.51	9.51	0.00	-0.01%	0.90	0.48	-0.42	-46.41%
P61	9.53	9.52	-0.01	-0.14%	0.89	0.71	-0.18	-20.70%
P62	9.38	9.41	0.03	0.33%	1.00	0.72	-0.28	-27.58%
P63	9.42	9.42	0.01	0.06%	0.93	1.06	0.13	14.41%
P64	9.28	9.32	0.04	0.46%	0.95	1.06	0.11	11.45%
P65	9.36	9.38	0.01	0.15%	0.91	1.18	0.27	29.38%
P66	9.46	9.44	-0.01	-0.14%	0.84	0.96	0.12	13.97%

Table 4-1 Summary of impacts for Hurricane Gustav (Peak Surge and Velocity)

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Summary of Impacts for Hurricane Gustav								
Point ID	Significant Wave Height Hs (ft.)				Mean Wave Period Tm10 (sec.)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (sec)	WP (sec)	Dif. (sec)	% Dif
LB1	5.49	5.56	0.07	1.36%	4.05	4.10	0.05	1.18%
LB2	5.26	5.25	-0.01	-0.11%	4.16	4.13	-0.02	-0.52%
LB3	5.59	5.60	0.01	0.23%	4.06	4.08	0.02	0.50%
LB4	5.54	5.45	-0.09	-1.71%	4.05	4.04	-0.01	-0.36%
LB5	6.00	6.02	0.02	0.37%	4.09	4.11	0.02	0.48%
LB6	5.50	5.50	0.00	0.05%	4.07	4.08	0.01	0.14%
LB7	5.51	5.51	0.00	0.01%	4.03	4.03	0.01	0.15%
LB8	5.88	5.91	0.03	0.49%	4.07	4.09	0.03	0.62%
LB9	5.18	5.19	0.01	0.18%	3.91	3.93	0.02	0.39%
LB10	4.27	4.32	0.06	1.30%	3.39	3.44	0.04	1.24%
LB11	3.62	3.65	0.02	0.69%	3.13	3.18	0.05	1.55%
LB12	5.18	5.22	0.04	0.77%	3.87	3.86	0.00	-0.12%
LB13	5.21	5.05	-0.16	-3.15%	3.90	3.83	-0.07	-1.72%
LB14	5.29	5.32	0.02	0.46%	3.93	4.01	0.08	2.11%
LB15	5.36	5.53	0.16	3.02%	3.92	4.10	0.18	4.48%
LB16	5.46	5.51	0.05	0.89%	3.94	4.05	0.11	2.66%
LB17	5.50	5.59	0.09	1.57%	3.94	3.99	0.05	1.27%
LB18	5.42	5.50	0.08	1.47%	3.90	3.97	0.07	1.91%
LB19	5.34	5.39	0.06	1.05%	3.89	3.94	0.05	1.41%
LB20	5.36	5.34	-0.02	-0.29%	3.95	3.95	0.00	-0.06%
LB21	4.79	4.80	0.02	0.38%	3.68	3.70	0.02	0.43%
LB22	4.68	4.73	0.06	1.21%	3.57	3.62	0.05	1.44%
LB23	4.26	4.19	-0.07	-1.72%	3.36	3.32	-0.04	-1.27%
LB24	3.86	3.89	0.03	0.87%	3.18	3.23	0.05	1.47%
LB25	4.90	4.96	0.06	1.14%	3.55	3.58	0.03	0.86%
LB26	5.48	5.56	0.08	1.50%	3.82	3.89	0.07	1.82%
LB27	5.38	5.42	0.04	0.73%	3.85	3.89	0.04	0.95%
LB28	4.94	5.03	0.09	1.73%	3.74	3.85	0.11	3.05%
LB29	5.01	5.11	0.10	2.00%	3.73	3.83	0.10	2.75%
LB30	5.04	5.00	-0.04	-0.70%	3.71	3.74	0.04	0.96%
LB31	4.99	5.05	0.06	1.28%	3.64	3.82	0.18	5.06%
LB32	4.74	4.73	-0.01	-0.12%	3.59	3.74	0.15	4.16%
LB33	4.36	4.38	0.03	0.63%	3.46	3.54	0.08	2.32%
LB34	4.10	4.35	0.25	6.08%	3.37	3.49	0.12	3.63%
LB35	3.59	3.73	0.14	3.98%	3.09	3.13	0.04	1.21%
LB36	3.18	3.22	0.03	1.08%	2.68	2.83	0.15	5.47%
LB37	2.95	3.00	0.05	1.63%	2.53	2.59	0.05	2.08%
LB38	2.92	2.93	0.02	0.58%	2.55	2.59	0.04	1.38%

Table continued on following page

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Summary of Impacts for Hurricane Gustav								
Point ID	Significant Wave Height Hs (ft.)				Mean Wave Period Tm10 (sec.)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (sec)	WP (sec)	Dif. (sec)	% Dif
LB39	3.34	3.35	0.01	0.21%	2.77	2.75	-0.02	-0.82%
LB40	3.79	3.80	0.01	0.15%	3.06	3.04	-0.02	-0.64%
P41	5.64	6.24	0.60	10.70%	4.06	4.13	0.08	1.88%
P42	5.62	6.19	0.57	10.09%	3.99	4.02	0.02	0.53%
P43	5.20	5.62	0.41	7.95%	3.84	3.89	0.05	1.21%
P44	5.30	6.06	0.75	14.18%	3.91	4.07	0.16	4.06%
P45	5.39	5.94	0.56	10.36%	3.88	4.00	0.12	3.14%
P46	5.36	6.25	0.89	16.65%	3.88	4.14	0.26	6.67%
P47	5.37	6.21	0.84	15.57%	3.86	4.03	0.16	4.23%
P48	5.41	5.61	0.19	3.58%	3.87	3.85	-0.03	-0.70%
P49	5.37	6.06	0.69	12.84%	3.83	3.94	0.11	2.94%
P50	5.42	6.20	0.78	14.30%	3.83	4.06	0.23	6.02%
P51	5.34	6.11	0.77	14.32%	3.81	4.05	0.24	6.25%
P52	5.27	5.77	0.50	9.47%	3.73	3.83	0.10	2.65%
P53	5.19	6.11	0.92	17.69%	3.73	4.03	0.31	8.20%
P54	5.23	5.61	0.37	7.10%	3.70	3.77	0.07	2.02%
P55	4.87	5.13	0.26	5.33%	3.61	3.67	0.07	1.84%
P56	4.77	5.09	0.32	6.68%	3.50	3.59	0.08	2.37%
P57	5.28	6.15	0.87	16.46%	3.78	4.13	0.35	9.14%
P58	5.15	5.84	0.69	13.42%	3.73	4.00	0.27	7.33%
P59	5.24	5.78	0.54	10.39%	3.63	3.88	0.25	6.76%
P60	5.06	5.98	0.92	18.13%	3.63	4.03	0.40	10.97%
P61	5.15	6.04	0.90	17.42%	3.65	4.06	0.41	11.27%
P62	4.67	5.55	0.89	18.98%	3.45	3.77	0.32	9.25%
P63	4.81	5.24	0.44	9.05%	3.43	3.75	0.33	9.53%
P64	4.21	4.87	0.66	15.71%	3.19	3.53	0.34	10.60%
P65	4.50	4.89	0.38	8.54%	3.24	3.58	0.34	10.59%
P66	4.70	5.12	0.42	9.03%	3.36	3.60	0.24	7.08%

Table 4-2 Summary of impacts for Hurricane Gustav (Significant Wave Height)

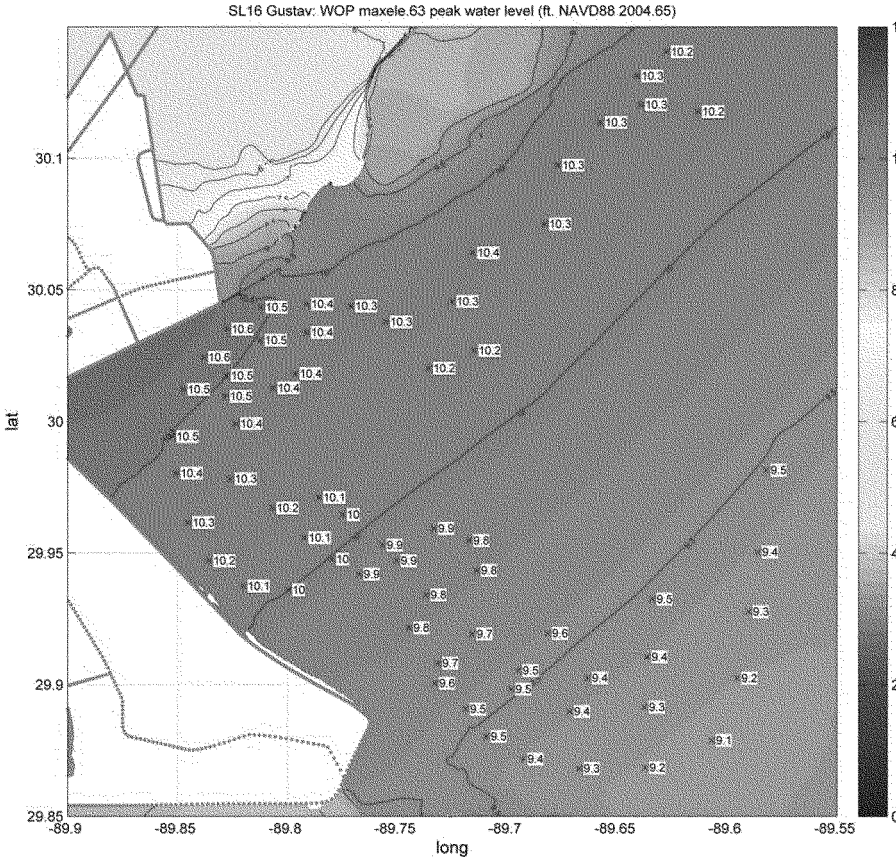

Figure 4-1 ADCIRC+SWAN Peak Surge Elevation for Hurricane Gustav

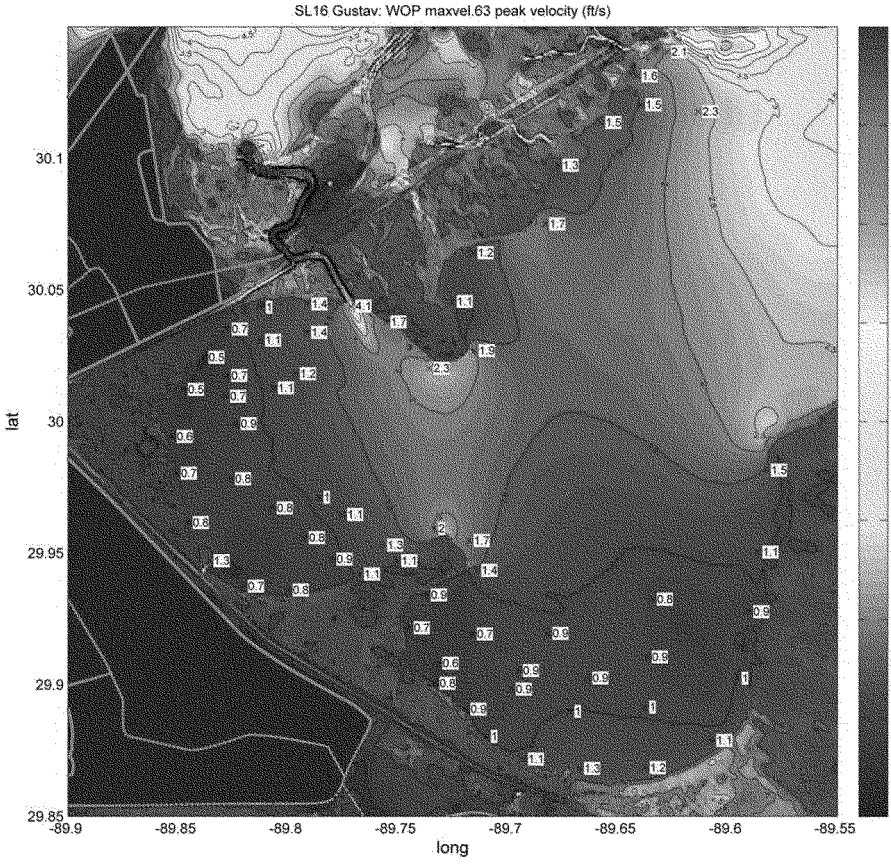

Figure 4-2 ADCIRC+SWAN Peak Velocity for Hurricane Gustav

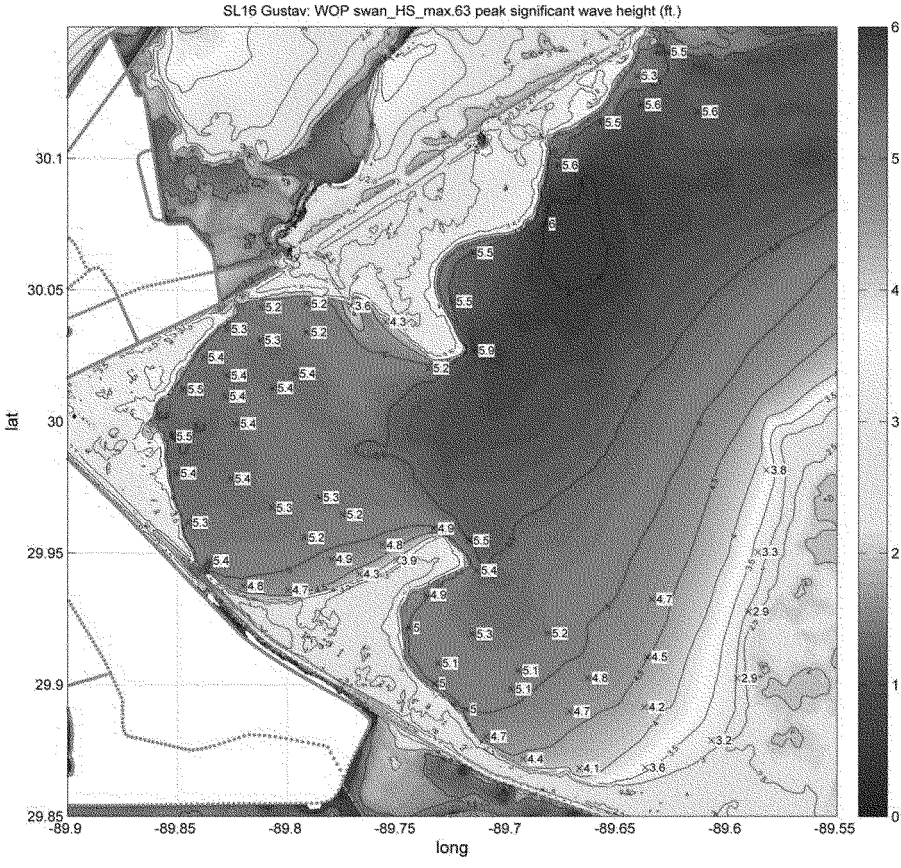

Figure 4-3 ADCIRC+SWAN Peak Significant Wave Height for Hurricane Gustav

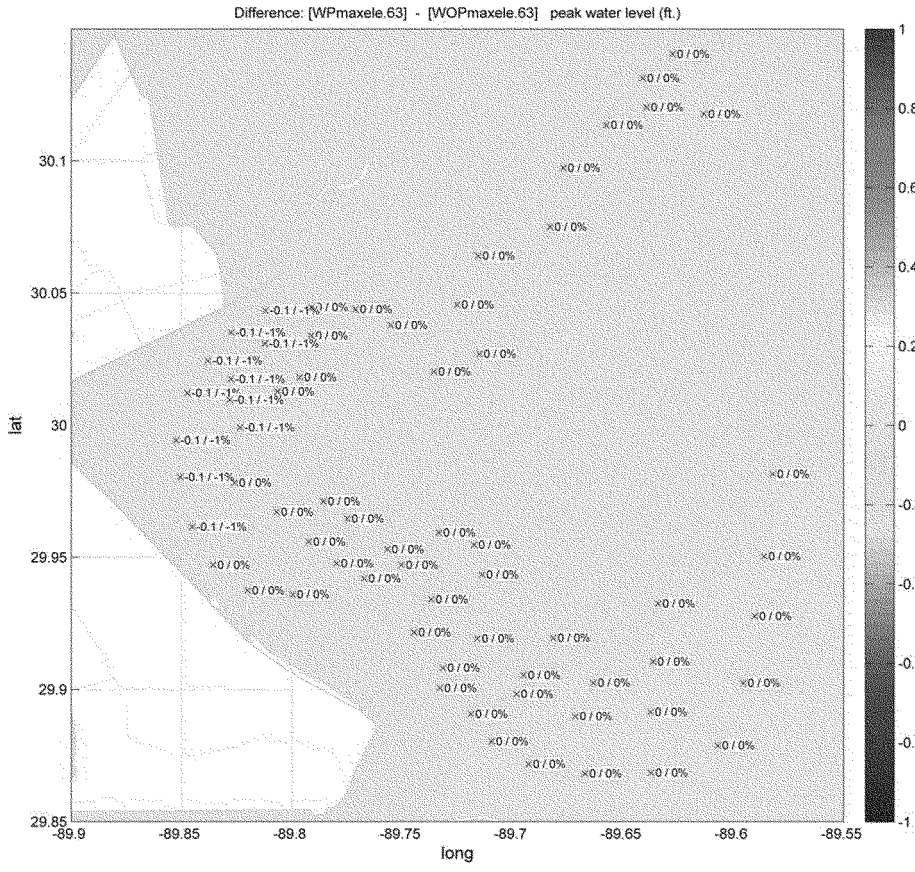

Figure 4-4 ADCIRC+SWAN Difference in Peak Surge Elevation

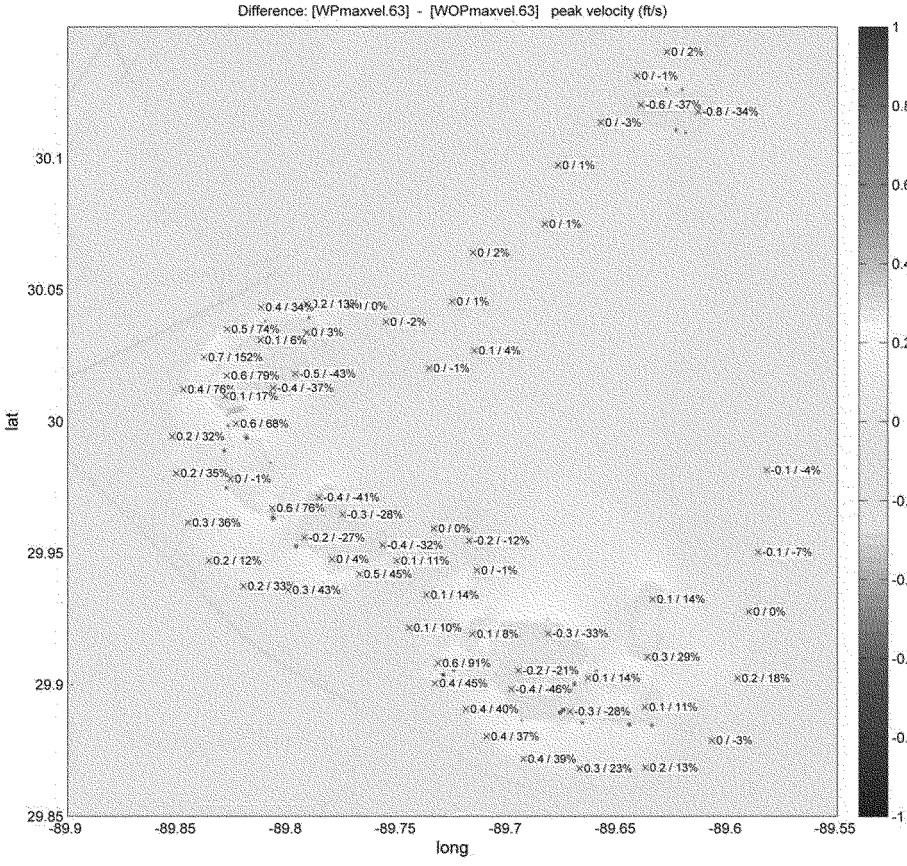

Figure 4-5 ADCIRC+SWAN Difference in Peak Velocity

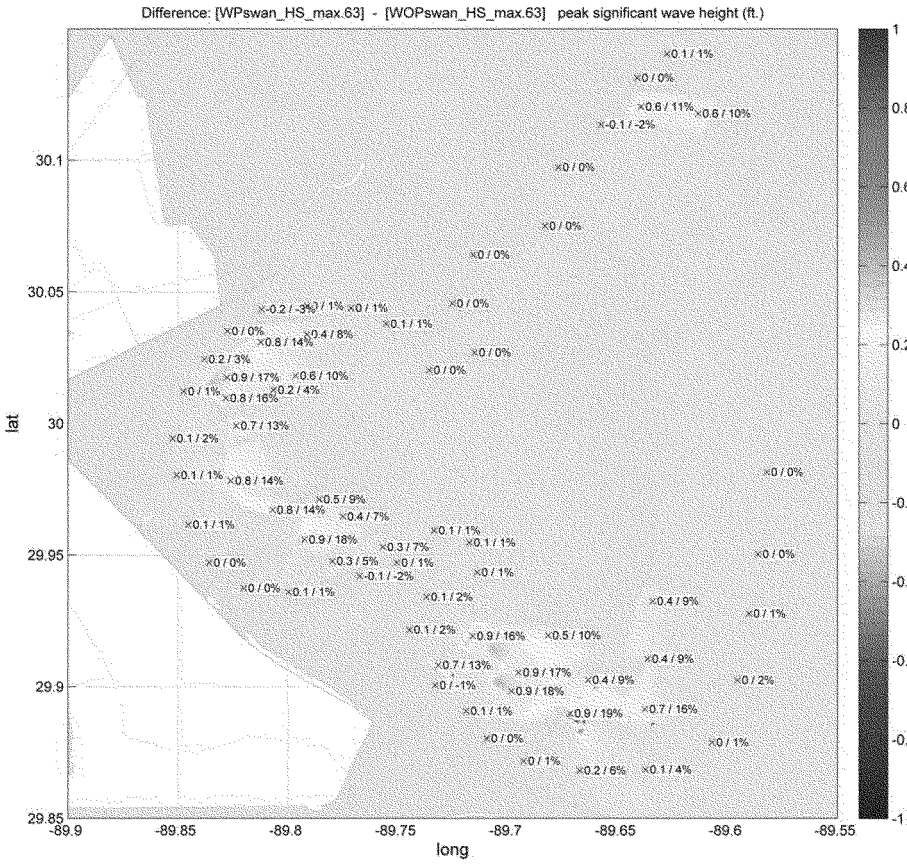

Figure 4-6 ADCIRC+SWAN Difference in Peak Significant Wave Height

5 Conclusions

Very little difference in significant wave height and mean wave period can be attributed to the proposed borrow pits along the Lake Borgne shoreline for the simulated "normal" or "non-storm" conditions. We have calculated a 0 to 4% increase in significant wave height, and a 0 to 3% increase in mean wave period along the shoreline. Within the borrow pits, there can be a substantial increases: 3 to 39% increase to significant wave height and up to a 10% increase in mean wave period. The model results show that much of the increased wave energy is not transferred out of the borrow pit areas. Once the larger waves exit the borrow pit areas, they appear to become depth limited rather quickly. With increased depths, perhaps larger waves developing within the borrow pit areas will propagate to the shoreline. With scenario W30H, we have increased the water lever to 2.5 ft NAVD88, which corresponds to a high tide in Lake Borgne. Even with the increased depth assigned in W30H, larger waves developing within the borrow pit areas do not propagate all the way to the shoreline because they appear to become depth limited.

The simulation of hurricane Gustav provides one example of what could happen during a high impact storm at the Lake Borgne area. Very little change in peak surge elevation was observed. The perturbation to the bottom bathymetry is not enough to significantly alter surge levels in the region of interest. However, the change in peak velocity surrounding the borrow pits is significant. We see a change of up to 0.7 ft/s at the Lake Borgne shoreline, which could be significant in terms of erosion and deposition patterns. The increase is velocity is suspected to occur because the increased depth at the borrow pits transitions suddenly to a shallower depth. As the water column becomes confined to a smaller depth, the velocity increases. For this analysis, we have chosen to use the 2D version of ADCIRC. Perhaps the increase in velocity can be attributed to the 2D nature of ADCIRC, and we could possibly see different results with 3D hydrodynamic modeling.

The simulation of hurricane Gustav shows relatively large significant wave heights forming in Lake Borgne, at about 5.5 ft with a depth of about 18.0 ft. When we add the borrow pits and re-run the simulations, we see a relatively large increase in significant wave height within the borrow pit areas, at about 10 to 20%, or almost 1.0 ft higher. For this simulation, the larger waves that are developing within the borrow pit areas to not propagate far from the borrow pit areas apparently due to depth limitation. The largest increase is about 0.2 ft or 3% at point LB15. Perhaps another storm, which produces greater surges and depths, would allow the larger wave that develop within the borrow pit areas to propagate to the shoreline. However, at a certain surge level, waves developing in Lake Borgne would not be depth limited, and the addition of the borrow pits would make no impact. It is important to note that we have modeled a single example of hurricane conditions in Lake Borgne. Other storms could perhaps draw significantly different conclusions.

6 Appendix A - Tabular Output

Summary of Impacts for Scenario W20								
Point ID	Significant Wave Height Hs (ft.)				Mean Wave Period Tm10 (sec.)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (sec)	WP (sec)	Dif. (sec)	% Dif
LB1	1.46	1.47	0.01	0.71%	2.16	2.17	0.01	0.39%
LB2	1.48	1.48	0.00	0.29%	2.25	2.26	0.01	0.27%
LB3	1.68	1.68	0.00	0.00%	2.37	2.37	0.00	0.02%
LB4	1.78	1.78	0.00	0.01%	2.43	2.43	0.00	0.02%
LB5	1.81	1.82	0.01	0.36%	2.40	2.40	0.00	0.18%
LB6	1.41	1.41	0.00	0.09%	2.13	2.13	0.00	0.06%
LB7	1.78	1.78	0.00	0.06%	2.42	2.42	0.00	0.07%
LB8	2.05	2.05	0.00	0.12%	2.62	2.62	0.00	0.10%
LB9	1.45	1.45	0.00	0.11%	2.22	2.22	0.00	0.01%
LB10	1.45	1.45	0.00	0.05%	2.12	2.12	0.00	0.02%
LB11	1.59	1.59	0.00	0.01%	2.21	2.21	0.00	0.01%
LB12	1.53	1.54	0.01	0.46%	2.18	2.19	0.01	0.41%
LB13	1.32	1.34	0.02	1.68%	1.98	2.00	0.03	1.40%
LB14	1.31	1.33	0.02	1.23%	1.96	1.98	0.02	1.07%
LB15	1.33	1.34	0.01	0.83%	1.96	1.99	0.03	1.68%
LB16	1.42	1.43	0.01	1.01%	2.09	2.11	0.02	1.00%
LB17	1.60	1.63	0.03	1.67%	2.21	2.23	0.02	1.05%
LB18	1.69	1.72	0.03	1.58%	2.33	2.35	0.03	1.16%
LB19	1.82	1.85	0.02	1.27%	2.46	2.48	0.02	0.87%
LB20	1.82	1.83	0.01	0.79%	2.44	2.46	0.02	0.68%
LB21	1.62	1.63	0.01	0.69%	2.30	2.31	0.01	0.50%
LB22	1.74	1.76	0.01	0.67%	2.40	2.41	0.01	0.54%
LB23	1.90	1.91	0.01	0.30%	2.56	2.56	0.00	0.17%
LB24	1.87	1.87	0.00	0.13%	2.56	2.56	0.00	-0.08%
LB25	2.14	2.14	0.00	0.03%	2.70	2.70	0.00	-0.03%
LB26	2.13	2.13	0.00	0.06%	2.68	2.68	0.00	0.06%
LB27	1.99	2.00	0.00	0.09%	2.61	2.61	0.00	0.02%
LB28	1.76	1.78	0.02	1.25%	2.43	2.45	0.02	0.86%
LB29	1.87	1.88	0.02	0.88%	2.49	2.51	0.02	0.85%
LB30	1.90	1.92	0.02	1.02%	2.50	2.52	0.02	0.89%
LB31	1.86	1.89	0.03	1.52%	2.46	2.49	0.03	1.38%
LB32	1.62	1.64	0.03	1.55%	2.25	2.28	0.02	1.04%
LB33	1.56	1.57	0.02	1.00%	2.21	2.22	0.01	0.64%
LB34	1.50	1.51	0.00	0.29%	2.16	2.17	0.01	0.31%
LB35	1.61	1.61	0.01	0.36%	2.26	2.26	0.00	0.15%
LB36	1.59	1.61	0.02	1.23%	2.24	2.26	0.02	1.02%

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DRAFT

Summary of Impacts for Scenario W20								
Point ID	Significant Wave Height Hs (ft.)				Mean Wave Period Tm10 (sec.)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (sec)	WP (sec)	Dif. (sec)	% Dif
LB37	1.74	1.76	0.02	1.10%	2.37	2.39	0.02	0.98%
LB38	1.83	1.84	0.01	0.82%	2.43	2.44	0.01	0.59%
LB39	1.76	1.77	0.01	0.53%	2.37	2.38	0.01	0.32%
LB40	1.75	1.76	0.01	0.30%	2.37	2.37	0.00	0.16%
P41	1.65	1.78	0.13	8.10%	2.28	2.36	0.08	3.53%
P42	1.60	1.75	0.14	8.96%	2.26	2.34	0.08	3.43%
P43	1.47	1.54	0.08	5.13%	2.12	2.17	0.05	2.37%
P44	1.24	1.34	0.10	8.04%	1.90	1.99	0.08	4.44%
P45	1.40	1.48	0.08	5.57%	2.06	2.11	0.06	2.76%
P46	1.47	1.59	0.12	7.95%	2.12	2.21	0.09	4.25%
P47	1.56	1.67	0.11	7.03%	2.20	2.27	0.07	3.36%
P48	1.45	1.52	0.07	4.88%	2.09	2.14	0.05	2.20%
P49	1.57	1.66	0.10	6.35%	2.21	2.27	0.06	2.80%
P50	1.65	1.79	0.13	8.01%	2.29	2.38	0.09	4.01%
P51	1.81	1.91	0.10	5.74%	2.43	2.49	0.05	2.22%
P52	1.78	1.88	0.10	5.45%	2.41	2.46	0.05	2.02%
P53	1.93	2.06	0.13	6.58%	2.56	2.61	0.06	2.16%
P54	2.01	2.11	0.10	5.07%	2.61	2.63	0.03	0.99%
P55	2.04	2.14	0.10	4.71%	2.64	2.67	0.03	1.26%
P56	2.04	2.11	0.07	3.35%	2.66	2.67	0.01	0.23%
P57	1.80	1.90	0.10	5.65%	2.40	2.45	0.05	2.09%
P58	1.87	1.98	0.11	6.01%	2.46	2.50	0.04	1.77%
P59	1.95	2.04	0.09	4.60%	2.53	2.56	0.03	1.24%
P60	1.80	1.95	0.15	8.38%	2.43	2.52	0.09	3.71%
P61	1.92	2.01	0.10	5.13%	2.52	2.56	0.04	1.71%
P62	1.63	1.76	0.13	7.96%	2.29	2.38	0.09	3.92%
P63	1.88	1.98	0.10	5.43%	2.48	2.52	0.05	1.83%
P64	1.67	1.75	0.08	4.59%	2.27	2.32	0.05	2.13%
P65	1.83	1.93	0.10	5.36%	2.45	2.50	0.05	2.19%
P66	1.91	2.00	0.08	4.42%	2.50	2.53	0.04	1.42%

Table 6-1 Summary of Impacts for Scenario W20

DRAFT

Summary of Impacts for Scenario W30								
Point ID	Significant Wave Height Hs (ft.)				Mean Wave Period Tm10 (sec.)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (sec)	WP (sec)	Dif. (sec)	% Dif
LB1	2.06	2.07	0.02	0.73%	2.45	2.47	0.01	0.60%
LB2	1.92	1.92	0.00	0.15%	2.54	2.55	0.01	0.24%
LB3	2.44	2.44	0.00	-0.01%	2.72	2.72	0.00	0.02%
LB4	2.54	2.54	0.00	0.02%	2.81	2.81	0.00	0.05%
LB5	2.62	2.65	0.03	0.96%	2.75	2.76	0.02	0.62%
LB6	2.07	2.07	0.00	0.00%	2.46	2.46	0.00	0.10%
LB7	2.52	2.53	0.01	0.25%	2.75	2.76	0.01	0.24%
LB8	2.90	2.91	0.01	0.28%	2.97	2.98	0.00	0.15%
LB9	2.14	2.14	0.00	0.17%	2.51	2.51	0.00	0.00%
LB10	2.12	2.12	0.00	0.10%	2.47	2.47	0.00	0.02%
LB11	2.52	2.52	0.00	0.07%	2.61	2.61	0.00	0.02%
LB12	2.31	2.35	0.03	1.48%	2.57	2.59	0.02	0.74%
LB13	1.93	2.01	0.08	4.14%	2.28	2.35	0.07	2.96%
LB14	1.89	1.93	0.04	2.31%	2.25	2.29	0.04	1.89%
LB15	1.95	1.98	0.03	1.68%	2.26	2.32	0.06	2.47%
LB16	2.03	2.09	0.06	2.72%	2.38	2.43	0.05	2.20%
LB17	2.36	2.44	0.08	3.48%	2.55	2.61	0.06	2.23%
LB18	2.49	2.56	0.07	2.84%	2.68	2.74	0.06	2.16%
LB19	2.65	2.71	0.06	2.19%	2.83	2.88	0.05	1.60%
LB20	2.63	2.67	0.04	1.37%	2.81	2.84	0.03	0.95%
LB21	2.32	2.34	0.02	0.82%	2.66	2.68	0.02	0.60%
LB22	2.51	2.53	0.02	0.87%	2.78	2.79	0.02	0.55%
LB23	2.73	2.75	0.01	0.47%	2.94	2.95	0.00	0.17%
LB24	2.74	2.74	0.00	0.08%	2.95	2.94	0.00	-0.07%
LB25	3.08	3.08	0.00	0.01%	3.08	3.08	0.00	0.02%
LB26	3.01	3.01	0.00	0.04%	3.05	3.05	0.00	0.04%
LB27	2.74	2.74	0.00	0.02%	2.98	2.98	0.00	0.05%
LB28	2.37	2.41	0.03	1.43%	2.77	2.84	0.07	2.62%
LB29	2.62	2.66	0.04	1.58%	2.86	2.91	0.05	1.82%
LB30	2.72	2.80	0.08	2.92%	2.88	2.96	0.07	2.57%
LB31	2.65	2.74	0.09	3.26%	2.81	2.89	0.08	2.72%
LB32	2.28	2.35	0.07	3.11%	2.55	2.61	0.06	2.40%
LB33	2.23	2.28	0.04	1.98%	2.52	2.55	0.04	1.47%
LB34	2.19	2.21	0.02	0.99%	2.49	2.51	0.02	0.67%
LB35	2.39	2.41	0.02	1.00%	2.63	2.64	0.01	0.40%
LB36	2.27	2.34	0.07	3.23%	2.55	2.62	0.07	2.56%
LB37	2.49	2.58	0.09	3.57%	2.72	2.80	0.08	2.96%
LB38	2.62	2.67	0.05	1.94%	2.77	2.81	0.04	1.54%

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DRAFT

Summary of Impacts for Scenario W30								
Point ID	Significant Wave Height Hs (ft.)				Mean Wave Period Tm10 (sec.)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (sec)	WP (sec)	Dif. (sec)	% Dif
LB39	2.58	2.61	0.03	1.17%	2.73	2.76	0.02	0.84%
LB40	2.64	2.65	0.01	0.37%	2.78	2.79	0.01	0.33%
P41	2.37	2.69	0.32	13.55%	2.61	2.72	0.11	4.30%
P42	2.31	2.63	0.32	13.90%	2.61	2.70	0.09	3.51%
P43	2.21	2.37	0.17	7.54%	2.48	2.53	0.05	1.91%
P44	1.79	2.07	0.28	15.61%	2.19	2.35	0.15	7.01%
P45	2.04	2.27	0.24	11.53%	2.37	2.47	0.09	3.82%
P46	2.13	2.46	0.33	15.74%	2.42	2.59	0.16	6.68%
P47	2.27	2.55	0.28	12.30%	2.53	2.64	0.11	4.34%
P48	2.12	2.29	0.17	7.97%	2.42	2.48	0.06	2.49%
P49	2.34	2.56	0.22	9.25%	2.57	2.64	0.07	2.80%
P50	2.41	2.74	0.32	13.44%	2.64	2.77	0.13	4.90%
P51	2.61	2.84	0.23	8.70%	2.80	2.85	0.05	1.89%
P52	2.59	2.81	0.23	8.84%	2.77	2.83	0.05	1.94%
P53	2.78	3.14	0.36	13.01%	2.93	3.02	0.09	3.13%
P54	2.88	3.05	0.18	6.08%	2.97	2.97	0.00	-0.04%
P55	2.89	3.17	0.28	9.77%	3.01	3.06	0.05	1.73%
P56	2.92	3.04	0.12	4.12%	3.04	3.02	-0.02	-0.79%
P57	2.72	3.00	0.28	10.13%	2.83	2.90	0.07	2.39%
P58	2.74	2.98	0.24	8.70%	2.86	2.92	0.05	1.91%
P59	2.91	3.10	0.19	6.60%	2.96	2.97	0.01	0.45%
P60	2.69	3.01	0.33	12.12%	2.80	2.93	0.14	4.85%
P61	2.80	3.14	0.34	12.08%	2.92	3.00	0.08	2.89%
P62	2.40	2.68	0.27	11.28%	2.65	2.76	0.11	4.04%
P63	2.70	2.90	0.20	7.40%	2.83	2.87	0.04	1.34%
P64	2.56	2.82	0.26	10.17%	2.69	2.80	0.11	3.98%
P65	2.62	2.93	0.31	11.88%	2.79	2.89	0.10	3.56%
P66	2.84	3.07	0.23	7.93%	2.92	2.95	0.03	1.08%

Table 6-2 Summary of Impacts for Scenario W30

DRAFT

Summary of Impacts for Scenario W40								
Point ID	Significant Wave Height Hs (ft.)				Mean Wave Period Tm10 (sec.)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (sec)	WP (sec)	Dif. (sec)	% Dif
LB1	2.22	2.24	0.02	0.77%	2.54	2.55	0.01	0.51%
LB2	2.21	2.22	0.01	0.36%	2.63	2.64	0.01	0.27%
LB3	2.58	2.58	0.00	0.01%	2.78	2.78	0.00	0.01%
LB4	2.70	2.71	0.00	0.03%	2.87	2.87	0.00	0.05%
LB5	2.77	2.79	0.02	0.67%	2.81	2.82	0.01	0.44%
LB6	2.19	2.19	0.00	0.00%	2.51	2.52	0.00	0.08%
LB7	2.67	2.67	0.00	0.16%	2.81	2.82	0.01	0.18%
LB8	3.06	3.07	0.01	0.17%	3.04	3.04	0.00	0.15%
LB9	2.27	2.27	0.00	0.18%	2.59	2.59	0.00	0.01%
LB10	2.25	2.25	0.00	0.06%	2.53	2.53	0.00	0.04%
LB11	2.60	2.60	0.00	0.05%	2.66	2.66	0.00	0.02%
LB12	2.43	2.46	0.03	1.14%	2.61	2.63	0.02	0.60%
LB13	2.04	2.11	0.06	3.11%	2.35	2.40	0.05	2.23%
LB14	2.01	2.05	0.03	1.73%	2.32	2.36	0.03	1.48%
LB15	2.06	2.08	0.03	1.24%	2.33	2.36	0.03	1.33%
LB16	2.14	2.19	0.05	2.18%	2.44	2.48	0.04	1.61%
LB17	2.48	2.54	0.07	2.63%	2.60	2.64	0.04	1.60%
LB18	2.62	2.68	0.06	2.31%	2.73	2.78	0.05	1.74%
LB19	2.80	2.85	0.06	1.99%	2.88	2.92	0.04	1.36%
LB20	2.77	2.80	0.04	1.31%	2.86	2.89	0.03	0.93%
LB21	2.44	2.46	0.02	0.78%	2.70	2.71	0.02	0.56%
LB22	2.62	2.65	0.02	0.85%	2.82	2.83	0.01	0.50%
LB23	2.87	2.88	0.01	0.36%	2.99	3.00	0.01	0.22%
LB24	2.88	2.88	0.00	0.10%	3.01	3.01	0.00	0.00%
LB25	3.23	3.23	0.00	0.04%	3.14	3.15	0.00	0.04%
LB26	3.19	3.19	0.00	0.05%	3.12	3.12	0.00	0.04%
LB27	2.97	2.98	0.00	0.06%	3.04	3.04	0.00	0.03%
LB28	2.68	2.73	0.06	2.14%	2.88	2.93	0.06	1.93%
LB29	2.87	2.92	0.06	2.02%	2.96	3.02	0.06	1.89%
LB30	2.92	3.00	0.08	2.67%	2.97	3.04	0.07	2.23%
LB31	2.84	2.92	0.07	2.55%	2.90	2.96	0.07	2.33%
LB32	2.45	2.51	0.06	2.25%	2.64	2.69	0.05	1.76%
LB33	2.40	2.43	0.03	1.34%	2.61	2.63	0.03	0.98%
LB34	2.33	2.35	0.02	0.81%	2.56	2.57	0.01	0.54%
LB35	2.51	2.53	0.02	0.69%	2.69	2.70	0.01	0.34%
LB36	2.42	2.48	0.06	2.34%	2.63	2.68	0.05	1.97%
LB37	2.66	2.74	0.08	2.99%	2.80	2.86	0.06	2.31%
LB38	2.77	2.82	0.05	1.80%	2.84	2.88	0.04	1.29%

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DRAFT

Summary of Impacts for Scenario W40								
Point ID	Significant Wave Height Hs (ft.)				Mean Wave Period Tm10 (sec.)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (sec)	WP (sec)	Dif. (sec)	% Dif
LB39	2.71	2.74	0.03	1.02%	2.79	2.81	0.02	0.71%
LB40	2.77	2.78	0.01	0.28%	2.83	2.84	0.01	0.27%
P41	2.51	2.81	0.29	11.57%	2.68	2.79	0.11	4.01%
P42	2.42	2.70	0.28	11.47%	2.65	2.75	0.09	3.57%
P43	2.30	2.45	0.15	6.34%	2.52	2.58	0.05	2.02%
P44	1.89	2.12	0.23	12.14%	2.25	2.40	0.15	6.86%
P45	2.17	2.39	0.22	10.32%	2.42	2.53	0.10	4.23%
P46	2.23	2.51	0.29	12.80%	2.47	2.62	0.14	5.73%
P47	2.39	2.63	0.24	10.08%	2.59	2.69	0.10	3.98%
P48	2.22	2.37	0.15	6.91%	2.47	2.53	0.06	2.39%
P49	2.45	2.65	0.20	8.07%	2.62	2.69	0.08	2.87%
P50	2.52	2.81	0.28	11.27%	2.68	2.81	0.13	4.71%
P51	2.73	2.93	0.20	7.49%	2.84	2.90	0.06	2.19%
P52	2.70	2.91	0.21	7.79%	2.82	2.88	0.06	2.06%
P53	2.92	3.24	0.32	10.82%	2.99	3.08	0.09	3.03%
P54	3.04	3.20	0.16	5.36%	3.04	3.05	0.01	0.32%
P55	3.05	3.30	0.24	7.97%	3.07	3.13	0.06	1.80%
P56	3.08	3.19	0.11	3.52%	3.10	3.09	-0.01	-0.32%
P57	2.89	3.13	0.24	8.20%	2.91	2.97	0.06	2.03%
P58	2.93	3.16	0.23	7.85%	2.95	3.01	0.06	1.96%
P59	3.05	3.23	0.17	5.69%	3.02	3.04	0.02	0.71%
P60	2.84	3.13	0.29	10.20%	2.87	2.99	0.12	4.06%
P61	2.95	3.24	0.29	10.01%	2.98	3.06	0.08	2.75%
P62	2.53	2.77	0.25	9.71%	2.71	2.81	0.10	3.84%
P63	2.84	3.03	0.19	6.63%	2.90	2.94	0.04	1.49%
P64	2.71	2.93	0.22	8.00%	2.76	2.85	0.09	3.33%
P65	2.78	3.06	0.28	9.95%	2.87	2.96	0.09	3.11%
P66	2.97	3.17	0.19	6.55%	2.97	3.01	0.03	1.05%

Table 6-3 Summary of Impacts for Scenario W40

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Summary of Impacts for Scenario W50								
Point ID	Significant Wave Height Hs (ft.)				Mean Wave Period Tm10 (sec.)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (sec)	WP (sec)	Dif. (sec)	% Dif
LB1	2.47	2.49	0.02	0.88%	2.62	2.63	0.01	0.22%
LB2	2.05	2.05	0.00	0.11%	2.73	2.73	0.00	0.11%
LB3	2.82	2.82	0.00	0.01%	2.96	2.96	0.00	0.02%
LB4	2.97	2.97	0.00	0.00%	3.05	3.05	0.00	-0.01%
LB5	3.32	3.35	0.03	0.94%	3.04	3.06	0.02	0.76%
LB6	2.68	2.68	0.00	0.00%	2.80	2.80	0.00	0.03%
LB7	3.02	3.02	0.00	0.02%	3.02	3.02	0.00	0.09%
LB8	3.42	3.42	0.00	0.09%	3.17	3.17	0.00	0.09%
LB9	2.59	2.60	0.00	0.16%	2.73	2.74	0.01	0.40%
LB10	2.55	2.55	0.00	0.04%	2.66	2.66	0.00	0.05%
LB11	3.24	3.25	0.01	0.16%	2.85	2.85	0.00	0.01%
LB12	2.79	2.84	0.04	1.59%	2.76	2.81	0.05	1.77%
LB13	2.47	2.56	0.09	3.85%	2.52	2.60	0.08	3.36%
LB14	2.42	2.49	0.07	2.90%	2.49	2.55	0.07	2.64%
LB15	2.52	2.60	0.08	3.02%	2.54	2.61	0.07	2.74%
LB16	2.58	2.65	0.07	2.73%	2.63	2.69	0.06	2.35%
LB17	2.94	3.02	0.08	2.75%	2.80	2.86	0.06	2.19%
LB18	3.04	3.08	0.04	1.26%	2.95	3.00	0.05	1.85%
LB19	3.11	3.13	0.02	0.52%	3.08	3.11	0.03	0.90%
LB20	3.12	3.12	0.01	0.30%	2.99	3.00	0.01	0.21%
LB21	2.92	2.92	0.00	0.06%	3.05	3.04	-0.01	-0.21%
LB22	3.11	3.12	0.01	0.46%	3.12	3.14	0.02	0.50%
LB23	3.28	3.31	0.03	1.05%	3.20	3.22	0.02	0.49%
LB24	3.28	3.28	0.01	0.18%	3.19	3.18	-0.01	-0.22%
LB25	3.62	3.62	0.00	-0.06%	3.30	3.30	0.00	-0.08%
LB26	3.43	3.43	0.00	0.01%	3.27	3.27	0.00	-0.05%
LB27	3.00	3.00	0.00	0.00%	3.22	3.22	0.00	-0.01%
LB28	2.54	2.55	0.01	0.56%	2.86	2.93	0.07	2.48%
LB29	2.86	2.88	0.01	0.43%	2.97	3.01	0.04	1.48%
LB30	3.08	3.12	0.04	1.26%	3.04	3.11	0.06	2.13%
LB31	3.13	3.17	0.04	1.28%	3.03	3.10	0.07	2.28%
LB32	2.91	2.96	0.05	1.85%	2.85	2.89	0.05	1.60%
LB33	2.80	2.83	0.04	1.38%	2.76	2.80	0.04	1.48%
LB34	2.76	2.79	0.03	0.95%	2.75	2.77	0.02	0.66%
LB35	2.95	2.97	0.02	0.66%	2.90	2.91	0.01	0.34%
LB36	2.76	2.81	0.04	1.62%	2.78	2.84	0.06	2.27%
LB37	2.94	2.98	0.03	1.17%	2.95	3.03	0.08	2.71%
LB38	3.20	3.23	0.03	0.97%	3.04	3.09	0.04	1.42%

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Summary of Impacts for Scenario W50								
Point ID	Significant Wave Height Hs (ft.)				Mean Wave Period Tm10 (sec.)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (sec)	WP (sec)	Dif. (sec)	% Dif
LB39	3.25	3.28	0.03	0.96%	3.02	3.04	0.03	0.89%
LB40	3.18	3.19	0.01	0.18%	3.03	3.04	0.01	0.33%
P41	2.92	3.54	0.63	21.51%	2.88	3.01	0.13	4.46%
P42	2.82	3.50	0.68	23.90%	2.96	3.02	0.07	2.24%
P43	2.75	3.11	0.36	13.00%	2.73	2.79	0.06	2.20%
P44	2.33	2.79	0.46	19.62%	2.45	2.63	0.18	7.35%
P45	2.63	3.06	0.43	16.46%	2.65	2.73	0.08	3.07%
P46	2.73	3.30	0.57	21.06%	2.69	2.88	0.19	7.19%
P47	2.85	3.34	0.49	17.07%	2.78	2.91	0.13	4.67%
P48	2.75	3.02	0.27	9.70%	2.71	2.75	0.04	1.55%
P49	2.95	3.32	0.37	12.49%	2.84	2.90	0.06	2.08%
P50	3.09	3.66	0.56	18.26%	2.93	3.09	0.15	5.28%
P51	3.27	3.66	0.39	12.05%	3.10	3.13	0.03	0.87%
P52	3.25	3.65	0.40	12.23%	3.08	3.10	0.02	0.71%
P53	3.35	4.06	0.71	21.04%	3.17	3.29	0.12	3.67%
P54	3.39	3.71	0.32	9.34%	3.19	3.14	-0.05	-1.54%
P55	3.33	3.95	0.62	18.69%	3.20	3.29	0.09	2.77%
P56	3.34	3.62	0.29	8.67%	3.23	3.17	-0.05	-1.69%
P57	3.14	3.69	0.55	17.51%	3.03	3.11	0.08	2.64%
P58	3.12	3.45	0.33	10.75%	3.01	3.03	0.02	0.70%
P59	3.50	3.84	0.34	9.70%	3.18	3.18	0.00	-0.07%
P60	3.28	4.02	0.74	22.64%	3.07	3.25	0.17	5.63%
P61	3.37	4.11	0.74	21.82%	3.15	3.29	0.14	4.41%
P62	3.14	3.58	0.44	14.02%	3.00	3.08	0.08	2.75%
P63	3.35	3.65	0.30	9.00%	3.09	3.10	0.01	0.29%
P64	3.25	3.80	0.56	17.10%	2.98	3.14	0.15	5.18%
P65	3.25	3.79	0.54	16.69%	3.04	3.16	0.12	4.01%
P66	3.50	3.93	0.42	12.02%	3.19	3.22	0.03	0.91%

Table 6-4 Summary of Impacts for Scenario W50

Summary of Impacts for Scenario W30H								
Point ID	Significant Wave Height Hs (ft.)				Mean Wave Period Tm10 (sec.)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (sec)	WP (sec)	Dif. (sec)	% Dif
LB1	2.68	2.70	0.02	0.76%	2.63	2.65	0.02	0.74%
LB2	2.12	2.12	0.00	0.16%	2.80	2.80	0.00	0.13%
LB3	2.92	2.93	0.00	0.13%	3.06	3.06	0.00	0.02%
LB4	3.10	3.10	0.00	-0.02%	3.16	3.16	0.00	0.02%
LB5	3.77	3.78	0.01	0.29%	3.34	3.35	0.01	0.38%
LB6	2.99	2.99	0.00	-0.04%	2.98	2.98	0.00	-0.13%
LB7	3.16	3.16	0.00	0.00%	3.10	3.10	0.00	-0.08%
LB8	3.64	3.64	0.00	-0.02%	3.28	3.27	-0.01	-0.18%
LB9	2.72	2.72	0.00	0.03%	2.85	2.85	0.00	0.14%
LB10	2.68	2.70	0.02	0.59%	2.72	2.72	0.00	0.12%
LB11	3.58	3.62	0.03	0.94%	2.93	2.94	0.01	0.33%
LB12	2.98	3.02	0.04	1.29%	2.83	2.91	0.07	2.57%
LB13	2.73	2.77	0.04	1.44%	2.64	2.69	0.05	1.86%
LB14	2.74	2.80	0.06	2.17%	2.65	2.72	0.07	2.73%
LB15	2.96	3.02	0.06	1.99%	2.76	2.83	0.06	2.35%
LB16	2.94	2.97	0.02	0.84%	2.79	2.81	0.02	0.74%
LB17	3.23	3.26	0.03	1.07%	2.94	2.98	0.04	1.29%
LB18	3.20	3.21	0.01	0.36%	3.04	3.06	0.02	0.69%
LB19	3.23	3.24	0.00	0.12%	3.11	3.13	0.01	0.48%
LB20	3.29	3.29	0.00	0.01%	2.97	2.97	-0.01	-0.26%
LB21	3.04	3.04	0.00	0.07%	3.07	3.04	-0.03	-0.85%
LB22	3.25	3.27	0.02	0.60%	3.21	3.22	0.01	0.31%
LB23	3.44	3.49	0.05	1.44%	3.29	3.30	0.01	0.43%
LB24	3.46	3.48	0.02	0.54%	3.25	3.24	-0.01	-0.23%
LB25	3.80	3.80	0.00	0.03%	3.36	3.36	0.00	-0.14%
LB26	3.54	3.54	0.00	0.04%	3.30	3.30	0.00	-0.12%
LB27	3.07	3.07	0.00	0.00%	3.34	3.34	-0.01	-0.16%
LB28	2.61	2.62	0.00	0.08%	2.91	2.91	0.00	-0.04%
LB29	2.97	2.97	0.00	0.00%	3.01	3.00	-0.01	-0.18%
LB30	3.22	3.24	0.01	0.35%	3.12	3.13	0.01	0.47%
LB31	3.31	3.32	0.01	0.36%	3.14	3.17	0.03	0.86%
LB32	3.23	3.27	0.04	1.12%	2.98	3.03	0.05	1.57%
LB33	3.01	3.03	0.02	0.57%	2.88	2.90	0.02	0.64%
LB34	2.96	2.98	0.02	0.81%	2.79	2.83	0.04	1.48%
LB35	3.11	3.12	0.01	0.38%	2.95	3.00	0.05	1.68%
LB36	2.95	2.95	0.00	-0.09%	2.93	2.91	-0.02	-0.62%
LB37	3.09	3.09	0.01	0.16%	3.07	3.10	0.03	0.83%
LB38	3.39	3.40	0.01	0.22%	3.15	3.16	0.02	0.53%

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Summary of Impacts for Scenario W30H								
Point ID	Significant Wave Height Hs (ft.)				Mean Wave Period Tm10 (sec.)			
	WOP (ft)	WP (ft)	Dif. (ft)	% Dif	WOP (sec)	WP (sec)	Dif. (sec)	% Dif
LB39	3.55	3.56	0.01	0.15%	3.18	3.18	0.01	0.21%
LB40	3.35	3.36	0.01	0.28%	3.10	3.11	0.01	0.44%
P41	3.14	4.27	1.13	36.07%	3.08	3.23	0.14	4.67%
P42	2.95	4.11	1.15	38.94%	3.05	3.20	0.16	5.16%
P43	2.95	3.66	0.71	23.94%	2.79	2.97	0.18	6.32%
P44	2.73	3.48	0.75	27.53%	2.65	2.86	0.21	7.88%
P45	2.93	3.76	0.83	28.23%	2.77	2.96	0.19	6.89%
P46	3.09	4.02	0.93	30.11%	2.82	3.09	0.27	9.66%
P47	3.10	3.96	0.85	27.54%	2.84	3.04	0.20	6.89%
P48	3.08	3.57	0.49	15.81%	2.87	2.90	0.03	1.01%
P49	3.15	3.82	0.68	21.49%	2.91	3.01	0.10	3.52%
P50	3.33	4.34	1.01	30.23%	2.99	3.24	0.25	8.37%
P51	3.47	4.11	0.64	18.37%	3.17	3.20	0.03	0.90%
P52	3.51	4.19	0.68	19.36%	3.18	3.21	0.02	0.78%
P53	3.52	4.66	1.14	32.55%	3.22	3.41	0.19	5.92%
P54	3.54	4.14	0.60	17.07%	3.20	3.14	-0.06	-1.76%
P55	3.48	4.42	0.94	27.09%	3.25	3.38	0.13	4.03%
P56	3.48	4.07	0.60	17.17%	3.27	3.20	-0.06	-1.94%
P57	3.29	4.11	0.82	24.90%	3.10	3.21	0.11	3.55%
P58	3.27	3.74	0.47	14.37%	3.06	3.05	-0.02	-0.58%
P59	3.70	4.45	0.75	20.30%	3.24	3.26	0.02	0.53%
P60	3.50	4.84	1.34	38.11%	3.24	3.46	0.23	6.98%
P61	3.56	4.88	1.32	36.98%	3.22	3.44	0.22	6.81%
P62	3.46	4.31	0.84	24.30%	3.06	3.23	0.17	5.62%
P63	3.65	4.14	0.49	13.51%	3.30	3.25	-0.06	-1.73%
P64	3.51	4.61	1.10	31.36%	3.12	3.37	0.25	8.11%
P65	3.54	4.30	0.76	21.54%	3.20	3.31	0.11	3.44%
P66	3.73	4.39	0.66	17.64%	3.25	3.30	0.04	1.38%

Table 6-5 Summary of Impacts for Scenario W30H

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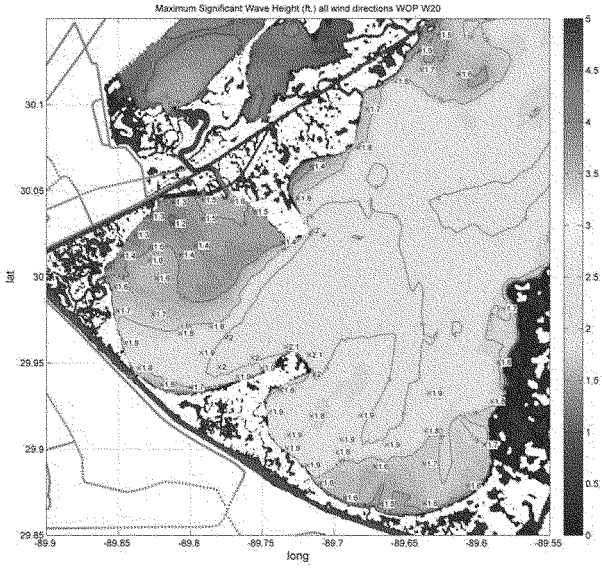
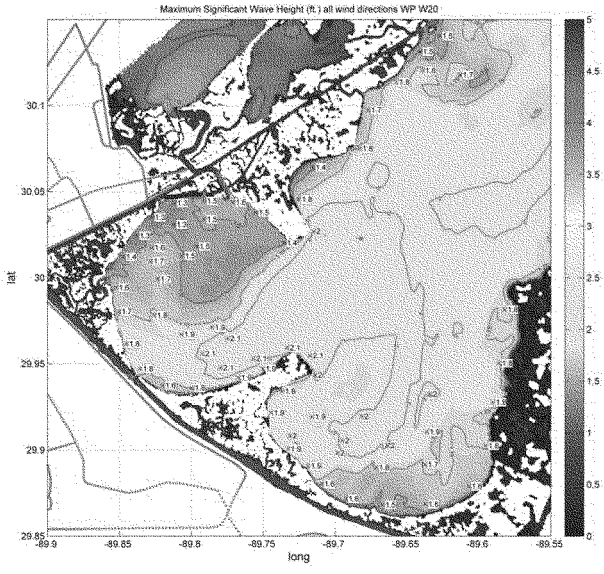
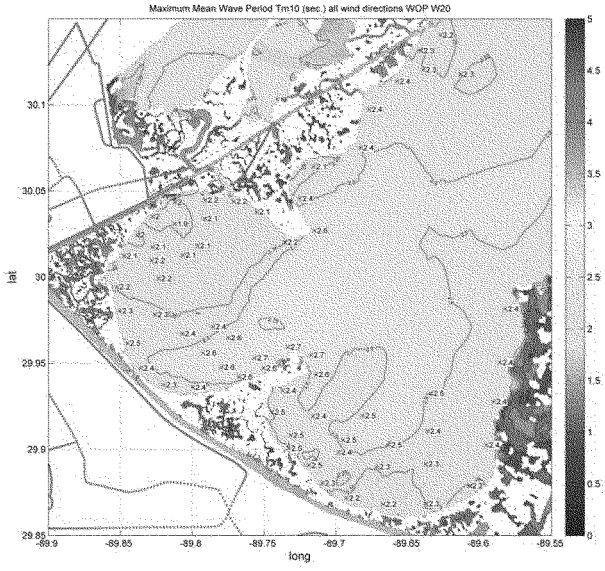
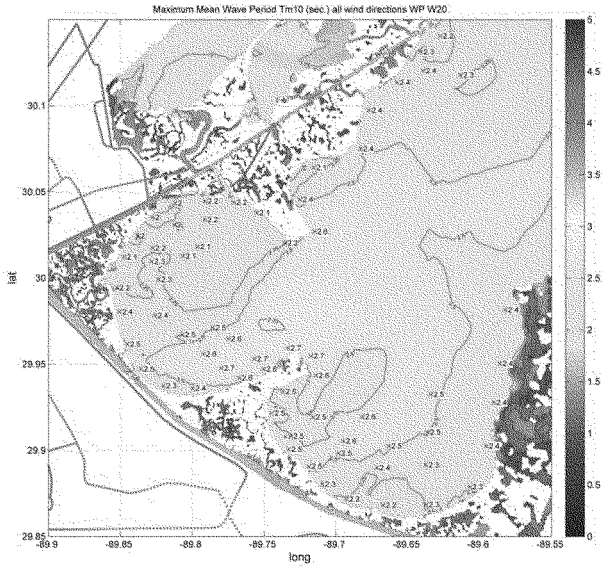
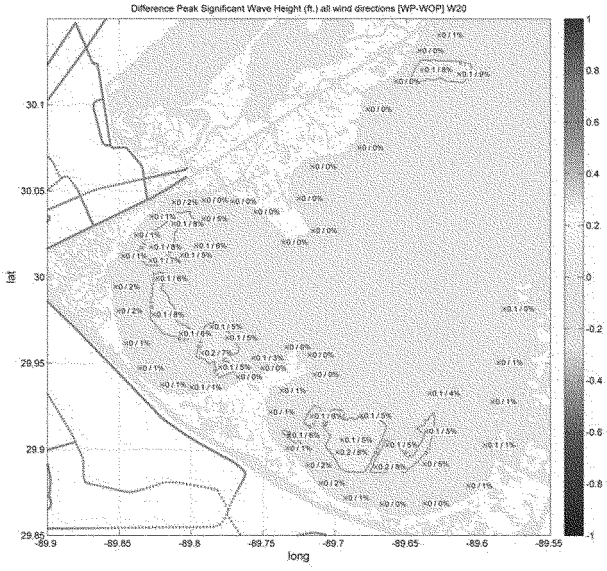
7 Appendix B - 2D SWAN Output

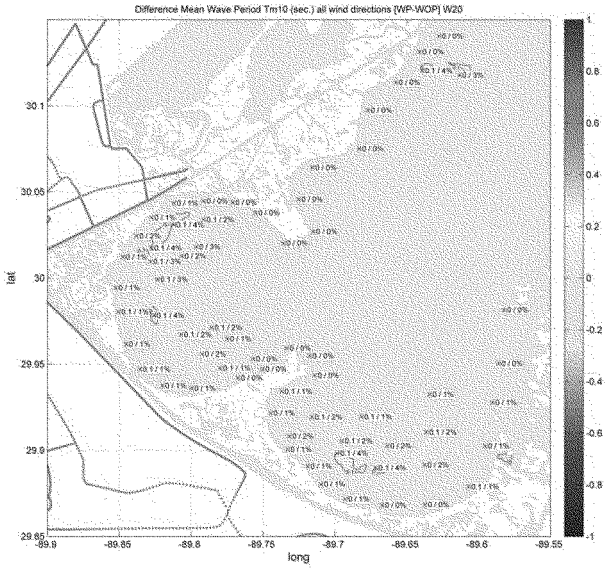


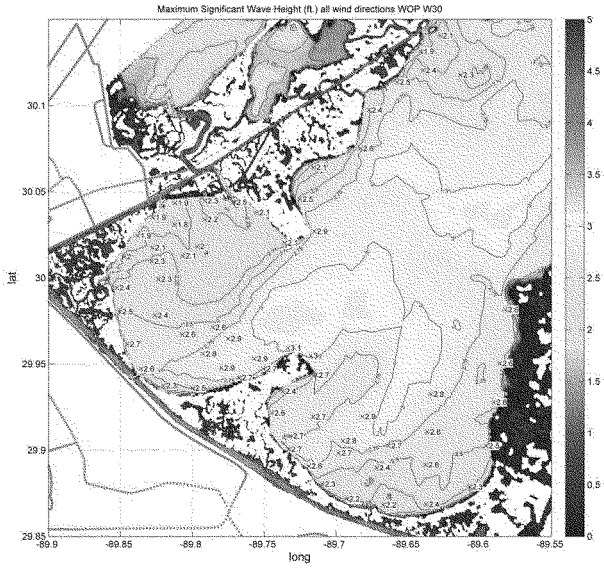


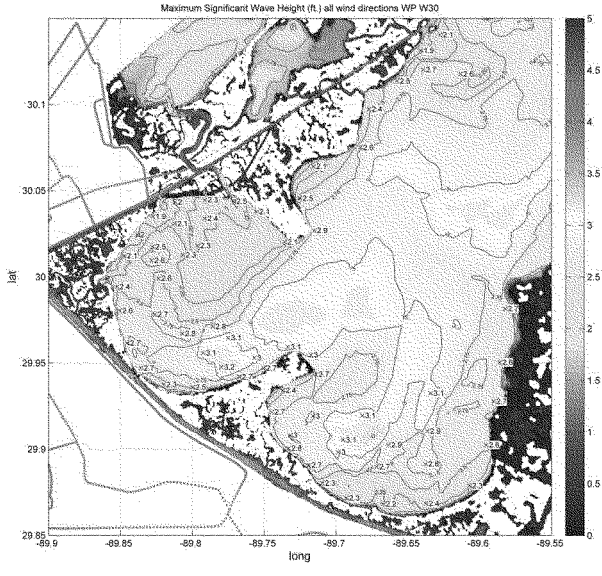

Maximum Mean Wave Period Tm10 (sec.) all wind directions WOP W20
lat
long
30.1
30.05
30
29.95
29.9
29.85
-89.9
-89.85
-89.8
-89.75
-89.7
-89.65
-89.6
-89.55
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


Maximum Mean Wave Period Tm10 (sec.) all wind directions WP W20
lat
long
30.1
30.05
30
29.95
29.9
29.85
-89.9
-89.85
-89.8
-89.75
-89.7
-89.65
-89.6
-89.55
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


Difference Peak Significant Wave Height (ft.) all wind directions [WP-WOP] W20
lat
long
30.1
30.05
30
29.95
29.9
29.85
-89.9
-89.85
-89.8
-89.75
-89.7
-89.65
-89.6
-89.55
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1


Difference Mean Wave Period Tm10 (sec.) all wind directions [WP-WOP] W20
lat
long
30.1
30.05
30
29.95
29.9
29.85
-89.9
-89.85
-89.8
-89.75
-89.7
-89.65
-89.6
-89.55
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1


Maximum Significant Wave Height (ft.) all wind directions WOP W30
lat
long
30.1
30.05
30
29.95
29.9
29.85
-89.9
-89.85
-89.8
-89.75
-89.7
-89.65
-89.6
-89.55
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


Maximum Significant Wave Height (ft.) all wind directions WP W30
lat
long
30.1
30.05
30
29.95
29.9
29.85
-89.9
-89.85
-89.8
-89.75
-89.7
-89.65
-89.6
-89.55
5
4.5
4
3.5
3
2.5
2
1.5
1
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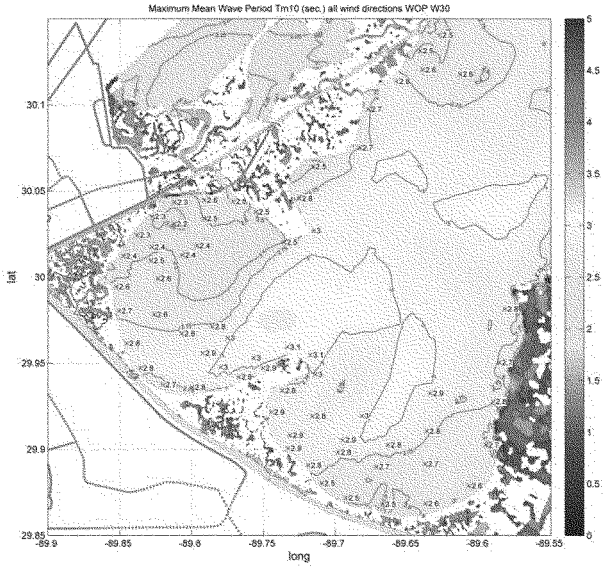
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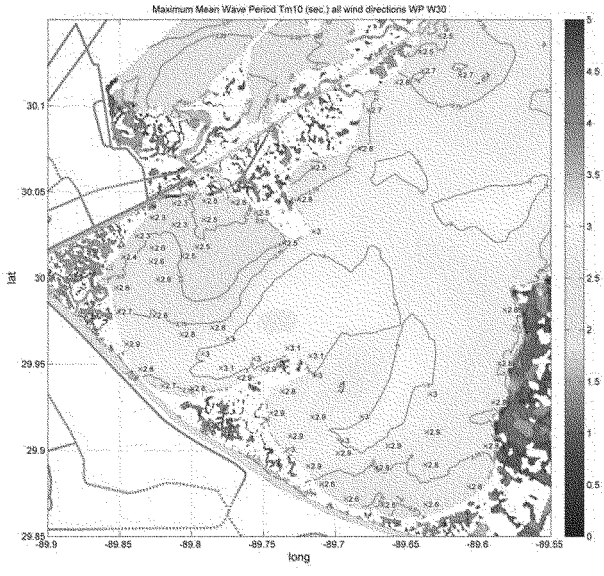
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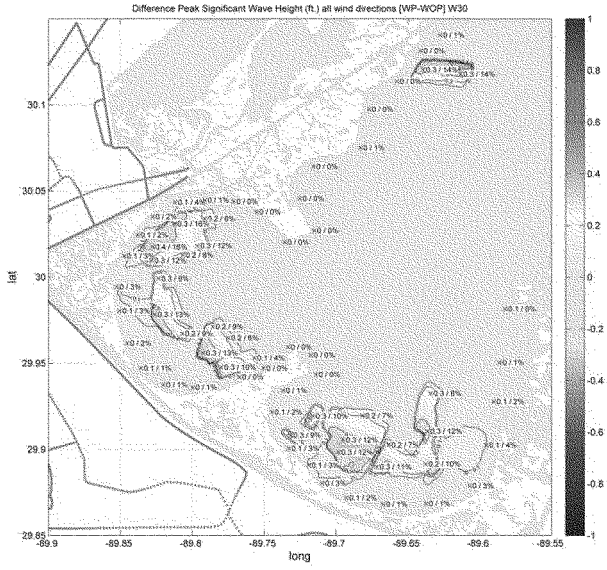
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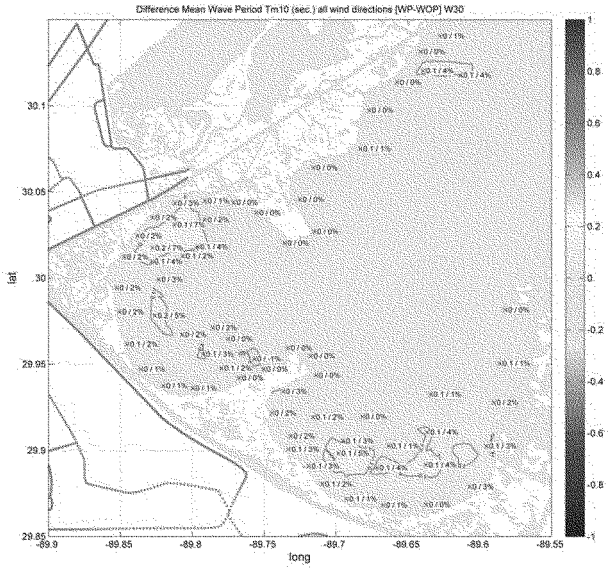
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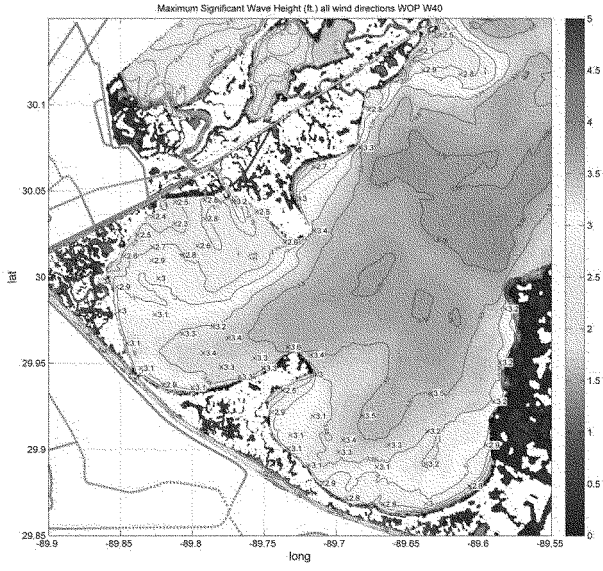
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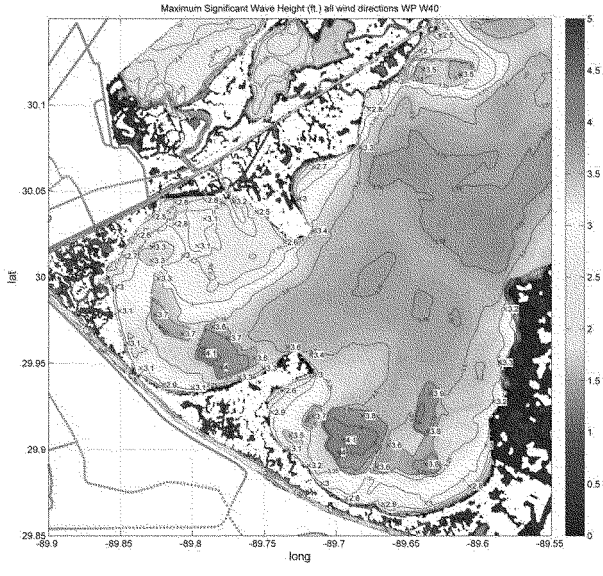
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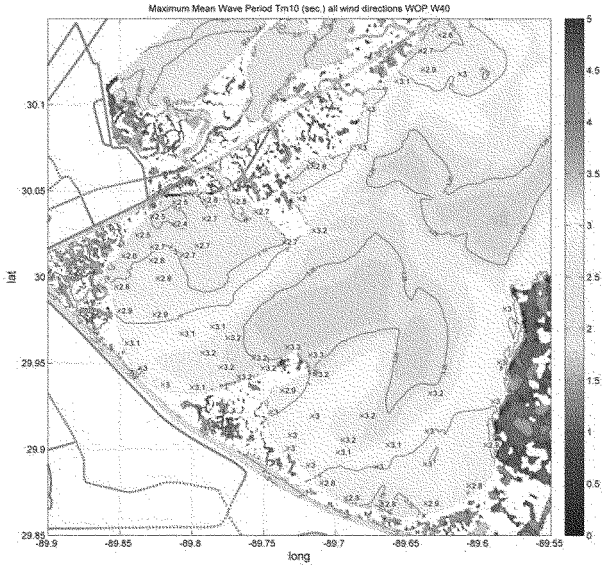
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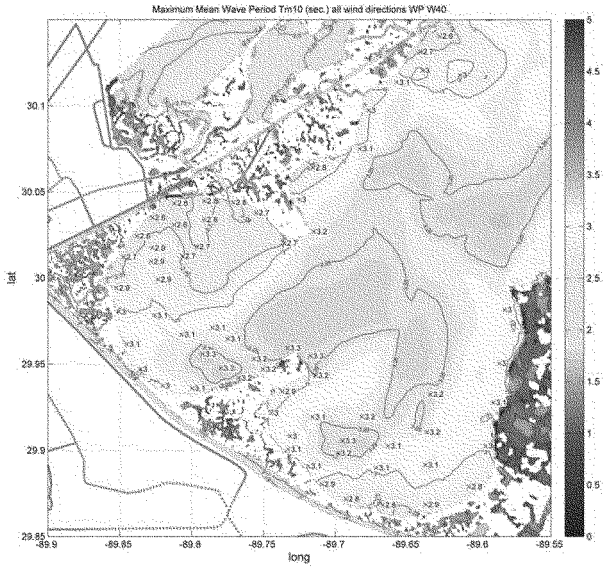
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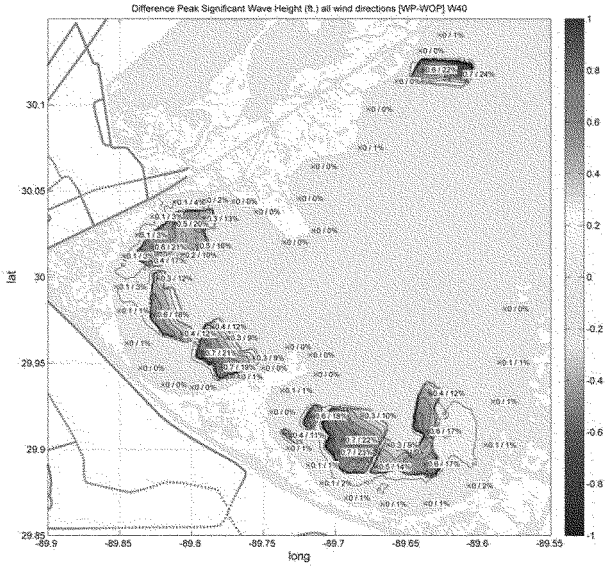
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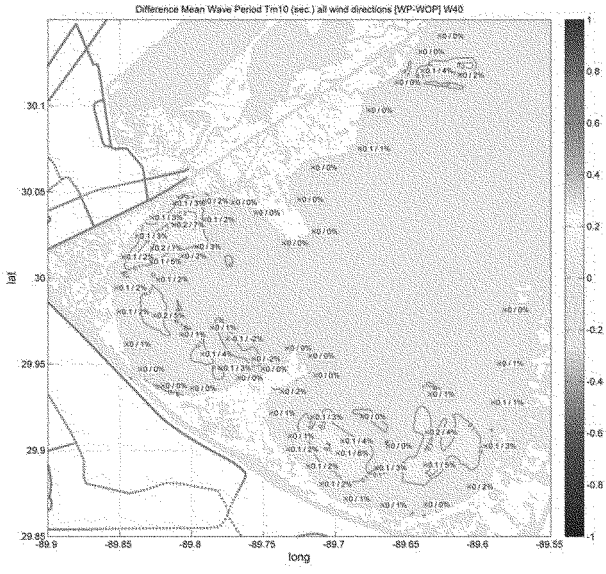
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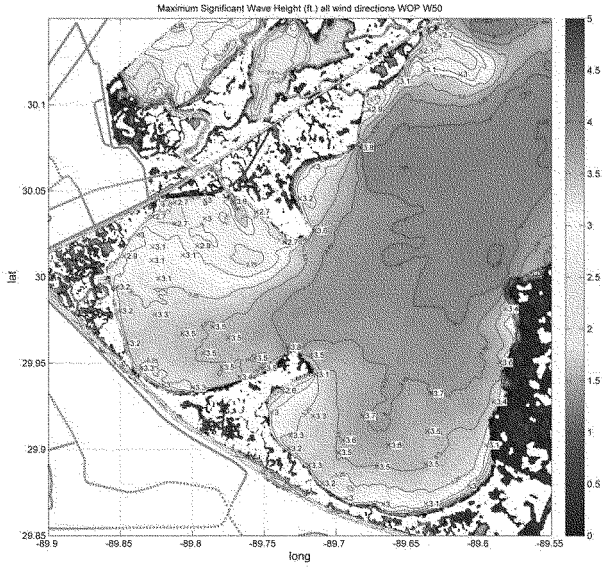
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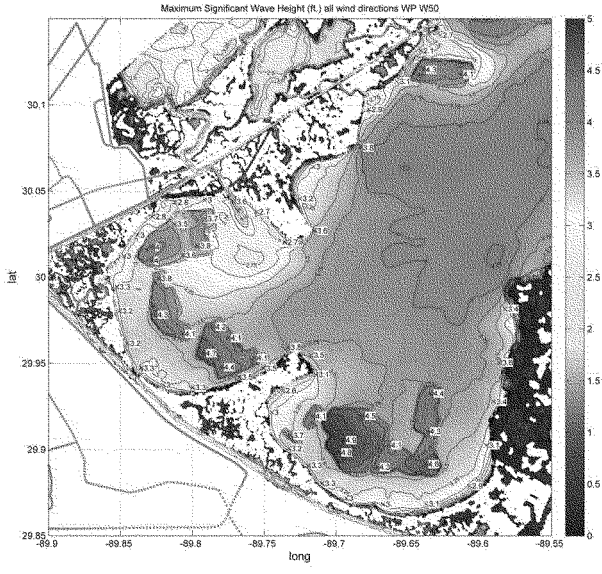
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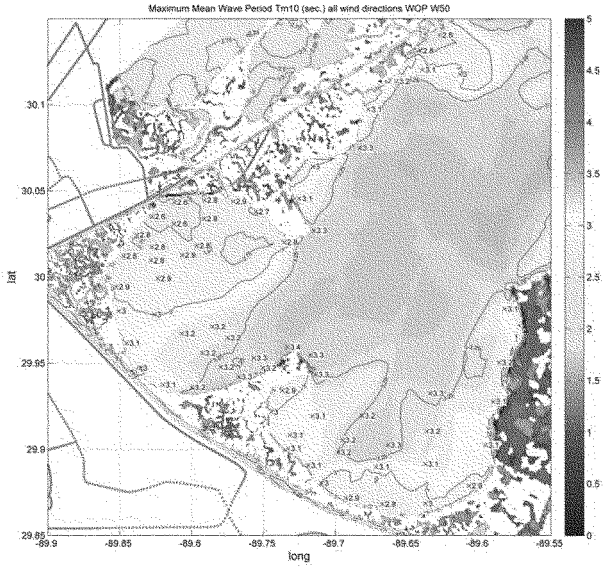
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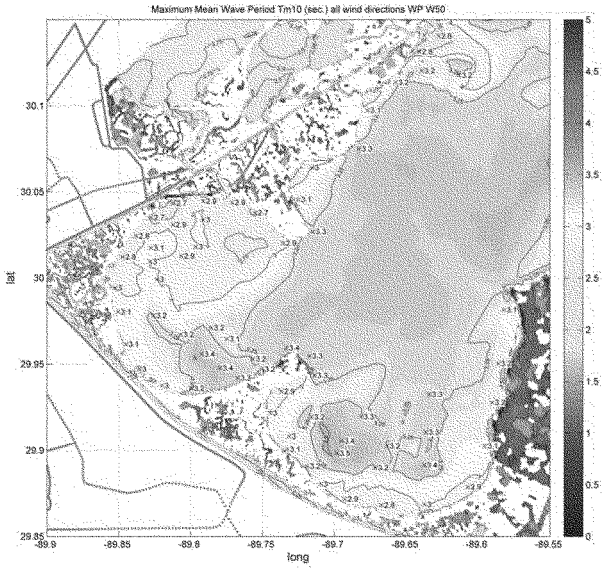
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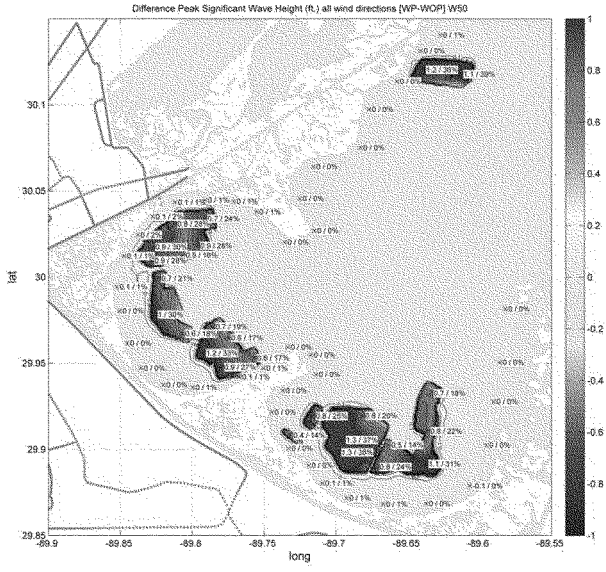
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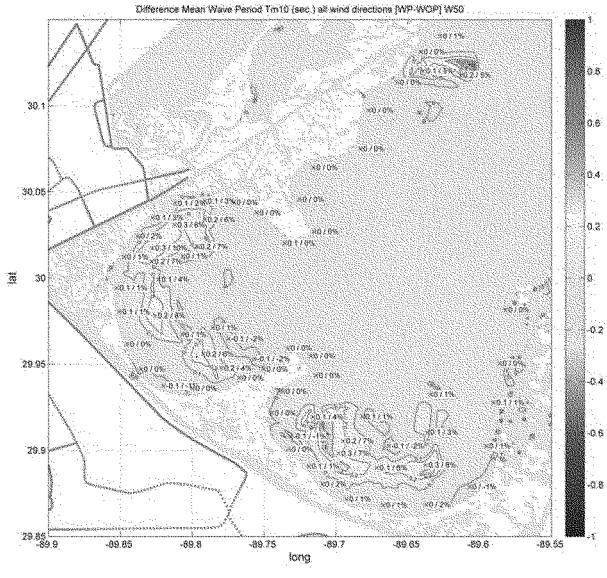
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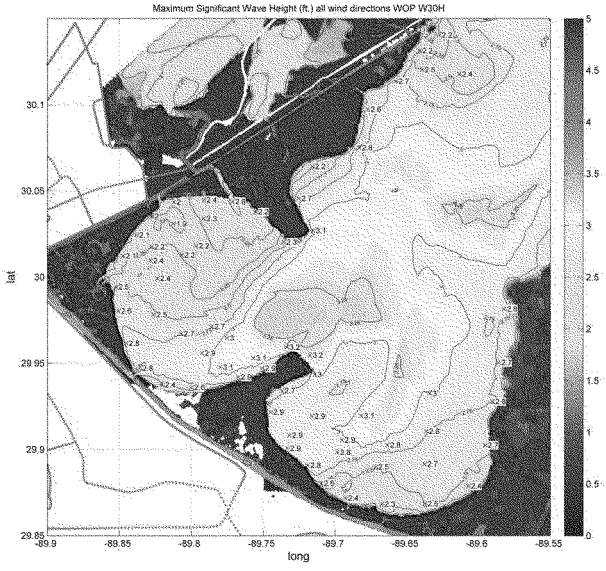
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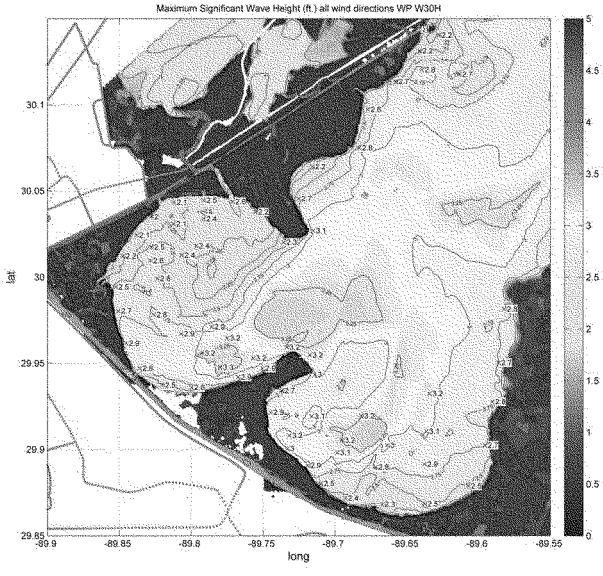
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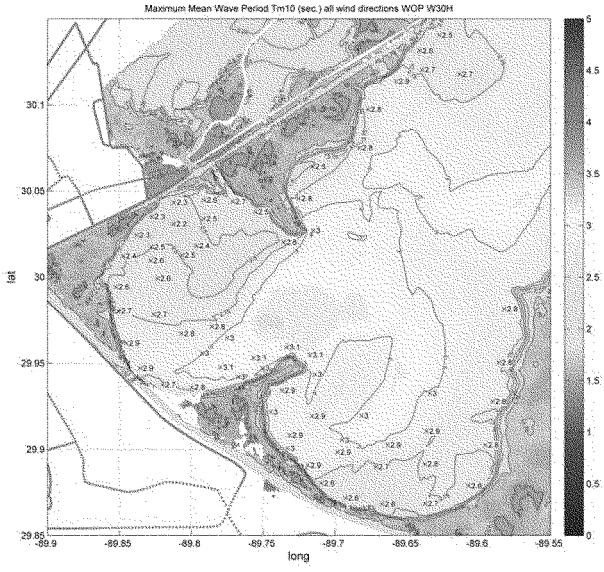
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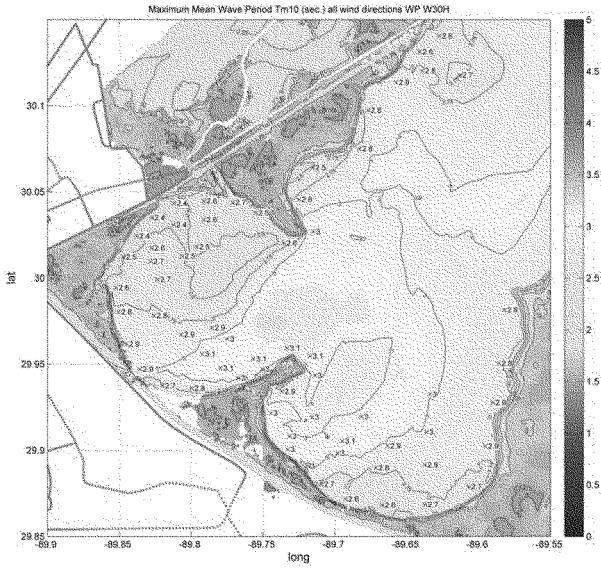
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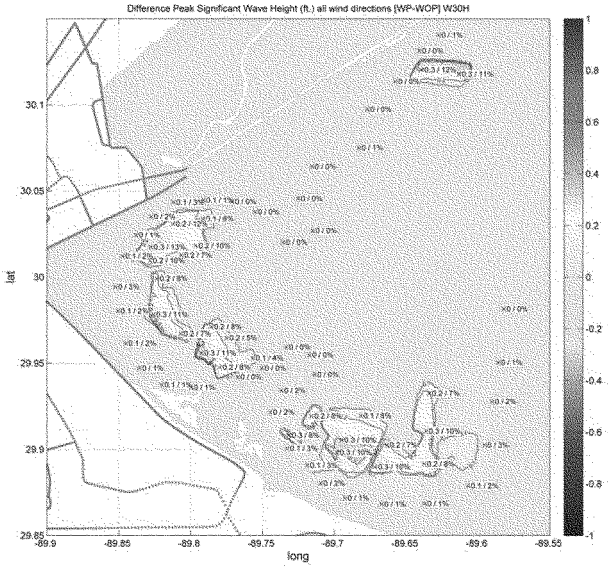
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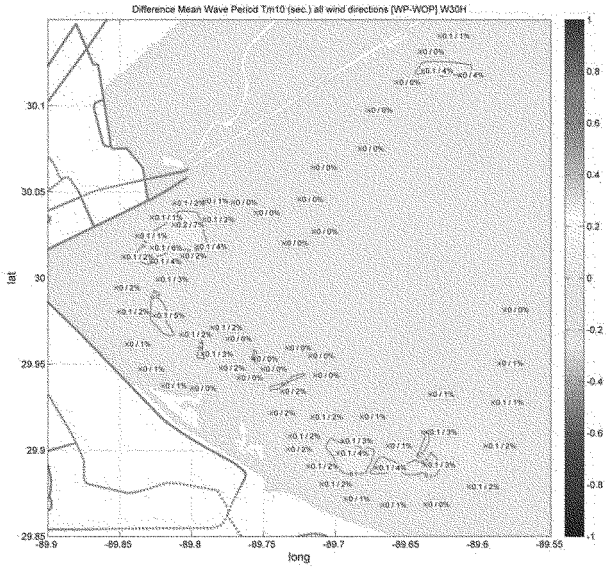
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ANNEX 3

WATER QUALITY ANALYSIS

MISSISSIPPI RIVER – GULF OUTLET (MRGO)
ECOSYSTEM RESTORATION STUDY
LOUISIANA AND MISSISSIPPI

Preliminary Assessment of Potential Water Quality Impacts for a Proposed Freshwater Diversion in the Vicinity of Violet, Louisiana

REVISED DRAFT SUMMARY DOCUMENT

Submitted: March 12, 2010

New Orleans District

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BACKGROUND

The Mississippi River Gulf Outlet (MRGO) Ecosystem Restoration Plan Feasibility Study is being conducted to comply with the Water Resources Development Act (WRDA) of 2007 (P.L. 110-114) Section 7013 to develop a plan to restore the areas affected by the MRGO, and to consider diversions of fresh water from the Mississippi River to restore the Lake Borgne ecosystem. Prior investigations under Section 7013 have determined that a freshwater diversion at or near Violet, Louisiana is needed to achieve ecosystem restoration goals for the Biloxi Marsh and Lake Borgne ecosystem (Salinity Working Group 2009).

Section 3083 of the 2007 WRDA authorizes the diversion of freshwater at or near Violet for the purposes of reducing salinity in Western Mississippi Sound, enhancing oyster production, and promoting the sustainability of coastal wetlands. Reductions in salinity are required for enhancing oyster production in this area (Salinity Working Group 2009) and to promote the sustainability of coastal wetlands within the Lake Borgne and Biloxi Marsh region (Salinity Working Group 2009) via the benefits to marsh vegetation of salinity reduction (i.e., Caffey et al. 2002). Section 3083 of the 2007 WRDA states The project shall be designed to meet, or maximize the ability to meet, the salinity levels identified in the feasibility study of the Corps of Engineers entitled "Mississippi and Louisiana Estuarine Areas: Freshwater Diversion at Lake Pontchartrain Basin and Mississippi Sound" (1984). The Salinity Working Group's summary report (2009) for the MRGO Ecosystem Restoration Plan validated the use of the Chatry et al. (1983) targets for ecosystem restoration.

Preliminary investigations have determined that a diversion of Mississippi River water near the town of Violet could be designed to allow for sufficient freshwater flow to establish an appropriate salinity regime (as defined by Chatry et al. 1983) 4 to 5 years out of 10 within the Biloxi Marsh (Preliminary Hydrodynamic and Hydraulic Modeling for a Proposed Freshwater Diversion in the Vicinity of Violet, Louisiana; USACE 2009).

This study builds on prior documentation of the changes in salinity expected in Lake Borgne and the Biloxi Marsh, as well as West Mississippi Sound, based on design features capable of producing sufficient freshwater flows to reach salinity targets in the Biloxi Marsh (Preliminary Hydrodynamic and Hydraulic Modeling for a Proposed Freshwater Diversion in the Vicinity of Violet, Louisiana; USACE 2009). This prior modeling effort used the University of New Orleans (UNO) Mass Balance Model to predict changes in salinity on a monthly basis throughout Lake Borgne and the Biloxi Marsh. Freshwater diversions to reduce salinities in Biloxi Marsh are necessary during the month of May, with no apparent need for salinity depression in remaining months. Modeling also indicates that the combination of the closure of the MRGO, the closure of the existing connection between the MRGO and Lake Borgne (just northeast of Bayou Dupre) and diversions of around 7,000 cubic feet per second (cfs) during the months of April and May would be capable of reducing salinities within the Biloxi Marsh by 2 to 3 part per thousand (ppt) in May (on average). In months other than April and May, a diversion rate of approximately 1,000 cfs is proposed to allow for restoration of historical salinities within the Central Wetlands, allowing for the reestablishment of historical cypress stands. The 2009 USACE study indicated that salinity values in Biloxi Marsh are heavily dependent upon the flow of the Pearl River. It is thus important to note that water quality in West Mississippi Sound and Biloxi Marsh during most of the year, even with diversions, would be more strongly influenced by the Pearl River than by the proposed diversion at Violet.

This report examines the potential water quality impacts to Lake Borgne, Biloxi Marsh, and West Mississippi Sound associated with the implementation of a salinity reduction project that

incorporates the diversion of Mississippi River water near Violet and the closure of the inlet connecting MRGO and Lake Borgne near Bayou Dupre.

The report consists of three main parts. The first part describes the role that freshwater diversions would play in the restoration of cypress stands in the Central Wetlands. The second part summarizes water quality standards for the State of Louisiana, and compares and contrasts water quality within the regions of the Mississippi River, the Central Wetlands, the MRGO, Lake Borgne, and the Biloxi Marsh. Potential changes in water quality are discussed in relation to existing water quality standards. The third part of the report focuses on the potential impacts of the diversion project on common indicators of eutrophication in estuarine systems. This third portion relies upon empirically-derived predictive models that were developed for Lake Borgne, the Biloxi Marsh, and West Mississippi Sound. This portion also summarizes the impacts of the closure of the MRGO on dissolved oxygen levels within MRGO and Lake Borgne, and describes potential changes in dissolved oxygen levels within MRGO and Lake Borgne that might occur with freshwater diversions.

PART ONE
ROLE OF FRESHWATER DIVERSIONS ON RESTORATION OF CYPRESS IN THE CENTRAL WETLANDS

The loss of large extensive areas of bald cypress (*Taxodium distichum*) swamps along the Gulf of Mexico has been attributed primarily to the effects of saltwater intrusion (Conner and Inabinette 2005, Krauss et al. 2000). Although harvesting of adult trees has had obvious and documented impacts in the Central Wetlands, the inability of harvested swamps to regenerate over time in areas such as the Central Wetlands is likely due to salinity alterations. As outlined later in this report (Table 2.11), the median salinity value for the Central Wetlands region is in excess of 9 ppt, although the majority of salinity readings appear to have been taken in either Bayou Bienvenue or the Violet Canal, rather than in the more interior portions of the Central Wetlands. These data support the contention that salinity levels in the Central Wetlands are currently too high to allow for the restoration of cypress trees.

Recent restoration efforts throughout the Gulf of Mexico coastal region have focused on the planting of "moderately" (i.e. 1-4 ppt) salt tolerant bald cypress in former swamps (Conner and Inabinette 2005, Krauss et al. 2000, Krause 1998, Allen et al. 1994b). Studies indicate that genotypic screening of bald cypress may improve growth and vigor of seedlings planted in wetlands impacted by saltwater intrusion (Krauss et al. 2000). Manipulative studies have indicated substantial intraspecific variation in salt tolerance within bald cypress populations (Allen et al. 1997), but limited information exists from field studies (Krauss et al. 2000). More recent studies have concluded that germination (Krauss et al. 2000) and subsequent seedling success (Conner and Inabinette 2005) under low and moderate salinity conditions are greater for Louisiana bald cypress in comparison with bald cypress in other parts of the southeastern U.S. These findings are especially relevant to restoration efforts focused on the Central Wetlands and other areas of coastal Louisiana.

Bald cypress vary in their tolerance to salinity regimes (Krauss et al. 1998, 2000). For example, at 2.8 ppt salinity (during the growing season) seed germination ranged from 94 to 58 percent of optimum values (obtained in freshwater; Krauss et al. 1998). Following germination, herbivory and competition may limit or prevent successful establishment of bald cypress. Higher salinity field conditions (> 6 ppt) severely limit bald cypress seed germination. Based on these results, bald cypress identified as moderately salt-tolerant based on physiological and morphological parameters may have equally successful seed germination under similarly saline conditions.

Although bald cypress typically occur at low salinities (Penfound and Hathaway 1938, Harlow and Harrar 1969), they are generally considered to be salt sensitive (Brown and Montz 1986, Pezeshki et al. 1986, 1987). In addition, bald cypress exhibit a variable relationship between salt tolerance at the germination stage and salt tolerance at the seedling stage (Allen 1994, Allen et al. 1994b, Pezeshki et al. 1995). Although individual trees and stands of bald cypress occur at sites with moderately high salinity (Pezeshki et al. 1990, Yanosky et al. 1995) 8.9 ppt is reportedly the maximum salinity tolerated by mature bald cypress in southern Louisiana (Penfound and Hathaway 1938). In other studies, constant salinity levels of 8 ppt resulted in 27 percent mortality of seedlings (Allen et al. 1994) and all seedlings were killed at 10 ppt (Conner 1994). These reports indicate that 8 and 10 ppt may be the threshold for most bald cypress. As salinity values in the Central Wetlands often exceed these threshold values (median salinity of 9.3 ppt) it appears that current conditions in the Central Wetlands are such that salinities are too high for restoration of the historical cypress forest without supplemental freshwater inflows sufficient in magnitude to allow for a system-wide reduction in salinity levels.

In a relevant study (Conner and Inabinette 2005), bald cypress seeds from estuaries in six states in the southeastern U.S. (NC, SC, AL, FL, MS, and AL) were germinated in freshwater and 2 year seedlings were planted in abandoned rice fields in SC. The seed from LA came from an area of degraded forests along the MRGO. Salinity levels at the field site in SC reached 18.5 ppt during 2001 at the peak of the worst drought on record, and by 2002 the only seedlings surviving were those from LA, AL, and FL. After 5 years in the field, LA seedlings had the lowest mortality rate (27 percent), compared with 78 percent for AL seedlings and 85 percent for FL seedlings.

Effler and Goyer (2006) concluded from their experiments that water tupelo sapling growth is favored over bald cypress in freshwater swamps experiencing land subsidence or prolonged flooding, but when subsidence or prolonged flooding is coupled with salt, bald cypress trees have greater success. The authors suggest that based on these results, river diversions may be a viable management tool for improving health and productivity of declining forested wetlands. Further biologic and genetic evaluations of trees growing in the LA site may determine if they represent a source of bald cypress with greater salinity tolerance. Also, brackish water seed sources do not necessarily produce greater salt tolerance and since salinity has increased over only the past few decades. Therefore, the most salt tolerant bald cypress sources may actually be located hundreds of miles from the coast (Conner and Inabinette 2005).

PART TWO
WATER QUALITY STANDARDS AND CURRENT WATER QUALITY

1. General. This section describes, compares, and evaluates existing water quality in a segment of the Mississippi River near New Orleans and in an adjacent estuarine area, the Central Wetlands Area (CWA), Lake Borgne Wetlands Area (LBWA), Lake Borgne, Mississippi River Gulf Outlet (MRGO) and the Biloxi Marsh Complex. The comparative evaluation of water quality provides a basis for identifying potential water quality related impacts associated with diverting Mississippi River water to the Biloxi Marsh to reduce the water salinity for the encouragement of oyster production. The section considers the applicable standards and criteria used to gage existing water quality in the area. Where available data permits, the existing physical, chemical, and bacteriological quality of the Mississippi River, CWA, LBWA, Lake Borgne, MRGO and the Biloxi Marsh waters will be considered and the potential water quality impacts of the project will be identified.

2. Water Quality Standards and Criteria. Both the Louisiana Department of Environmental Quality (LDEQ) and the US Environmental Protection Agency (EPA) have established ambient water quality criteria applicable to surface waters in the State of Louisiana. These criteria are discussed in the following paragraphs.

a. Applicable Louisiana state standards. The LDEQ has established general written water quality criteria which are applicable to all waters of the State of Louisiana. The general written standards relate to the condition of the water as affected by waste discharges or human activity as opposed to purely natural phenomena, and are as follows. The criteria were last revised in December 2009.

(1) Descriptive Water Quality Standards

(a) Aesthetics. The waters of the state shall be maintained in an aesthetically attractive condition and shall meet the generally accepted aesthetic qualifications.

1) All waters shall be free from such concentrations of substances attributable to wastewater or other discharges sufficient to:

i. settle to form objectionable deposits;

ii. float as debris, scum, oil, or other matter to form nuisances or to negatively impact the aesthetics;

iii. result in objectionable color, odor, taste, or turbidity;

iv. injure, be toxic, or produce demonstrated adverse physiological or behavioral responses in humans, animals, fish, shellfish, wildlife, or plants; or

v. produce undesirable or nuisance aquatic life.

(b) Color. Water color shall not be increased to the extent that it will interfere with present usage or projected future use of the state's water bodies.

1) Waters shall be free from significant increases over natural background color levels.

2) A source of drinking water supply shall not exceed 75 color units on the platinum-cobalt scale.

3) No increases in true or apparent color shall reduce the level of light penetration below that required by desirable indigenous species of aquatic life.

(c) Floating, Suspended, and Settleable Solids. There shall be no substances present in concentrations sufficient to produce distinctly visible solids or scum, nor shall there be any formation of long-term bottom deposits of slimes or sludge banks attributable to waste discharges from municipal, industrial, or other sources including agricultural practices, mining, dredging, and the exploration for and production of oil and natural gas. The administrative authority may exempt certain short-term activities permitted under Sections 402 or 404 and certified under Section 401 of the Clean Water Act, such as maintenance dredging of navigable waterways or other short-term activities determined by the state as necessary to accommodate legitimate uses or emergencies or to protect the public health and welfare.

(d) Taste and Odor. Taste- and odor- producing substances in the waters of the state shall be limited to concentrations that will not interfere with the production of potable water by conventional water treatment methods or impart unpalatable flavor to food fish, shellfish, and wildlife, or result in offensive odors arising from the waters, or otherwise interfere with the designated water uses.

(e) Toxic Substances. No substances shall be present in the waters of the state or the sediments underlying said waters in quantities that alone or in combination will be toxic to human, plant, or animal life or significantly increase health risks due to exposure to the substances or consumption of contaminated fish or other aquatic life. The numerical criteria (LAC 33:IX.1113.C.6) specify allowable concentrations in water for several individual toxic substances to provide protection from the toxic effects of these substances. Requirements for the protection from the toxic effects of other toxic substances not included in the numerical criteria and required under the general criteria are described in LAC 33:IX.1121.

(f) Oil and Grease. Free or floating oil or grease shall not be present in quantities large enough to interfere with the designated water uses, nor shall emulsified oils be present in quantities large enough to interfere with the designated uses.

(g) Foaming or Frothing Materials. Foaming or frothing materials of a persistent nature are not permitted.

(h) Nutrients. The naturally occurring range of nitrogen-phosphorous ratios shall be maintained. This range shall not apply to designated intermittent streams. To establish the appropriate range of ratios and compensate for natural seasonal fluctuations, the administrative authority will use site-specific studies to establish limits for nutrients. Nutrient concentrations that produce aquatic growth to the extent that it creates a public nuisance or interferes with designated water uses shall not be added to any surface waters.

(i) Turbidity. Turbidity other than that of natural origin shall not cause substantial visual contrast with the natural appearance of the waters of the state or impair any designated water use. Turbidity shall not significantly exceed background; background is defined as the natural condition of the water. Determination of background will be on a case-by-case basis.

As a guideline, maximum turbidity levels, expressed as nephelometric turbidity units (NTU), are established and shall apply for the following named water bodies and major aquatic habitat types of the state:

1) Red, Mermentau, Atchafalaya, Mississippi, and Vermilion Rivers and Bayou Teche—150 NTU;

2) estuarine lakes, bays, bayous, and canals—50 NTU;

3) Amite, Pearl, Ouachita, Sabine, Calcasieu, Tangipahoa, Tickfaw, and Tchefuncte rivers—50 NTU;

4) freshwater lakes, reservoirs, and oxbows—25 NTU;

5) designated scenic streams and outstanding natural resource waters not specifically listed in Clauses B.9.b.i-iv of this Section—25 NTU; and

6) for other state waters not included in Clauses B.9.b.i-v of this Section, and in water body segments where natural background turbidity exceeds the values specified in these clauses, turbidity in NTU caused by any discharges shall be restricted to the appropriate background value plus 10 percent. This shall not apply to designated intermittent streams.

The administrative authority may exempt for short periods certain activities permitted under Sections 402 or 404 and certified under Section 401 of the Clean Water Act, such as maintenance dredging of navigable waterways or other short-term activities that the state determines are necessary to accommodate legitimate uses or emergencies or to protect the public health and welfare.

(j) Flow. The natural flow of state waters shall not be altered to such an extent that the basic character and water quality of the ecosystem are adversely affected except in situations where alterations are necessary to protect human life or property. If alterations to the natural flow are deemed necessary, all reasonable steps shall be taken to minimize the adverse impacts of such alterations. Additionally, all reasonable steps shall be taken to mitigate the adverse impacts of unavoidable alterations.

(k) Radioactive Materials. Radioactive materials in the surface waters of the state designated for drinking water supply use shall not exceed levels established pursuant to the Federal Safe Drinking Water Act (P.L. 93-523 et seq.).

(l) Biological and Aquatic Community Integrity

1) The biological and community structure and function in state waters shall be maintained, protected, and restored except where not attainable and feasible as defined in LAC 33:IX.1109. This is the ideal condition of the aquatic community inhabiting the unimpaired water bodies of a specified habitat and region as measured by community structure and function. The biological integrity will be guided by the fish and wildlife propagation use designated for that particular water body. Fish and wildlife propagation uses are defined in LAC 33:IX.1111.C. The condition of these aquatic communities shall be determined from the measures of physical, chemical, and biological characteristics of each surface water body type, according to its designated use (LAC 33:IX.1123). Reference site conditions will represent naturally attainable conditions. These sites should be the least impacted and most

representative of water body types. Such reference sites or segments of water bodies shall be those observed to support the greatest variety and abundance of aquatic life in the region as is expected to be or has been recorded during past surveys in natural settings essentially undisturbed by human impacts, development, or discharges. This condition shall be determined by consistent sampling and reliable measures of selected, indicative communities of animals (i.e., fish, invertebrates, etc.) and/or plants as established by the department and may be used in conjunction with acceptable chemical, physical, and microbial water quality measurements and records as deemed appropriate for this purpose.

2) Assessment of Biological Integrity for Wetlands Approved for Wastewater Assimilation Projects Pursuant to the Water Quality Management Plan, Volume 3, Section 10, Permitting Guidance Document for Implementing Louisiana Surface Water Quality Standards. Wetland biological integrity will be guided by above-ground wetland vegetative productivity with consideration given to floral diversity. Due to effluent addition, the discharge area of a wetland shall have no more than a 20 percent reduction in the rate of total above-ground wetland productivity over a five-year period as compared to a reference area. The *discharge area* is the area of a wetland directly affected by effluent addition. For each location, the discharge area will be defined by the volume of discharge. The *reference area* is the wetland area that is nearby and similar to the discharge area but that is not affected by effluent addition. Above-ground productivity is a key measurement of overall ecosystem health in the wetlands of south Louisiana. Primary productivity is dependent on a number of factors, and the methods for measurement of above-ground productivity and floral diversity are found in the current Water Quality Management Plan, Volume 3, Section 10, Permitting Guidance Document for Implementing Louisiana Surface Water Quality Standards.

(m) Other Substances and Characteristics. General criteria on other substances and characteristics not specified in this Subsection will be developed as needed.

(2) Numerical Criteria. Numerical criteria identified in LAC 33:IX.1123, Table 2.1, apply to the specified water bodies, and to their tributaries, distributaries, and interconnected streams and water bodies contained in the water management subsegment if they are not specifically named therein, unless unique chemical, physical, and/or biological conditions preclude the attainment of the criteria. In those cases, natural background levels of these conditions may be used to establish site-specific water quality criteria. Those water bodies officially approved and designated by the state and EPA as intermittent streams, man-made water bodies, or naturally dystrophic waters may be excluded from some or all numerical criteria as stated in LAC 33:IX.1109. Although naturally occurring variations in water quality may exceed criteria, water quality conditions attributed to human activities must not exceed criteria when flows are greater than or at critical conditions (as defined in LAC 33:IX.1115.C).

(a) pH. The pH shall fall within the range of 6.0 to 9.0 unless natural conditions exceed this range or where otherwise specified in the table (LAC 33:IX.1123). No discharge of wastes shall cause the pH of a water body to vary by more than one pH unit within the specified pH range for the subsegment where the discharge occurs.

(b) Chlorides, Sulfates, and Total Dissolved Solids. Numerical criteria for these parameters generally represent the arithmetic mean of existing data from the nearest sampling location plus three standard deviations. For estuarine and coastal marine waters subsegments in Table

2.1 that have no listed criteria (i.e., designated N/A), criteria will be established on a case-by-case basis using field determination of ambient conditions and the designated uses. For water bodies not specifically listed in the Numerical Criteria and Designated Table, increases over background levels of chlorides, sulfates, and total dissolved solids may be permitted. Such increases will be permitted at the discretion of the department on a case-by-case basis and shall not cause in-stream concentrations to exceed 250, 250, and 500 mg/L for chlorides, sulfates, and total dissolved solids, respectively, except where a use attainability analysis indicates that higher levels will not affect the designated uses. In permitting such increases, the department shall consider their potential effects on resident biota and downstream water bodies in addition to the background conditions. Under no circumstances shall an allowed increase over background conditions cause any numerical criteria to be exceeded in any listed water body or any other general or numerical criteria to be exceeded in either listed or unlisted water bodies.

(c) Dissolved Oxygen. The statewide dissolved oxygen (DO) values represent minimum criteria for the types of water specified. (That is, a level below the criterion, as opposed to above the criterion, may indicate potential impairment.) These DO criteria are designed to protect indigenous wildlife and aquatic life species associated with the aquatic environment and shall apply except in those water bodies that have ecoregional-specific or site-specific criteria, or where exempted or excluded elsewhere in these standards. DO criteria for specific state water bodies are contained in LAC 33:IX.1123. Naturally occurring variations below the criterion specified may occur for short periods (for a few hours each day). These variations reflect such natural phenomena as the reduction in photosynthetic activity and oxygen production by plants during hours of darkness. However, no waste discharge or human activity shall lower the DO concentration below the specified minimum.

1) Fresh Water. For fresh water, the DO criterion is 5 mg/L. *Fresh warm-water biota* is defined in LAC 33:IX.1105.

2) Estuarine Waters. For estuarine waters, the DO criterion is 4 mg/L.

3) Coastal Marine Waters (Including Nearshore Gulf of Mexico). For coastal marine waters, the DO criterion is 5 mg/L.

(d) Temperature

1) The temperature criteria enumerated in the tables in most cases represent maximum values obtained from existing data. In a few cases, however, a limited number of unusually high temperatures in the range of 35° to 36°C (95-97°F) have been deleted because these values are believed to have been recorded during conditions of unseasonably high temperatures and/or unusually low flows or water levels and therefore do not represent normal maximum temperatures.

2) The criterion consists of two parts, a temperature differential and a maximum temperature. The temperature differential represents the maximum permissible increase above ambient conditions after mixing. No additional process heat shall be added once the ambient temperature reaches the maximum temperature specified in the standards, except under natural conditions such as unusually hot, dry weather, as provided for in LAC 33:IX.1113.C.4.b.i-ii.

Fresh Water. The following temperature standards apply to fresh water:

- maximum of 2.8°C (5°F) rise above ambient for streams and rivers;
- maximum of 1.7°C (3°F) rise above ambient for lakes and reservoirs; a
- maximum temperature of 32.2°C (90°F), except where otherwise listed in the tables.
- Maximum temperature may be varied on a case-by-case basis to allow for the effects of natural conditions such as unusually hot and/or dry weather.

Estuarine and Coastal Waters. The following temperature standards apply to estuarine and coastal waters:

- maximum of 2.2°C (4°F) rise above ambient from October through May;
- maximum of 1.1°C (2°F) rise above ambient from June through September; and
- maximum temperature of 35°C (95°F), except when natural conditions elevate temperature above this level.

3) These temperature criteria shall not apply to privately owned reservoirs or to reservoirs constructed solely for industrial cooling purposes.

(e) Bacteria. The applicability of bacterial criteria to a particular stream subsegment depends upon the use designation of that individual stream subsegment. Criteria are established to protect water quality commensurate with the most stringent designated use assigned to the subsegment. Applicable bacterial criteria for the most stringent designated use of each individual Louisiana stream subsegment are listed in the "BAC" column of Table 2.1, LAC 33:IX.1123. For water quality monitoring and assessment purposes the following criteria shall be used to determine support for the designated uses.

1) Primary Contact Recreation. No more than 25 percent of the total samples collected on a monthly or near-monthly basis shall exceed a fecal coliform density of 400/100 mL. This primary contact recreation criterion shall apply only during the defined recreational period of May 1 through October 31. During the nonrecreational period of November 1 through April 30, the criteria for secondary contact recreation shall apply.

2) Secondary Contact Recreation. No more than 25 percent of the total samples collected on a monthly or near-monthly basis shall exceed a fecal coliform density of 2,000/100 mL. This secondary contact recreation criterion shall apply year round.

3) Drinking Water Supply. No more than 30 percent of the total samples collected on a monthly or near-monthly basis shall exceed a fecal coliform density of 2,000/100 mL.

4) Oyster Propagation. The fecal coliform median most probable number (MPN) shall not exceed 14 fecal coliforms per 100 mL, and not more than 10 percent of the samples shall exceed an MPN of 43 per 100 mL for a five-tube decimal dilution test in those portions of the area most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions.

(f) Toxic Substances. Numerical criteria for specific toxic substances are listed in Tables 2.2a and 2b.

1) Numerical criteria for specific toxic substances are mostly derived from the following publications of the Environmental Protection Agency: Water Quality Criteria, 1972 (commonly referred to as the "Blue Book"; Quality Criteria for Water, 1976 (commonly referred to as the "Red Book"; Ambient Water Quality Criteria, 1980 (EPA 440/5-80); Ambient Water Quality Criteria, 1984 (EPA 440/5-84-85); and Quality Criteria for Water, 1986—with updates (commonly referred to as the "Gold Book"). Natural background conditions, however, are also considered. These toxic substances are selected for criteria development because of their known or suspected occurrence in Louisiana waters and potential threat to attainment of designated water uses.

2) The criteria for protection of aquatic life are based on acute and chronic concentrations in fresh and marine waters (see LAC 33:IX.1105) as specified in the EPA criteria documents and are developed primarily for attainment of the fish and wildlife propagation use. Where a specific numerical criterion is not derived in EPA criteria documents, a criterion is developed by applying an appropriate application factor for acute and chronic effects to the lowest LC50 value for a representative Louisiana species. The application of either freshwater toxics criteria or marine toxics criteria in brackish waters will be determined by the average salinity of the water body (see LAC 33:IX.1105). In cases where the average salinity is 2 parts per thousand or greater and less than 10 parts per thousand, the more stringent criteria will be used unless an alternative site-specific criterion is developed (as described in EPA-822-R-02-047, November 2002).

3) Criteria for human health are derived using EPA guidelines, procedures, and equations for water bodies used as drinking water supplies and those not used as drinking water supplies. Criteria applied to water bodies designated as drinking water supplies are developed to protect that water supply for human consumption, including protection against taste and odor effects, to protect it for primary and secondary contact recreation, and to prevent contamination of fish and aquatic life consumed by humans. Criteria for water bodies not designated as drinking water supplies are developed to protect them for primary and secondary contact recreation and to prevent contamination of fish and aquatic life consumed by humans. In some cases, the maximum contaminant levels (MCLs) from the National Drinking Water Regulations, when more restrictive, are used as the criteria. For those toxic substances that are suspected or proven carcinogens, an incremental cancer risk level of 10^{-6} (1 in 1,000,000) is used in deriving criteria, with the exception of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) and hexachlorocyclohexane (lindane, gamma BHC), in which case 10^{-5} (1 in 100,000) is used to derive the criteria.

4) Metals criteria are based on dissolved metals concentrations in ambient waters. Hardness values are averaged from two-year data compilations contained in the latest Louisiana Water Quality Data Summary or other comparable data compilations or reports. Metals criteria have been developed for both fresh and marine waters, but not brackish waters. The application of either freshwater metals criteria or marine metals criteria in brackish waters will be determined by the average salinity of the water body (see LAC 33:IX.1105). In cases where the average salinity is 2 parts per thousand or greater and less than 10 parts per thousand, the more stringent criteria will be used unless an alternative site-specific criterion is developed (as described in EPA-822-R-02-047, November 2002).

5) For purposes of criteria assessment, the most stringent criteria for each toxic substance will apply. For determination of criteria attainment in ambient water where the criteria are below

the detection limit, then no detectable concentrations will be allowed. However, for dilution calculations or water quality modeling used to develop total maximum daily load and waste load allocations, the assigned criteria, even if below the detection limit, will be used.

6) The use of clean techniques may be required to definitively assess ambient levels of some pollutants (e.g., EPA Method 1669 for metals) or to assess such pollutants when numeric or narrative water quality standards are not being attained. *Clean techniques* are defined in LAC 33:IX.1105.

Table 2.1. Numerical Criteria and Designated Uses

A-Primary Contact Recreation; B-Secondary Contact Recreation; C-Fish And Wildlife Propagation; L-Limited Aquatic Life and Wildlife Use;
D-Drinking Water Supply; E-Oyster Propagation; F-Agriculture; G-Outstanding Natural Resource Waters

Code	Stream Description	Designated Uses	Numerical Criteria						
			CL	SO_4	DO	pH	BAC	°C	TDS
Lake Pontchartrain Basin (04)									
041703	Intracoastal Waterway–From Chef Menteur Pass to Lake Borgne (Estuarine)	A B C E	N/A	N/A	4.0	6.5-9.0	4	32	N/A
041801	Bayou Bienvenue–From headwaters to hurricane gate at MRGO (Estuarine)	A B C	N/A	N/A	4.0	6.5-9.0	1	35	N/A
041802	Bayou Chaperon (Scenic)(Estuarine)	A B C G	N/A	N/A	4.0	6.5-9.0	1	35	N/A
041803	Bashman Bayou–From headwaters to Bayou Dupre (Scenic) (Estuarine)	A B C G	N/A	N/A	4.0	6.5-9.0	1	35	N/A
041804	Bayou Dupre–From Lake Borgne Canal to Terre Beau Bayou (Scenic) (Estuarine)	A B C G	N/A	N/A	4.0	6.5-9.0	1	35	N/A
041805	Lake Borgne Canal–From Mississippi River siphon at Violet to Bayou Dupre; also called Violet Canal (Scenic) (Estuarine)	A B C G	N/A	N/A	4.0	6.5-9.0	1	35	N/A
041806	Pirogue Bayou–From Bayou Dupre to New Canal (Scenic) (Estuarine)	A B C G	N/A	N/A	4.0	6.5-9.0	1	35	N/A
041807	Terre Beau Bayou–From Bayou Dupre to New Canal (Scenic) (Estuarine)	A B C G	N/A	N/A	4.0	6.5-9.0	1	35	N/A
041808	New Canal (Estuarine)	A B C	N/A	N/A	4.0	6.5-9.0	1	35	N/A
041809	Poydras-Verret Marsh Wetland–Forested and marsh wetland located 1.5 miles north of St. Bernard, south of Violet Canal, and northeast of Forty Arpent Canal	B C	[17]	[17]	[17]	[17]	2	[17]	[17]
041901	Mississippi River Gulf Outlet (MRGO)–From ICWW to Breton Sound at MRGO mile 30	A B C E	N/A	N/A	5.0	6.5-9.0	4	35	N/A
042001	Lake Borgne	A B C E	N/A	N/A	5.0	6.5-9.0	4	35	N/A
042002	Bayou Bienvenue–From Bayou Villere to Lake Borgne (Scenic) (Estuarine)	A B C E G	N/A	N/A	4.0	6.5-9.0	4	35	N/A
042003	Bayou La Loutre–From MRGO to Eloi Bay (Estuarine)	A B C E	N/A	N/A	4.0	6.5-9.0	4	35	N/A
042004	Bayou Bienvenue–From MRGO to Bayou Villere (Estuarine)	A B C E	N/A	N/A	4.0	6.5-9.0	4	35	N/A
042204	Drum Bay	A B C E	N/A	N/A	5.0	6.5-9.0	4	35	N/A
042205	Morgan Harbor	A B C E	N/A	N/A	5.0	6.5-9.0	4	35	N/A
042206	Eloi Bay	A B C E	N/A	N/A	5.0	6.5-9.0	4	35	N/A
Mississippi River Basin (07)									
070201	Mississippi River–From Old River Control Structure to Monte Sano Bayou	A B C D	75	120	5.0	6.0-9.0	1	32	400
070301	Mississippi River–From Monte Sano Bayou to Head of Passes	A B C D	75	120	5.0	6.0-9.0	1	32	400

Table 2.2a.Numerical Criteria for Specific Toxic Substances

[In micrograms per liter (µg/L or parts per billion (ppb)]

Toxic Substance	Aquatic Life Protection						Human Health Protection	
	Freshwater		Marine Water		Brackish Water		Drinking Water Supply[1]	Non-Drinking Water Supply[2]
	Acute	Chronic	Acute	Chronic	Acute	Chronic		
Aldrin	3.00	--	1.300	--	1.300	--	$4x10^{-5}$	$4x10^{-5}$
Benzene	2,249	1,125	2,700	1,350	2,249	1,125	0.58	6.59
Benzidine	250	125	--	--	250	125	$8x10^{-5}$	$1.7x10^{-4}$
Bromodichloromethane	--	--	--	--	--	--	0.52	6.884
Bromoform (Tribromomethane)	2,930	1,465	1,790	895	1790	895	3.9	34.7
Carbon Tetrachloride (Tetrachloromethane)	2,730	1,365	15,000	7,500	2,730	1,365	0.22	1.2
Chlordane	2.40	0.0043	0.090	0.0040	.090	0.0040	$1.9x10^{-4}$	$1.9x10^{-4}$
Chloroform (Trichloromethane)	2,890	1,445	8,150	4,075	2,890	1,445	5.3	70
2-Chlorophenol	258	129	--	--	258	129	0.10	126.4
3-Chlorophenol	--	--	--	--	--	--	0.10	--
4-Chlorophenol	383	192	535	268	383	192	0.10	--
Cyanide	45.9	5.4	1.0	--	1.0	--	663.8	12,844
DDE	52.5	10.5000	0.700	0.1400	0.700	0.1400	$1.9x10^{-4}$	$1.9x10^{-4}$
DDT	1.10	0.0010	0.130	0.0010	0.130	0.0010	$1.9x10^{-4}$	$1.9x10^{-4}$
Dibromochloromethane	--	--	--	--	--	--	0.39	5.08
1,2-Dichloroethane (EDC)	11,800	5,900	11,300	5,650	11,300	5,650	0.36	6.8
1,1-Dichloroethylene	1,160	580	22,400	11,200	1,160	580	0.05	0.58
2,4-Dichlorophenoxyacetic acid (2,4-D)	--	--	--	--	--	--	100.00	--
2,3-Dichlorophenol	--	--	--	--	--	--	0.04	--
2,4-Dichlorophenol	202	101	--	--	202	101	0.30	232.6
2,5-Dichlorophenol	--	--	--	--	--	--	0.50	--
2,6-Dichlorophenol	--	--	--	--	--	--	0.20	--
3,4-Dichlorophenol	--	--	--	--	--	--	0.30	--
1,-3-Dichloropropene	606	303	79	39.5	79	39.5	0.33	5.51
Dieldrin	0.2374	0.0557	0.710	0.0019	0.2374	0.0019	$5x10^{-5}$	$5x10^{-5}$
Endosulfan	0.22	0.0560	0.034	0.0087	0.034	0.0087	0.47	0.64
Endrin	0.0864	0.0375	0.037	0.0023	0.037	0.0023	0.26	0.26
Ethylbenzene	3,200	1,600	8,760	4,380	3,200	1,600	247	834
Heptachlor	0.52	0.0038	0.053	0.0036	0.053	0.0036	$7x10^{-5}$	$7x10^{-5}$
Hexachlorobenzene	--	--	--	--	--	--	$2.5x10^{-4}$	$2.5x10^{-4}$
Hexachlorobutadiene[3]	5.1	1.02	1.6	0.32	1.6	0.32	0.09	0.11
Hexachlorocyclohexane (gamma BHC; Lindane)	5.30	0.21	0.160	--	0.160	--	0.11	0.20
Methyl chloride (Chloromethane)	55,000	27,500	27,000	13,500	27,000	13,500	--	--
Methylene chloride (Dichloromethane)	19,300	9,650	25,600	12,800	19,300	9,650	4.4	87
Phenol (Total)[4]	700	350	580	290	580	290	5.00	50.0
Polychlorinated Biphenyls, Total (PCBs)	2.00	0.0140	10.000	0.0300	2.00	0.0140	$5.59x10^{-5}$	$5.61x10^{-5}$
TDE (DDD)	0.03	0.0060	1.250	0.2500	0.03	0.0060	$2.7x10^{-4}$	$2.7x10^{-4}$
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)[5]	--	--	--	--	--	--	$0.71x10^{-6}$	$0.72x10^{-6}$
1,1,2,2-Tetrachloroethane	932	466	902	451	902	451	0.16	1.8
Tetrachloroethylene	1,290	645	1,020	510	1020	510	0.65	2.5
Toluene	1,270	635	950	475	950	475	6,100	46,200
Toxaphene	0.73	0.0002	0.210	0.0002	0.210	0.0002	$2.4x10^{-4}$	$2.4x10^{-4}$
1,1,1-Trichloroethane	5,280	2,640	3,120	1,560	3,120	1,560	200.0	--
1,1,2-Trichloroethane	1,800	900	--	--	1,800	900	0.56	6.9
Trichloroethylene	3,900	1,950	200	100	200	100	2.8	21

Table 2.2a.Numerical Criteria for Specific Toxic Substances

[In micrograms per liter (μg/L or parts per billion (ppb)]

Toxic Substance	Aquatic Life Protection						Human Health Protection	
	Freshwater		Marine Water		Brackish Water		Drinking Water Supply[1]	Non-Drinking Water Supply[2]
	Acute	Chronic	Acute	Chronic	Acute	Chronic		
2-(2,4,5-Trichlorophenoxy) propionic acid (2,4,5-TP; Silvex)	--	--	--	--	--	--	10.00	--
Vinyl Chloride (Chloroethylene)	--	--	--	--	--	--	2.37×10^{-2}	0.45

[1] Applies to surface water bodies designated as a Drinking Water Supply and also protects for primary and secondary contact recreation and fish consumption.

[2] Applies to surface water bodies not designated as a Drinking Water Supply and protects for primary and secondary contact recreation and fish consumption.

[3] Includes Hexachloro-1,3-butadiene.

[4] Total phenol as measured by the 4-aminoantipyrine (4AAP) method.

[5] Advances in scientific knowledge concerning the toxicity, cancer potency, metabolism, or exposure pathways of toxic pollutants that affect the assumptions on which existing criteria are based may necessitate a revision of dioxin numerical criteria at any time. Such revisions, however, will be accomplished only after proper consideration of designated water uses. Any proposed revision will be consistent with state and federal regulations.

Table 2.2b.
Numerical Criteria for Metals and Inorganics
[In micrograms per liter (µg/L) or parts per billion (ppb)]

Toxic Substance	Aquatic Life Protection						Human Health Protection
	Freshwater		Marine Water		Brackish Water[f]		Drinking Water Supply[a]
	Acute	Chronic	Acute	Chronic	Acute	Chronic	
Arsenic[c]	339.8	150	69.00	36.00	69	36	10.0
Chromium III (Tri)[b,c]	**Acute:** $e^{(0.8190[\ln(hardness)] + 3.6880)} \times 0.316$ **Chronic:** $e^{(0.8190[\ln(hardness)] + 1.5610)} \times 0.86$		515.00	103.00	*	*	50.0
Chromium VI (Hex)[c]	16	11	1,100	50.00	16	11	50.0
Zinc[b,c]	**Acute:** $e^{(0.8473[\ln(hardness)] + 0.8604)} \times 0.978$ **Chronic:** $e^{(0.8473[\ln(hardness)] + 0.7614)} \times 0.986$		90	81	*	*	5,000
Cadmium[b,c]	**Acute:** $e^{(1.1280[\ln(hardness)] - 1.6774)} \times (1.136672-[\ln(hardness)(0.041838)])$ **Chronic:** $e^{(0.7852[\ln(hardness)] - 3.4900)} \times (1.101672-[\ln(hardness)(0.041838)])$		45.35	10.00	*	*	10.0
Copper[b,c]	**Acute:** $e^{(0.9422[\ln(hardness)] - 1.3844)} \times 0.960$ **Chronic:** $e^{(0.8545[\ln(hardness)] - 1.3860)} \times 0.960$		3.63	3.63	*	*	1000
Lead[b,c]	**Acute:** $e^{(1.2730[\ln(hardness)] - 1.4600)} \times (1.46203-[\ln(hardness)(0.145712)])$ **Chronic:** $e^{(1.2730[\ln(hardness)] - 4.7050)} \times (1.46203-[\ln(hardness)(0.145712)])$		209	8.08	*	*	50.0
Mercury[c]	2.04[d]	0.012[e]	2[d]	0.025[e]	2[d]	0.012[e]	2.0
Nickel[b,c]	**Acute:** $e^{(0.8460[\ln(hardness)] + 3.3612)} \times 0.998$ **Chronic:** $e^{(0.8460[\ln(hardness)] + 1.1645)} \times 0.997$		74	8.2	*	*	--

* For hardness-dependent criteria, values are calculated using average hardness (mg/L $CaCO_3$) from two-year data compilations contained in the latest Louisiana Water Quality Data Summary or other comparable data compilations or reports, as described in LAC 33:IX.1113.C.6.

[a] Applies to surface water bodies designated as Drinking Water Supply and also protects for primary and secondary contact recreation and fish consumption.

[b] Hardness-dependent criteria for freshwater are based on the natural logarithm formulas multiplied by conversion factors (CF) for acute and chronic protection. The minimum and maximum hardness values used for criteria calculation are 25 mg/L and 400 mg/L $CaCO_3$, as specified in 40 CFR 131.36.

[c] Freshwater and saltwater metals criteria are expressed in terms of the dissolved metal in the water column. The standard was calculated by multiplying the previous water quality criteria by a conversion factor (CF). The CF represents the EPA-recommended conversion factors found in EPA-822-R-02-047, November 2002.

[d] Conversion factor is from: Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria, October 1, 1993. Factors were expressed to two decimal places.

[e] It is not appropriate to apply CF to chronic value for mercury because it is based on mercury residues in aquatic organisms rather than toxicity.

[f] According to LAC 33:IX.1113.C.6.d, the most stringent criteria (freshwater or marine) will be used.

3. EPA water quality criteria. The EPA has established ambient water quality criteria applicable to surface waters in the study area. EPA has approved and accepted the water quality standards designated by the State of Louisiana for Clean Water Act purposes (http://www.epa.gov/waterscience/standards/wqslibrary/). These state quality standards constitute the baseline of water quality standards in effect for Clean Water Act purposes. Any revisions determined to be less stringent were approved by EPA prior to use in Clean Water Act programs. Therefore, the numerical standards and criteria defined by the state of Louisiana were used for this evaluation.

4. Source of Water Quality Data and Method of Analysis. No water quality samples were specifically collected and analyzed to provide data for this study. Water quality data used in the investigation were obtained from the USGS Water Resources or the Louisiana Department of Environmental Quality databases. It is assumed in this evaluation that the samples collected by the various agencies are representative and that the retrieved data are valid in terms of confidence in sampling, analytical competence, and accurate storage into the data base. For the water quality characterization and analysis, data from several sampling stations in each area of investigation were aggregated (Figure 2.1). Thus, data presented for each area of investigation represent both the spatial and temporal variations in water quality. There are several inconsistencies inherent in this approach that could lead to inaccurate conclusions:

   - Not all water quality parameters of interest were measured at each sampling station in a data aggregate.
   - Typically, stations within each data aggregate have different periods of records.
   - Various chemical analysis techniques were used to determine constituent concentrations.
   - Sampling stations were not uniformly distributed over each area investigated.

Listings of sample collection agency codes and the identification numbers of each station that contributed to each data aggregate are presented in Appendix A of this Water Quality Report. A total of twenty-seven water quality sites were queried. A list of all parameters evaluated is available in Table 2.3. Only general chromium data was available for analysis, therefore; it was compared to the chromium III and chromium VI criteria.

Figure 2.1. Water Quality Sites Used for Assessment

Sites combined for further analysis are shown in the same color. Circle sites were collected by LDEQ. Square sites were collected by USGS. USGS 7374525 is located at the Mississippi River at Belle Chasse, but GIS coordinates appear to be incorrect.

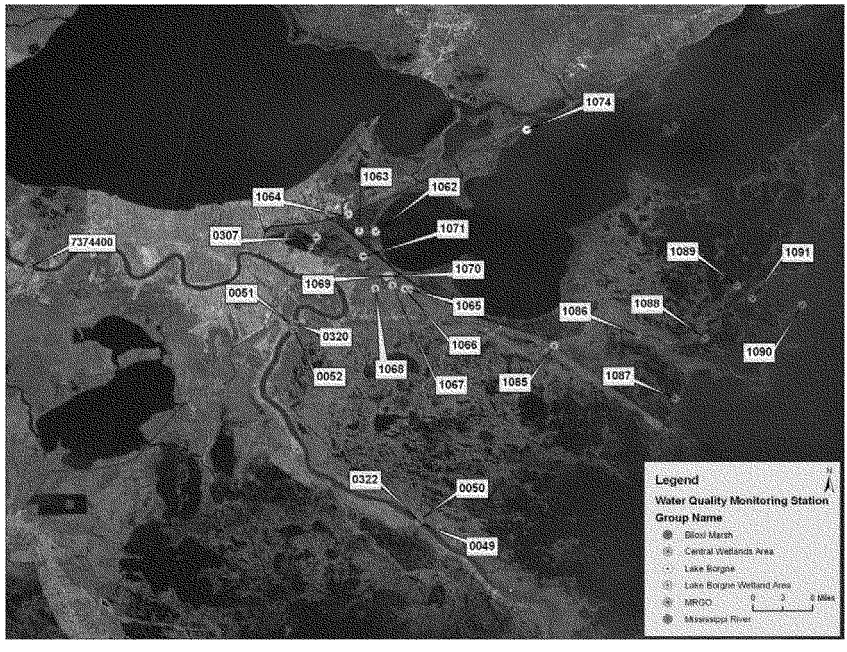


Table 2.3. List of available parameters for analysis from USGS and LDEQ.

CATEGORY	PARAMETER	CATEGORY	PARAMETER
General	Dissolved Oxygen	Agricultural and Industrial chemicals (continued)	Aldrin
	Water Temperature		Benzene
	Sulfate		Benzidine
	Total Dissolved Solids		Bromodichloromethane
	pH		Bromoform (Tribromomethane)
	Specific Conductance, Field		Carbon Tetrachloride (Tetrachloromethane)
	Nitrate + Nitrite Nitrogen		Chlordane
	Total Organic Carbon		Chloroform (Trichloromethane)
	Turbidity		DDE
	Total Suspended Solids		DDT
Bacteriological	Fecal Coliform		Dibromochloromethane
Trace metals and selected trace inorganics	Arsenic		Dieldrin
	Cadmium		Endosulfan
	Chromium		Endrin
	Copper		Ethylbenzene
	Lead		Heptachlor
	Mercury		Hexachlorobenzene
	Nickel		Hexachlorobutadiene
	Zinc		Hexachlorocyclohexane (gamma BHC; Lindane)
Agricultural and Industrial chemicals	1,1,1-Trichloroethane		Methyl chloride (Chloromethane)
	1,1,2,2-Tetrachloroethane		Methylene chloride (Dichloromethane)
	1,1,2-Trichloroethane		Phenol (Total)4
	1,2-Dichloroethane (EDC)		TDE (DDD)
	1,-3-Dichloropropene		Toluene
	2-(2,4,5-Trichlorophenoxy) propionic acid (2,4,5-TP; Silvex)		Toxaphene
	2,4-Dichlorophenol		Trichloroethylene
	2,4-Dichlorophenoxyacetic acid (2,4-D)		Vinyl Chloride (Chloroethylene)
	2-Chlorophenol		

All statistical analysis was completed using SAS v 9.1. Only data collected between 1990 and 2010 were included in the data analysis, to reduce the impact (if any) of prior water quality conditions that may no longer be relevant. Summary statistics were generated using the Univariate Procedure in SAS by site and group for each parameter (Appendix B). Thresholds were applied to the sampled data, and the percentage of each parameter in exceedance of the applicable thresholds was generated using the Frequency Procedure in SAS for each site and group (Appendix C). In order to identify parameters where the sample value was likely to be the method minimum detection limit (MDL), the Frequency Procedure was used to tabulate the frequency of occurrence of each unique sample value for each parameter. If parameter had a unique value occurring in 20% or more of the samples, that parameter was reviewed.

The calculation of the numerical criteria for those trace metals dependent upon hardness (Chromium III, Zinc, Cadmium, Copper, Lead, and Nickel) is described below. The two year mean hardness was calculated for each group. For example, the mean value for 1990 was calculated from all sampled hardness values collected during 1989 and 1990 within each grouped sampling area. The equations listed in Table 2.2b were applied to the two year average hardness values, and sampled metals concentrations were compared to these criteria. The Chromium data were compared to both the (III) and (VI) as the collected data do not indicate which valence state was tested.

5. Mississippi River: Existing Water Quality. The general character of a water body can be gaged by the examination of various chemical and physical parameters including those indicating available dissolved oxygen concentration, Hydrogen ion concentration, temperature, dissolved solids content and the concentrations of major inorganic ions and nutrients. Dissolved oxygen (DO) historically has been the single major constituent of interest in water quality investigations. It has been generally considered significant for protecting aesthetic qualities of water as well as for maintaining fish and other aquatic life. DO concentrations are an important gage of existing water quality and the ability of a water body to support a well-balanced aquatic fauna. Eight water quality stations were queried for data within the Mississippi River (Map 1). Two of the stations are sampled by the US Geological Survey (USGS). The remaining six stations are sampled by the Louisiana Department of Environmental Quality (LDEQ).

a. General. The general water quality statistics for the Mississippi River during 1990 to 2010 from aggregated samples are presented in Table 2.4. DO concentrations are normally well above values cited as being desirable for maintenance of well-balanced fish populations. Measured DO at the Mississippi River sites averaged 8.8 mg/L. During this period, violations of the state DO standard of 5.0 mg/L were noted in only 2 percent of the 529 observations reported. As indicated in Table 2.1, the State of Louisiana has also published numerical standards for temperature (32°C) and ambient concentrations of chloride (CL- 75 mg/L), sulfate (SO_4- 120 mg/L), Hydrogen ion (pH- 6.0-9.0), and total dissolved solids (TDS- 400 mg/L). Data were not available for chloride at the stations and time period used for this report. The average water temperate was 19°C with a maximum of 33°C Violations of state standards for sulfate, pH and TDS occurred during the time period investigated. While the average sulfate concentration was 47 mg/L, values were reported up to 488 mg/L. Values exceeded the sulfate threshold in less than 1% of the samples collected in the Mississippi River. The pH averaged 7.9 with a range from 0.10 to 16.2, although low and high values are likely erroneous (due to their extremely acidic and basic values). Within the dataset analyzed, pH exceeded the numerical standards set by the state of Louisiana. TDS averaged 271 mg/L compared to the 400 mg/L standard for this reach of the Mississippi River. TDS values were reported up to 630 mg/L. Mississippi River exceeded the TDS threshold in 2% of the samples collected. Specific conductance averaged 400 μmhos/cm with a maximum value of 839 μmhos/cm. Within this reach of the Mississippi River, it is classified as a freshwater system.

The Mississippi River has a high concentration of nitrogen, with the majority of inorganic nitrogen in the form of nitrate + nitrite (NO_X). This reach of the river had an average NO_X concentration of 1.55 mg/L. The average total organic carbon was 5.48 mg/l with a maximum of 28 mg/L.

The river is normally characterized by highly turbid waters due to the enormous suspended sediment load transported. Data from the USGS indicates that approximately 77 percent of the river's suspended sediment discharge is transported as silt and clay (particles smaller than 0.062 millimeter in diameter). Maximum concentrations generally occur in late winter or early spring and have an average composition of about 82 percent silt and clay, with about 18 percent sand in the upper 20 percent of the water column. The suspended sediment concentration in the reach investigated averaged 88 mg/L and turbidity averaged 50 NTU. The maximum turbidity level was 252 NTU. The Mississippi River exceeded the turbidity standard of 150 NTU in 2% of the samples analyzed.

Table 2.4. Mississippi River Group General Summary Statistics from 1990-2010

General	Units	MEAN	NOBS	MAX	MEDIAN	MIN
DISSOLVED OXYGEN	MG/L	8.83	529	25.2	8.4	0.1
WATER TEMPERATURE	C	18.4	549	32.7	18.19	0.1
SULFATE	MG/L	47	530	488	43.4	9.3
TOTAL DISSOLVED SOLIDS	MG/L	271	369	630	268	67
pH	SU	7.94	531	16.2	7.73	0.1
SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	401	515	839	394	0.1
NITRATE+NITRITE NITROGEN	MG/L	1.55	453	9.38	1.41	0.02
TOTAL ORGANIC CARBON	MG/L	5.5	399	28	4.9	2
TURBIDITY	NTU	50	478	252	42	1.6
TOTAL SUSPENDED SOLIDS	MG/L	88	434	800	72.5	2

b. Bacteriological. Microbiological indicators of fecal contamination, such as *Escherichia coli* (*E. coli*) and *Enterococcus* spp. (enterococci), found in the gastrointestinal tracts of humans, as well as those of warm-blooded and some cold-blooded animals (APHA 1995, Harwood et al. 2000) have been used for over a century to warn of fecal contamination risk in water. These organisms, along with enteric pathogens, are shed in feces that can contaminate surface and ground water. Microorganisms from fecal sources that enter waters used by the public can pose a health threat, whether the water is used as a drinking water source, for recreational activities such as fishing or swimming, or for aquatic farming activities such as shellfish harvesting. In addition to public health risks, fecal contamination can result in adverse economic impacts due to the closure of recreational beaches and shellfish-harvesting areas. The state bacterial standard for shellfish water quality, which is based upon fecal density, has been widely accepted as an international standard.

The sanitary quality of the Mississippi River water, as characterized by the observed densities of the above-mentioned indicator organisms, is presented in Table 2.5. The State of Louisiana bacterial standards for primary contact recreation, secondary contact recreation and oyster propagation are as follows:

Primary Contact Recreation. No more than 25 percent of the total samples collected on a monthly or near-monthly basis shall exceed a fecal coliform density of 400 colony forming units (cfu) /100 mL. This primary contact recreation criterion shall apply only during the defined recreational period of May 1 through October 31. During the non-recreational period of November 1 through April 30, the criteria for secondary contact recreation shall apply.

Secondary Contact Recreation. No more than 25 percent of the total samples collected on a monthly or near-monthly basis shall exceed a fecal coliform density of 2,000 cfu /100 mL. This secondary contact recreation criterion shall apply year round.

Oyster Propagation. The fecal coliform median most probable number (MPN) shall not exceed 14 fecal coliform cfu per 100 mL, and not more than 10 percent of the samples shall exceed an MPN of 43 cfu per 100 mL.

The shellfish harvesting waters standards and criteria have been included because Mississippi River water would be diverted to some of the state's shellfish harvesting areas, although oyster propagation is not a classified designated use of the Mississippi River. Since river water would be diverted to shellfish harvesting areas, comparing the observed bacteria densities to the oyster propagation standard was thought to be useful.

The average fecal coliform concentration in the Mississippi River was 297 cfu /100mL. This average value is greater the value of 200 cfu /100 mL for the primary contact recreation standard, which is exceeded in 18 % of the samples. The comparison of the observed bacteria densities in the Mississippi River to the state shellfish harvesting standards is reported in Table 2.6. The fecal coliform concentrations exceed 43 CFU/100mL in 83% of the samples.

Table 2.5. Mississippi River Group Bacteriological Summary Statistics from 1990-2010

Bacteriological	Units	MEAN	NOBS	MAX	MEDIAN	MIN
FECAL COLIFORM	CFU/100 ML	297	380	9000	170	2

Table 2.6. Percent of measured fecal coliform values which exceed primary contact, secondary contact and oyster propagation standards in the Mississippi River.

Group	Primary Contact	Secondary Contact	Oyster Propagation
Mississippi River	18	2	83

c. Agricultural and industrial chemicals. Agricultural and industrial chemicals such as pesticides and volatile and semi-volatile organic compounds are discharged to surface waters from several sources. Sources include: tank and barge cleaning activities, spillage during materials handling operations, runoff discharged as stormwater from industrial sites, National Pollution Discharge Elimination System (NPDES) permitted discharges, and runoff from agricultural lands. The costs of analyzing water for many of these compounds are prohibitive. Consequently, such analyses are not routinely performed and only limited data on the occurrence of these compounds in the waters of the project area are available. Tables 2.7 and 8 provide the summary statistics for several pesticides in the Mississippi River and the percentage of observations exceeding Louisiana freshwater chronic and acute criteria. As can be noted by examining this table, organochlorine insecticides DDT, DDE, chlordane, dieldrin, endrin heptachlor, and toxaphene are detected frequently.

A subset of the parameters with high exceedances of the freshwater criteria were evaluated more thoroughly (toxaphene, heptachlor, dieldrin, endrin, and chlordane). A review of the reported results over time was completed to evaluate if an increasing or decreasing trend in concentrations was apparent (Figures 2-6). While Minimum Detection Limits (MDL) for each laboratory were not available in the dataset for each reported value, it appears that the MDL for most of these

parameters exceeds the criterion used in the development of water quality standards. That is, water quality standards often require a level of resolution greater than the laboratory's detection capabilities. In many instances, it is possible that "exceedances" are actually instances where laboratory MDL values are placed into the data set, despite these values being higher than existing water quality standards. This disconnect between standards and laboratory procedures complicates the determination of potential water quality impacts from diversion activities

Table 2.7. Mississippi River Group Agricultural and Industrial chemicals Summary Statistics from 1990-2010

Agricultural and Industrial chemicals	Units	MEAN	NOBS	MAX	MEDIAN	MIN
1,1,1-Trichloroethane	UG/L	0.15	195	6.3	0.1	0.1
1,1,2,2-Tetrachloroethane	UG/L	0.11	195	1	0.1	0.1
1,1,2-Trichloroethane	UG/L	0.11	195	1	0.1	0.1
1,2-Dichloroethane (EDC)	UG/L	0.24	196	17.3	0.1	0.1
1,-3-Dichloropropene	UG/L	0.11	196	1	0.1	0.1
2-(2,4,5-Trichlorophenoxy) propionic acid (2,4,5-TP; Silvex)	UG/L	0.03	31	0.5	0.01	0.01
2,4-Dichlorophenol	UG/L	0.10	107	0.1	0.1	0.1
2,4-Dichlorophenoxyacetic acid (2,4-D)	UG/L	0.04	31	0.5	0.01	0.01
2-Chlorophenol	UG/L	0.10	80	0.1	0.1	0.1
Aldrin	UG/L	0.61	136	8.25	0.1	0.01
Benzene	UG/L	0.11	195	1	0.1	0.1
Benzidine	UG/L	0.10	108	0.1	0.1	0.1
Bromodichloromethane	UG/L	0.11	195	2	0.1	0.1
Bromoform (Tribromomethane)	UG/L	0.13	197	2.6	0.1	0.1
Carbon Tetrachloride (Tetrachloromethane)	UG/L	0.10	194	0.2	0.1	0.1
Chlordane	UG/L	0.11	132	0.5	0.1	0.01
Chloroform (Trichloromethane)	UG/L	0.11	195	1	0.1	0.1
DDE	UG/L	0.53	136	9.94	0.1	0.01
DDT	UG/L	0.36	137	11.25	0.1	0.01
Dibromochloromethane	UG/L	0.14	197	2.5	0.1	0.1
Dieldrin	UG/L	0.39	136	10.03	0.1	0.01
Endosulfan	UG/L	1.03	136	20.56	0.2	0.01
Endrin	UG/L	0.26	132	10.44	0.1	0.01
Ethylbenzene	UG/L	0.11	195	1	0.1	0.1
Heptachlor	UG/L	0.50	136	9.26	0.1	0.01
Hexachlorobenzene	UG/L	0.10	108	0.1	0.1	0.1
Hexachlorobutadiene	UG/L	0.10	108	0.1	0.1	0.1
Hexachlorocyclohexane (gamma BHC; Lindane)	UG/L	0.26	127	6.82	0.1	0.05
Methyl chloride (Chloromethane)	UG/L	0.13	199	2	0.1	0.1
Methylene chloride (Dichloromethane)	UG/L	0.12	195	2	0.1	0.1
Phenol (Total)4	UG/L	0.81	108	77.1	0.1	0.1
TDE (DDD)	UG/L	0.18	136	10.72	0.1	0.01
Toluene	UG/L	0.11	195	1	0.1	0.1
Toxaphene	UG/L	0.41	136	5.5	0.1	0.1
Trichloroethylene	UG/L	0.11	195	1	0.1	0.1
Vinyl Chloride (Chloroethylene)	UG/L	0.11	195	1	0.1	0.1

Table 2.8. Percent exceedance of appropriate water quality standards by agricultural and industrial chemicals in the Mississippi River

Toxic Substance	N	Aquatic Life Protection						Human Health Protection	
		Freshwater		Marine Water		Brackish Water		Drinking Water Supply	Non-Drinking Water Supply
		Acute	Chronic	Acute	Chronic	Acute	Chronic		
1,1,2,2-TETRACHLOROETHANE	195	0	0	0	0	0	0	3	0
1,1,2-TRICHLOROETHANE	195	0	0	0	0	0	0	1	0
1,2-DICHLOROETHANE	196	0	0	0	0	0	0	4	1
4,4 -DDT	128	2	100	3	100	3	100	100	100
4,4'-DDD	125	95	100	95	100	1	1	0	0
4,4'-DDE	130	0	0	5	5	5	5	100	100
ALDRIN	133	7	0	7	0	7	0	100	100
BENZIDINE	108	0	0	0	0	0	0	100	100
BROMODICHLOROMETHANE	195	0	0	0	0	0	0	1	0
CHLORDANE	120	0	100	98	100	98	100	100	100
CIS-1,3-DICHLOROPROPENE	196	0	0	0	0	0	0	1	0
DIBROMOCHLOROMETHANE	197	0	0	0	0	0	0	3	0
DIELDRIN	128	3	91	3	100	3	100	100	100
ENDOSULFAN	130	0	0	0	0	0	0	100	0
ENDRIN	122	91	96	96	100	96	100	2	2
HEPTACHLOR	131	5	100	85	100	85	100	100	100
HEXACHLOROBENZENE	108	0	0	0	0	0	0	100	100
PHENOL	108	0	0	0	0	0	0	1	1
TOXAPHENE	124	13	100	15	100	15	100	100	100
VINYL CHLORIDE	195	0	0	0	0	0	0	100	1

Figure 2.2. Mississippi River sample area chlordane samples over time as sampled by LDEQ and USGS.

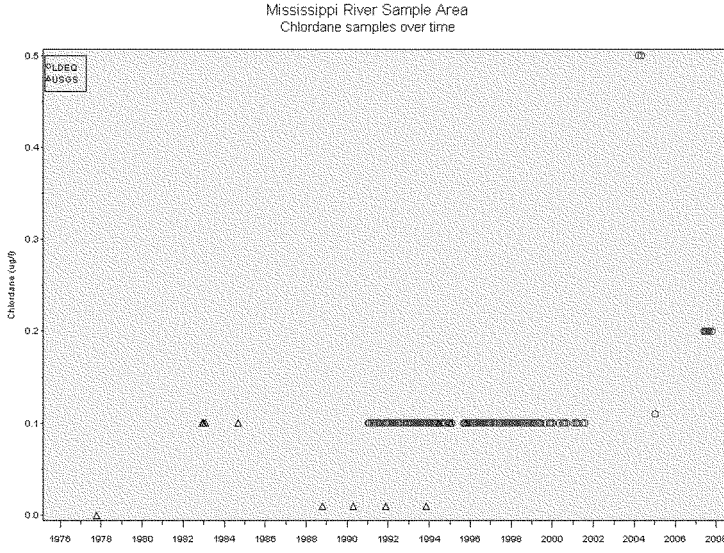


Figure 2.3. Mississippi River sample area dieldrin samples over time as sampled by LDEQ and USGS.

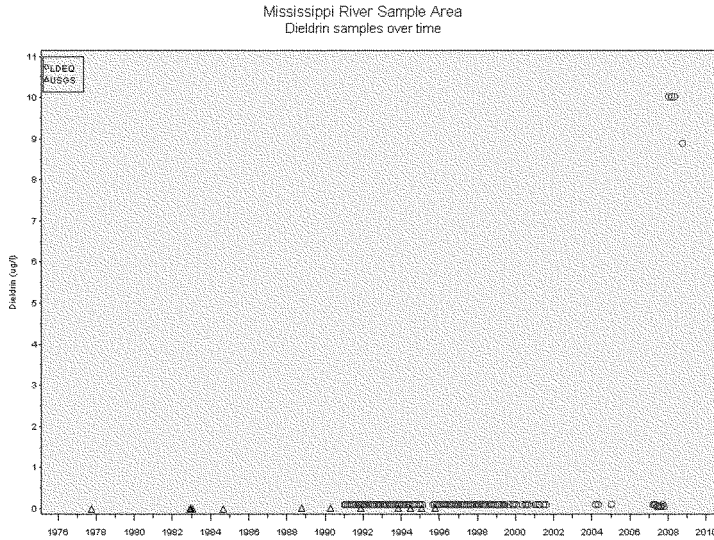


Figure 2.4. Mississippi River sample area endrin samples over time as sampled by LDEQ and USGS.

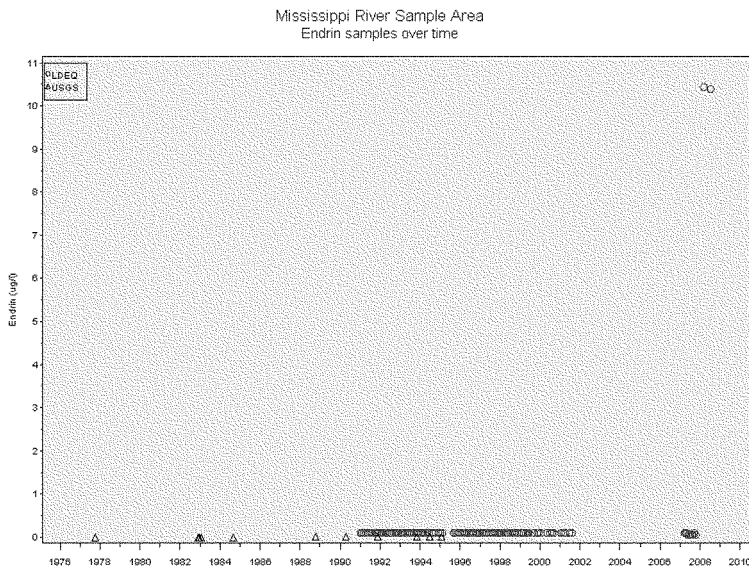


Figure 2.5. Mississippi River sample area heptachlor samples over time as sampled by LDEQ and USGS.

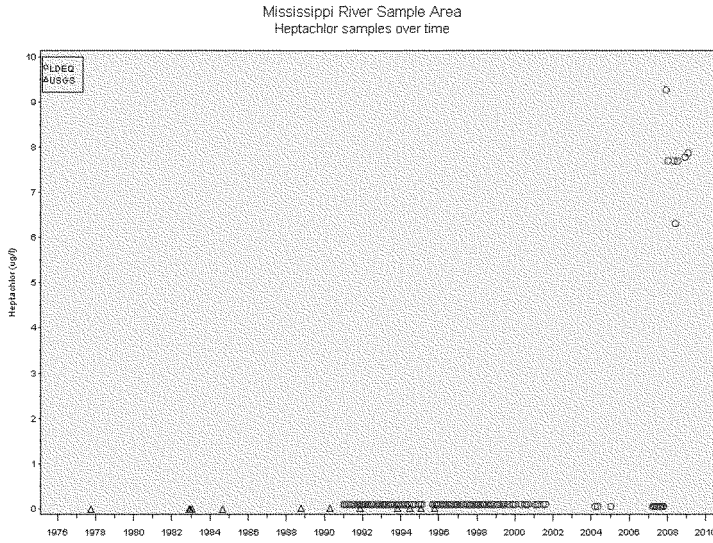
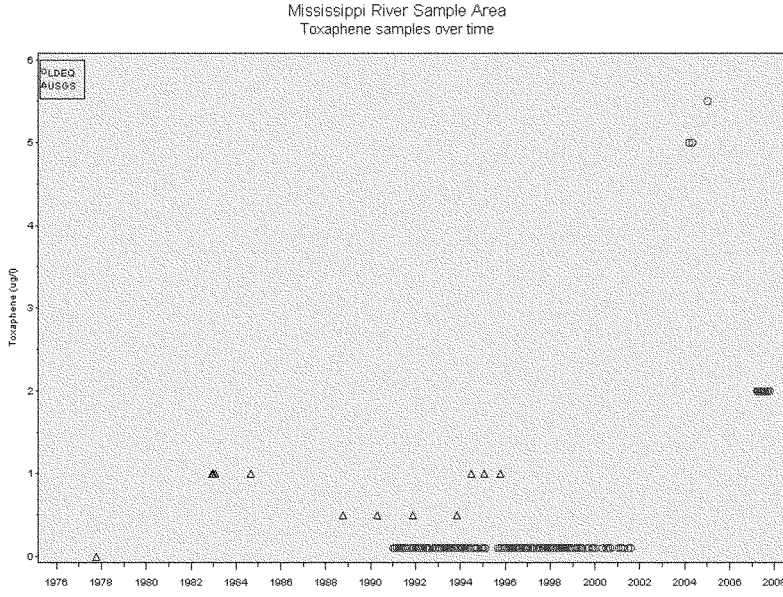


Figure 2.6. Mississippi River sample area toxaphene samples over time as sampled by LDEQ and USGS.



d. Trace metals and selected trace inorganics. Trace metals and trace inorganics enter surface waters via several routes and from several sources. Fallout and washout of contaminants from the polluted atmosphere of urban and highly industrialized areas can be significant nonpoint sources. Metallic salts leached from soils and natural ore deposits can also contribute significantly to the trace metal content of a surface water body. For the most part, heavy waste loading to project area surface waters is a consequence of continuing proliferation of industrial establishments adjacent to the river and general industrialization of the New Orleans-Baton Rouge urban corridor. Several metals that are frequent components of many industrial wastewaters and urban stormwater runoff have been detected in high concentrations. These metals are rarely found in more than trace quantities in unpolluted waters. Trace metals and selected trace inorganics routinely detected in the Mississippi River are characterized in Table 2.9. Data for unfiltered concentrations are presented. These data indicate that high trace metal concentrations are associated with suspended particulates in the river. The trace metals Lead, Mercury, Copper and Chromium (VI) have been detected at average concentrations of 2.66, 0.12, 6.62 and 3.27 µg/L, respectively. Such high concentrations are indicative of the impact of industrial and urban stormwater discharges to the river.

Exceedances of Louisiana freshwater aquatic life chronic and acute criteria are also presented in Table 2.10. The Louisiana criteria specify pollutant concentrations which, if not exceeded, should protect most aquatic life. The acute and chronic criteria are listed in Table 2.2b. The data of Table 2.10 show that the trace metals Lead, Mercury, Copper and Chromium (VI) consistently exceed the freshwater chronic criteria. These data also indicate potential problems associated with recurrent high concentrations of Copper and Chromium which exceed the acute criteria. Based upon a review of the frequency distribution of mercury data, it appears that the MDL for the technique used to calculate mercury concentration may be greater than the criteria established for freshwater, marine and brackish chronic toxicity.

Table 2.9. Mississippi River Group Trace metals and selected trace inorganics Summary Statistics from 1990-2010

Trace metals and selected trace inorganics	Units	MEAN	NOBS	MAX	MEDIAN	MIN
Arsenic	UG/L	2.53	337	10.7	2	0.5
Cadmium	UG/L	0.41	334	4	0.2	0.01
Chromium	UG/L	3.27	333	44	0.84	0.02
Copper	UG/L	6.62	334	43	4.9	0.5
Lead	UG/L	2.66	329	18.8	1.1	0.02
Mercury	UG/L	0.12	323	0.3	0.1	0.05
Nickel	UG/L	3.45	283	16	2.7	0.05
Zinc	UG/L	15.59	91	70	10	0.48

Table 2.10. Percent exceedance of appropriate water quality standards by trace metals in the Mississippi River

Trace Metal		Aquatic Life Protection	Human Health Protection

	N	Freshwater		Marine Water		Brackish Water		Drinking Water Supply
		Acute	Chronic	Acute	Chronic	Acute	Chronic	
Arsenic	337	0	0	0	0	0	0	1
Chromium III	333	0	0	0	0	-	-	0
Chromium VI	333	5	7	0	0	5	7	0
Copper	334	3	6	0	0	-	-	0
Mercury	304	0	100	0	100	0	100	0
Lead	329	0	41	0	0	-	-	0
Nickel	283	0	0	0	0	-	-	0
Zinc	91	0	0	0	0	-	-	1

6. Central Wetlands Area - Existing Water Quality. The CWA is bounded by Paris Road to the north, the MRGO levee and canal to the east, the Violet canal and Bayou Dupre to the south, and the 40 Arpent Canal to the west. The area encompasses approximately 10,380 acres, most of which is brackish marsh. Eight water quality sites were combined to characterize the CWA, all sites were collected by the LDEQ (Figure 2.1).

a. General. The general water quality statistics for the CWA over the time period of 1990 to 2010 from aggregated samples are presented in Table 2.11. DO concentrations widely fluctuate, with values ranging from 1.01 to 12.73 mg/L. Measured DO in the CWA averaged 6.1 mg/L during the period of 1999- 2010, and violations of the state DO standard of 4.0 mg/L were noted in 24 percent of the 240 observations reported. The State of Louisiana has not published numerical standards for chloride (CL), sulfate (SO_4) and total dissolved solids (TDS). A pH range of 6.5 to 9.0 and temperature criteria of 35°C has been established by the State of Louisiana for this water segment (Table 2.1). Data were not available for chloride at the stations and time period of this investigation. The average water temperate was 22°C with a maximum of 32°C. The average sulfate concentration was 836 mg/L, values were reported up to 2,756 mg/L. The pH averaged 7.3 with a range from 6.28 to 8.24. TDS averaged 9,822 mg/L with a maximum value of 22,460 mg/L. The specific conductance averaged 15,786 µmhos/cm with a range of 227 to 30,900 µmhos/cm. Therefore, the CWA fluctuates between freshwater and brackish to marine salinities.

The average NO_x concentration in the CWA was 0.157 mg/L with values ranging from 0.01 to 1.72 mg/L. The average total organic carbon was 9.97 mg/l with a maximum of 28.9 mg/L. The suspended sediment concentration averaged 24 mg/L and the turbidity averaged 13 NTU during the period 1999 through 2010. The maximum turbidity level was 140 NTU. The maximum turbidity level established by the state of Louisiana for estuarine lakes, bays, bayous and canals is 50 NTU. The CWA exceeded this criterion in 2% of the 248 samples collected.

Table 2.11. CWA Group General Summary Statistics from 1990-2010

General	Units	MEAN	NOBS	MAX	MEDIAN	MIN
DISSOLVED OXYGEN	MG/L	6.11	240	12.7	5.8	1.01
WATER TEMPERATURE	C	22	248	32.2	23.5	6.71
SULFATE	MG/L	836	248	2,756	789	38.6
TOTAL DISSOLVED SOLIDS	MG/L	9,822	248	22,460	9,730	72.0

pH	SU	7.34	248	8.2	7	6.28
SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	15,786	240	30,900	15,600	227
NITRATE+NITRITE NITROGEN	MG/L	0.16	193	1.7	0.08	0.01
TOTAL ORGANIC CARBON	MG/L	9.99	144	28.9	8.5	2.0
TURBIDITY	NTU	13.29	248	140	11.0	1.0
TOTAL SUSPENDED SOLIDS	MG/L	23.93	248	260	18.8	4.0

b. Bacteriological. The sanitary quality of the waters in the CWA, as characterized by observed fecal coliform bacteria densities, is presented in Table 2.12. The average fecal coliform concentration was 92 CFU/100mL, and the primary contact and oyster propagation standards were exceeded (5 and 44%, respectively; Table 2.13).

Table 2.12. CWA Group Bacteriological Summary Statistics from 1990-2010

Bacteriological	Units	MEAN	NOBS	MAX	MEDIAN	MIN
FECAL COLIFORM	CFU/100 ML	92	244	1,300	36	2

Table 2.13. Percent of measured fecal coliform values which exceed primary contact, secondary contact and oyster propagation standards in the CWA.

Group	Primary Contact	Secondary Contact	Oyster Propagation
Central Wetlands Area	5	0	44

c. Agricultural and industrial chemicals. Several pesticides have been detected in the CWA. Table 2.13 provides the general summary statistics for those pesticides for which the state of Louisiana have established criteria. The pesticides concentrations were compared to freshwater, brackish and marine aquatic life criteria due to the specific conductivity range found in the area (Table 2.14). Additionally, the pesticide concentrations were compared to the human health drinking water and non-drinking water standards.

No pesticide concentrations exceeded the acute or chronic aquatic life criteria for freshwater, marine or brackish water in the CWA. However, 1,2-Dichloroethane was found to exceed the human health standards for drinking water supply in 3% of the samples. It is important to note that the CWA is not designated for drinking water or oyster propagation. Additionally, vinyl chloride was found to exceed the drinking water supply in 100% of the samples. However, the QA/QC review of the data reported suggest that the MDL for vinyl chloride may be greater than the standard criteria as all values were reported as 0.10 μg/L.

Table 2.13a. CWA Group Agricultural and Industrial chemicals Summary Statistics from 1990-2010

Agricultural and Industrial chemicals	Units	MEAN	NOBS	MAX	MEDIAN	MIN
1,1,1-Trichloroethane	UG/L	0.10	36	0.10	0.10	0.10
1,1,2,2-Tetrachloroethane	UG/L	0.10	36	0.10	0.10	0.10
1,1,2-Trichloroethane	UG/L	0.10	36	0.10	0.10	0.10
1,2-Dichloroethane (EDC)	UG/L	0.11	37	0.55	0.10	0.10
1,-3-Dichloropropene	UG/L	0.10	36	0.10	0.10	0.10
Benzene	UG/L	0.10	36	0.10	0.10	0.10
Bromodichloromethane	UG/L	0.10	36	0.10	0.10	0.10

Bromoform (Tribromomethane)	UG/L	0.10	36	0.10	0.10	0.10
Carbon Tetrachloride (Tetrachloromethane)	UG/L	0.10	36	0.10	0.10	0.10
Chloroform (Trichloromethane)	UG/L	0.10	36	0.10	0.10	0.10
Dibromochloromethane	UG/L	0.10	36	0.10	0.10	0.10
Ethylbenzene	UG/L	0.12	38	0.60	0.10	0.10
Methyl chloride (Chloromethane)	UG/L	0.23	43	1.20	0.10	0.10
Methylene chloride (Dichloromethane)	UG/L	0.16	37	2.44	0.10	0.10
Toluene	UG/L	0.22	42	1.20	0.10	0.10
Trichloroethylene	UG/L	0.10	36	0.10	0.10	0.10
Vinyl Chloride (Chloroethylene)	UG/L	0.10	36	0.10	0.10	0.10

Table 2.14. Percent exceedance of appropriate water quality standards for Agricultural and Industrial chemicals in the CWA.

		Aquatic Life Protection						Human Health Protection	
		Freshwater		Marine Water		Brackish Water		Drinking	Non-Drinking Water Supply
Toxic Substance	N	Acute	Chronic	Acute	Chronic	Acute	Chronic	Water Supply	
1,2-DICHLOROETHANE	37	0	0	0	0	0	0	3	0
VINYL CHLORIDE	36	0	0	0	0	0	0	100	0

d. Trace metals and selected trace inorganics. Several trace metals have been detected in the CWA, the general summary statistics for those metals for which the state of Louisiana have established criteria are in Table 2.15. Detected concentrations of selected trace metals and metalloids were compared to the Louisiana fresh, marine and brackish criteria. A summary of the results of these comparisons is presented in Tables 2.16. In the CWA, Mercury and Lead exceeded the chronic freshwater aquatic life criteria (100 and 1%, respectively). Additionally, Mercury exceeded the marine and brackish chronic criteria (Table 2.16). Based upon a review of the frequency distribution of Mercury data, it appears that the MDL for the technique used to calculate Mercury concentration may be greater than the criteria established for freshwater, marine and brackish chronic toxicity.

Table 2.15. CWA Group Trace metals and selected trace inorganics Summary Statistics from 1990-2010

Trace metals and selected trace inorganics	Units	MEAN	NOBS	MAX	MEDIAN	MIN
Arsenic	UG/L	1.54	95	6.70	1.23	0.23
Cadmium	UG/L	0.20	90	1.03	0.03	0.01
Chromium	UG/L	0.58	67	2.80	0.30	0.02
Copper	UG/L	1.83	95	16.80	1.30	0.42
Lead	UG/L	0.94	92	25.44	0.19	0.01
Mercury	UG/L	0.10	61	0.20	0.05	0.05
Nickel	UG/L	1.74	95	5.00	1.50	0.06
Zinc	UG/L	2.47	51	16.50	1.82	0.73

Table 2.16. Percent exceedance of appropriate water quality standards for trace metals in the CWA.

Toxic Substance		Aquatic Life Protection						Human Health Protection
	N	Freshwater		Marine Water		Brackish Water		Drinking Water Supply
		Acute	Chronic	Acute	Chronic	Acute	Chronic	
Arsenic	95	0	0	0	0	0	0	0
Chromium III	67	0	0	0	0	-	-	0
Chromium VI	67	0	0	0	0	0	0	0
Copper	95	0	0	0	0	-	-	0
Mercury	43	0	100	0	100	0	100	0
Lead	92	0	1	0	0	-	-	0
Nickel	95	0	0	0	0	-	-	0
Zinc	51	0	0	0	0	-	-	0

7. Mississippi River Gulf Outlet (MRGO) - Existing Water Quality. The MRGO extends from New Orleans to the Gulf of Mexico along the western extent of Lake Borgne. A riprap barrier was constructed in 2010 near Shell Beach to block water flow. One water quality site was used to characterize the MRGO; the site was sampled by the LDEQ (Figure 2.1).

a. General. The general water quality statistics for the MRGO over the time period of 1990 to 2010 from aggregated samples are presented in Table 2.17. DO concentrations are relatively sTable 2.with values ranging from 4.48 to 10.4 mg/L. During this period, violations of the state DO standard of 5.0 mg/L were noted in 9 percent of the 23 observations reported. The State of Louisiana has not published numerical standards for chloride (CL), sulfate (SO_4), Hydrogen ion (pH), and total dissolved solids (TDS). The State of Louisiana has not published numerical standards for chloride (CL), sulfate (SO_4) and total dissolved solids (TDS). A pH range of 6.5 to 9.0 and temperature criteria of 35°C has been established by the State of Louisiana for this water segment (Table 2.1). Data were not available for chloride at the stations and time period of this investigation. The average water temperate was 23°C with a maximum of 32°C. The average sulfate concentration was 1,709 mg/L, values were reported up to 8,912 mg/L. The pH averaged 7.72 with a range from 7.33 to 8.36. TDS averaged 15,823 mg/L with a maximum value of 23,340 mg/L. The specific conductance averaged 23,970 µmhos/cm with a range of 16,680 to 34,350 µmhos/cm; the MRGO fluctuates from a brackish to marine salinities.

The average NO_X concentration in the MRGO was 0.078 mg/L with values ranging from 0.02 to 0.27 mg/L. The average total organic carbon was 6.96 mg/l with a maximum of 10.4 mg/L. The suspended sediment concentration averaged 19 mg/L and the turbidity averaged 9.5 NTU during the period 1999 through 2010. The maximum turbidity level was 19 NTU. The maximum turbidity level established by the state of Louisiana for estuarine lakes, bays, bayous and canals is 50 NTU. MRGO did not exceed these criteria in any of the 23 samples collected.

Table 2.17. MRGO Group General Summary Statistics from 1990-2010

General	Units	MEAN	NOBS	MAX	MEDIAN	MIN
DISSOLVED OXYGEN	MG/L	7.34	23	10.40	6.91	4.48
WATER TEMPERATURE	C	23.07	23	32.08	22.76	4.96
SULFATE	MG/L	1,709	23	8,912	1,251	826
TOTAL DISSOLVED SOLIDS	MG/L	15,823	23	23,340	15,440	11,120
pH	SU	7.72	23	8.36	7.68	7.33
SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23,970	23	34,350	23,410	16,680
NITRATE+NITRITE NITROGEN	MG/L	0.08	12	0.27	0.06	0.02
TOTAL ORGANIC CARBON	MG/L	6.96	16	10.40	6.80	5.20
TURBIDITY	NTU	9.50	23	19.00	8.20	2.60
TOTAL SUSPENDED SOLIDS	MG/L	19.23	23	40.50	19.30	4.00

b. Bacteriological. The sanitary quality of the waters in the MRGO, as characterized by observed fecal coliform bacteria densities, is presented in Tables 2.18. The average fecal coliform concentration was 17 CFU/100mL and the oyster propagation standard was exceeded (8%, respectively; Table 2.19).

Table 2.18. MRGO Group Bacteriological Summary Statistics from 1990-2010

Bacteriological	Units	MEAN	NOBS	MAX	MEDIAN	MIN
FECAL COLIFORM	CFU/100 ML	17	24	170	10	2

Table 2.19. Percent of measured fecal coliform values which exceed primary contact, secondary contact and oyster propagation standards in the MRGO.

Group	Primary Contact	Secondary Contact	Oyster Propagation
Central Wetlands Area	0	0	8

c. Agricultural and industrial chemicals. Several pesticides have been detected in the MRGO. Table 2.20 provides the general summary statistics for those pesticides for which the state of Louisiana have established criteria. The pesticides concentrations were compared to freshwater, brackish and marine aquatic life criteria. Additionally, the pesticide concentrations were compared to the human health drinking water and non-drinking water standards. No pesticide concentrations exceeded the acute or chronic aquatic life criteria for freshwater, marine or brackish water in MRGO. It is possible that the current minimum detection limits for some of these parameters are insufficient to evaluate concentrations at the low level required.

Vinyl chloride was found to exceed the drinking water supply in 100% of the samples. However, the QA/QC review of the data reported suggest that the MDL for vinyl chloride may be greater than the standard criteria as all values were reported as 0.10 µg/L. It is also important to note that MRGO is not classified for drinking water or oyster propagation.

Table 2.20. MRGO Group Agricultural and Industrial chemicals Summary Statistics from 1990-2010

Agricultural and Industrial chemicals	Units	MEAN	NOBS	MAX	MEDIAN	MIN
1,1,1-Trichloroethane	UG/L	0.10	3	0.10	0.10	0.10
1,1,2,2-Tetrachloroethane	UG/L	0.10	3	0.10	0.10	0.10

1,1,2-Trichloroethane	UG/L	0.10	3	0.10	0.10	0.10
1,2-Dichloroethane (EDC)	UG/L	0.10	3	0.10	0.10	0.10
1,-3-Dichloropropene	UG/L	0.10	3	0.10	0.10	0.10
Benzene	UG/L	0.10	3	0.10	0.10	0.10
Bromodichloromethane	UG/L	0.10	3	0.10	0.10	0.10
Bromoform (Tribromomethane)	UG/L	0.10	3	0.10	0.10	0.10
Carbon Tetrachloride (Tetrachloromethane)	UG/L	0.10	3	0.10	0.10	0.10
Chloroform (Trichloromethane)	UG/L	0.10	3	0.10	0.10	0.10
Dibromochloromethane	UG/L	0.10	3	0.10	0.10	0.10
Ethylbenzene	UG/L	0.10	3	0.10	0.10	0.10
Methyl chloride (Chloromethane)	UG/L	0.33	4	0.60	0.30	0.10
Methylene chloride (Dichloromethane)	UG/L	0.10	3	0.10	0.10	0.10
Toluene	UG/L	0.28	4	0.80	0.10	0.10
Trichloroethylene	UG/L	0.10	3	0.10	0.10	0.10
Vinyl Chloride (Chloroethylene)	UG/L	0.10	3	0.10	0.10	0.10

d. Trace metals and selected trace inorganics. Several trace metals have been detected in the MRGO, the general summary statistics for those metals for which the state of Louisiana have established criteria are in Table 2.21. Detected concentrations of selected trace metals and metalloids were compared to the Louisiana fresh, marine and brackish criteria. A summary of the results of these comparisons is presented in Tables 2.22

For MRGO, only Mercury exceeded the chronic freshwater, marine and brackish aquatic life criteria. Based upon a review of the frequency distribution of mercury data, it appears that the MDL for the technique used to calculate mercury concentration may be greater than the criteria established for freshwater, marine and brackish chronic toxicity. In addition, only one data point was reported for Mercury in MRGO.

Table 2.21. MRGO Group Trace metals and selected trace inorganics Summary Statistics from 1990-2010

Trace metals and selected trace inorganics	Units	MEAN	NOBS	MAX	MEDIAN	MIN
Arsenic	UG/L	0.70	6	1.53	0.63	0.21
Cadmium	UG/L	0.07	6	0.28	0.03	0.02
Chromium	UG/L	0.25	5	0.43	0.20	0.20
Copper	UG/L	1.14	6	2.08	0.97	0.83
Lead	UG/L	0.82	5	4.02	0.03	0.02
Mercury	UG/L	0.05	5	0.05	0.05	0.05
Nickel	UG/L	1.39	6	1.79	1.39	1.01
Zinc	UG/L	1.93	6	3.70	1.78	0.73

Table 2.22. Percent exceedance of appropriate water quality standards by trace metals in MRGO.

Toxic Substance		Aquatic Life Protection						Human Health Protection
	N	Freshwater		Marine Water		Brackish Water		Drinking Water Supply
		Acute	Chronic	Acute	Chronic	Acute	Chronic	
Arsenic	6	0	0	0	0	0	0	0
Chromium III	5	0	0	0	0	-	-	0
Chromium VI	5	0	0	0	0	0	0	0
Copper	6	0	0	0	0	-	-	0
Mercury	1	0	100	0	100	0	100	0
Lead	5	0	0	0	0	-	-	0
Nickel	6	0	0	0	0	-	-	0
Zinc	6	0	0	0	0	-	-	0

8. Lake Borgne Wetlands Area - Existing Water Quality. The LBWA is located east of MRGO between Bayou Villere and the channel that connects MRGO and Lake Borgne northeast of Alluvial City, and comprises 11,209 acres of brackish/saltwater wetlands. Three water quality sites were combined to characterize the LBWA, all sites were collected by the LDEQ (Figure 2.1).

a. General. The general water quality statistics for the LBWA over the time period of 1990 to 2010 from aggregated samples are presented in Table 2.23. DO concentrations were relatively constant with values ranging from 4.17 to 11.33 mg/L. Measured DO in the LBWA averaged 7.5 mg/L during the period of 1999- 2010. During this period, violations of the state DO standard of 4.0 mg/L were not noted in the 108 observations reported. The State of Louisiana has not published numerical standards for chloride (CL), sulfate (SO_4)and total dissolved solids (TDS). A pH range of 6.5 to 9.0 and temperature criteria of 35°C has been established by the State of Louisiana for this water segment (Table 1). Data were not available for chloride at the stations and time period of this investigation. The average water temperate was 22°C with a maximum of 32°C. The average sulfate concentration was 807 mg/L, values were reported up to 1691 mg/L. The pH averaged 7.5 with a range from 6.39 to 8.04. TDS averaged 10318 mg/L with a maximum value of 18,880 mg/L. The specific conductance averaged 15,984 µmhos/cm with a range of 21.5 to 28,600 µmhos/cm; the LBWA fluctuates from freshwater to marine salinities.

The average NO_x concentration in the LBWA was 0.10 mg/L with values ranging from 0.05 to 0.55 mg/L. The average total organic carbon was 7.5 mg/l with a maximum of 20.6 mg/L. The suspended sediment concentration averaged 20 mg/L and the turbidity averaged 11 NTU during the period 1999 through 2010. The maximum turbidity level was 36.5 NTU. The maximum turbidity level established by the state of Louisiana for estuarine lakes, bays, bayous and canals is 50 NTU. The LBWA did not exceed these criteria in any of the 248 samples collected.

Table 2.23. LBWA Group General Summary Statistics from 1990-2010

General	Units	MEAN	NOBS	MAX	MEDIAN	MIN

DISSOLVED OXYGEN	MG/L	7.55	108	11.33	7.22	4.17
WATER TEMPERATURE	C	21.70	108	31.95	22.92	7.88
SULFATE	MG/L	806.94	108	1,691	768.50	375
TOTAL DISSOLVED SOLIDS	MG/L	10,319	107	18,880	9,840	4,724
pH	SU	7.52	108	8.04	7.53	6.39
SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	15,985	107	28,600	15,270	21.5
NITRATE+NITRITE NITROGEN	MG/L	0.10	47	0.55	0.08	0.05
TOTAL ORGANIC CARBON	MG/L	7.54	51	20.6	7.0	2.0
TURBIDITY	NTU	10.82	108	36.5	9.0	3.2
TOTAL SUSPENDED SOLIDS	MG/L	19.97	108	81.0	16.0	4.0

b. Bacteriological. The sanitary quality of the waters in the MRGO, as characterized by observed fecal coliform bacteria densities, is presented in Tables 2.24 The average fecal coliform concentration was 36 CFU/100mL with oyster propagation standard was exceeded in 21% of the 102 samples collected (Table 2.19).

Table 2.24. Lake Borgne Wetlands Area Group Bacteriological Summary Statistics from 1990-2010

Bacteriological	Units	MEAN	NOBS	MAX	MEDIAN	MIN
FECAL COLIFORM	CFU/100 ML	36	102	350	10.5	2

Table 2.25. Percent of measured fecal coliform values which exceed primary contact, secondary contact and oyster propagation standards in the LBWA.

Group	Primary Contact	Secondary Contact	Oyster Propagation
Central Wetlands Area	0	0	21

c. Agricultural and industrial chemicals. Several pesticides have been detected in the LBWA. Table 2.26 provides the general summary statistics for those pesticides for which the state of Louisiana have established criteria. The pesticides concentrations were compared to freshwater, brackish and marine aquatic life criteria due to the specific conductivity range found in the area (Table 2.27). Additionally, the pesticide concentrations were compared to the human health drinking water and non-drinking water standards.

No pesticide concentrations exceeded the acute or chronic aquatic life criteria for freshwater, marine or brackish water in the LBWA. However, 1,2-Dichloroethane and carbon tetrachloride were both found to exceed the human health standards for drinking water supply in 10% of the samples (Table 2.28). It is important to note that the LBWA is not designated for drinking water. Vinyl chloride was found to exceed the drinking water supply in 100% of the samples. However, the QA/QC review of the data reported suggest that the MDL for vinyl chloride may be greater than the standard criteria as all values were reported as 0.10 µg/L.

Table 2.26. The LBWA Group Agricultural and Industrial chemicals Summary Statistics from 1990-2010

Agricultural and Industrial chemicals	Units	MEAN	NOBS	MAX	MEDIAN	MIN
1,1,1-Trichloroethane	UG/L	0.10	9	0.10	0.10	0.10
1,1,2,2-Tetrachloroethane	UG/L	0.10	9	0.10	0.10	0.10
1,1,2-Trichloroethane	UG/L	0.10	9	0.10	0.10	0.10
1,2-Dichloroethane (EDC)	UG/L	0.15	10	0.64	0.10	0.10
1,-3-Dichloropropene	UG/L	0.10	9	0.10	0.10	0.10
Benzene	UG/L	0.10	9	0.10	0.10	0.10
Bromodichloromethane	UG/L	0.10	9	0.10	0.10	0.10
Bromoform (Tribromomethane)	UG/L	0.10	9	0.10	0.10	0.10
Carbon Tetrachloride (Tetrachloromethane)	UG/L	0.22	10	1.27	0.10	0.10
Chloroform (Trichloromethane)	UG/L	0.10	9	0.10	0.10	0.10
Dibromochloromethane	UG/L	0.10	9	0.10	0.10	0.10
Ethylbenzene	UG/L	0.10	9	0.10	0.10	0.10
Methyl chloride (Chloromethane)	UG/L	0.32	12	0.80	0.10	0.10
Methylene chloride (Dichloromethane)	UG/L	0.80	12	3.89	0.10	0.10
Toluene	UG/L	0.10	9	0.10	0.10	0.10
Trichloroethylene	UG/L	0.10	9	0.10	0.10	0.10
Vinyl Chloride (Chloroethylene)	UG/L	0.10	9	0.10	0.10	0.10

Table 2.27. Percent exceedance of appropriate water quality standards for agricultural and industrial chemicals in the LBWA..

Toxic Substance		Aquatic Life Protection						Human Health Protection	
		Freshwater		Marine Water		Brackish Water		Drinking	Non-Drinking Water Supply
	N	Acute	Chronic	Acute	Chronic	Acute	Chronic	Water Supply	
VINYL CHLORIDE	9	0	0	0	0	0	0	100	0
1,2-DICHLOROETHANE	10	0	0	0	0	0	0	10	0
CARBON TETRACHLORIDE	10	0	0	0	0	0	0	10	10

d. Trace metals and selected trace inorganics. Several trace metals have been detected in the LBWA, the general summary statistics for those metals for which the state of Louisiana have established criteria are in Table 2.28. Detected concentrations of selected trace metals and metalloids were compared to the Louisiana fresh, marine and brackish criteria. No trace metals exceeded the numerical criteria established in Table 2.2A.

Table 2.28. Lake Borgne Wetlands Area Group Trace metals and selected trace inorganics Summary Statistics from 1990-2010

Trace metals and selected trace inorganics	Units	MEAN	NOBS	MAX	MEDIAN	MIN
Arsenic	UG/L	0.90	27	2.90	0.81	0.27
Cadmium	UG/L	0.02	24	0.06	0.02	0.01
Chromium	UG/L	0.17	17	0.22	0.20	0.02
Copper	UG/L	1.04	27	1.31	1.03	0.65
Lead	UG/L	0.04	19	0.11	0.04	0.02
Nickel	UG/L	1.41	27	2.15	1.31	1.03
Zinc	UG/L	2.20	27	15.20	1.69	0.63

9. Lake Borgne - Existing Water Quality. Lake Borgne is a well-flushed estuary located southeast of Lake Pontchartrain and east of MRGO. One water quality sampling site was used to characterize Lake Borgne; data from this location is collected by LDEQ (Figure 2.1).

a. General. The general water quality statistics for Lake Borgne over the time period of 1990 to 2010 from aggregated samples are presented in Table 2.29. DO concentrations were relatively constant with values ranging from 5.67 to 10.71 mg/L which is expected as the flushing time averages 17 days. Measured DO in Lake Borgne averaged 7.8 mg/L during the period of 1999- 2010. During this period, violations of the state DO standard of 5.0 mg/L were not observed in the 23 observations reported. The State of Louisiana has not published numerical standards for chloride (CL), sulfate (SO_4) and total dissolved solids (TDS). A pH range of 6.5 to 9.0 and temperature criteria of 35°C has been established by the State of Louisiana for this water segment (Table 2.1). Data were not available for chloride at the stations and time period of this investigation. The average water temperate was 22°C with a maximum of 30.8°C. The average sulfate concentration was 626 mg/L, values were reported up to 2,033 mg/L. The pH averaged 7.4 with a range from 6.91 to 7.83. TDS averaged 7,391 mg/L with a maximum value of 15,700 mg/L. The specific conductance averaged 11,830

μmhos/cm with a range of 1,256 to 26,100 μmhos/cm; Lake Borgne fluctuates from brackish to marine salinities.

The average NO_x concentration in Lake Borgne was 0.084 mg/L with values ranging from 0.05 to 0.14 mg/L. The average total organic carbon was 7.2 mg/l with a maximum of 9.4 mg/L. The suspended sediment concentration averaged 18 mg/L and the turbidity averaged 12 NTU during the period 1999 through 2010. The maximum turbidity level was 50 NTU. The maximum turbidity level established by the state of Louisiana for estuarine lakes, bays, bayous and canals is 50 NTU. The Lake Borgne did not exceed these criteria in any of the 24 samples collected.

Table 2.29. Lake Borgne Group General Summary Statistics from 1990-2010

General	Units	MEAN	NOBS	MAX	MEDIAN	MIN
DISSOLVED OXYGEN	MG/L	7.84	23	10.71	7.61	5.67
WATER TEMPERATURE	C	22.0	23	30.80	23.42	8.10
SULFATE	MG/L	626	24	2,033	497	1.30
TOTAL DISSOLVED SOLIDS	MG/L	7,391	24	15,700	6,279	2,068
pH	SU	7.36	23	7.83	7.38	6.91
SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	11,830	23	26,100	9,520	1,256
NITRATE+NITRITE NITROGEN	MG/L	0.08	14	0.14	0.08	0.05
TOTAL ORGANIC CARBON	MG/L	7.19	17	9.4	7.1	5.3
TURBIDITY	NTU	11.76	24	50	8.8	2.8
TOTAL SUSPENDED SOLIDS	MG/L	18.06	23	72	14.0	4.5

b. Bacteriological. The sanitary quality of the waters in the Lake Borgne, as characterized by observed fecal coliform bacteria densities, is presented in Tables 2.30 The average fecal coliform concentration was 18 CFU/100mL and the oyster propagation standard was exceeded in 9% of the 23 samples collected (Table 2.31).

Table 2.30. Lake Borgne Group Bacteriological Summary Statistics from 1990-2010

Bacteriological	Units	MEAN	NOBS	MAX	MEDIAN	MIN
FECAL COLIFORM	CFU/100 ML	18	23	130	8	2

Table 2.31. Percent of measured fecal coliform values which exceed primary contact, secondary contact and oyster propagation standards in the Lake Borgne.

Group	Primary Contact	Secondary Contact	Oyster Propagation
Central Wetlands Area	0	0	9

c. Agricultural and industrial chemicals. Several pesticides have been detected in the Lake Borgne. Table 2.32 provides the general summary statistics for those pesticides for which the state of Louisiana have established criteria. Only four samples were available for each of the parameters, all reporting 0.10 μg/L for every data point. The pesticides concentrations were compared to freshwater, brackish and marine aquatic life criteria (Table 2.33). Additionally, the pesticide concentrations were compared to the human health drinking water and non-drinking water standards.

No pesticide concentrations exceeded the acute or chronic aquatic life criteria for freshwater, marine or brackish water in Lake Borgne. Vinyl chloride was found to exceed the drinking water supply in 100% of the samples. However, the QA/QC review of the data reported suggest that the MDL for vinyl chloride may be greater than the standard criteria as all values were reported as 0.10 µg/L. It is important to note that Lake Borgne is not designated for drinking.

Table 2.32. Lake Borgne Group Agricultural and Industrial chemicals Summary Statistics from 1990-2010

Agricultural and Industrial chemicals	Units	MEAN	NOBS	MAX	MEDIAN	MIN
1,1,1-Trichloroethane	UG/L	0.10	4	0.10	0.10	0.10
1,1,2,2-Tetrachloroethane	UG/L	0.10	4	0.10	0.10	0.10
1,1,2-Trichloroethane	UG/L	0.10	4	0.10	0.10	0.10
1,2-Dichloroethane (EDC)	UG/L	0.10	4	0.10	0.10	0.10
1,-3-Dichloropropene	UG/L	0.10	4	0.10	0.10	0.10
Benzene	UG/L	0.10	4	0.10	0.10	0.10
Bromodichloromethane	UG/L	0.10	4	0.10	0.10	0.10
Bromoform (Tribromomethane)	UG/L	0.10	4	0.10	0.10	0.10
Carbon Tetrachloride (Tetrachloromethane)	UG/L	0.10	4	0.10	0.10	0.10
Chloroform (Trichloromethane)	UG/L	0.10	4	0.10	0.10	0.10
Dibromochloromethane	UG/L	0.10	4	0.10	0.10	0.10
Ethylbenzene	UG/L	0.10	4	0.10	0.10	0.10
Methyl chloride (Chloromethane)	UG/L	0.10	4	0.10	0.10	0.10
Methylene chloride (Dichloromethane)	UG/L	0.10	4	0.10	0.10	0.10
Toluene	UG/L	0.10	4	0.10	0.10	0.10
Trichloroethylene	UG/L	0.10	4	0.10	0.10	0.10
Vinyl Chloride (Chloroethylene)	UG/L	0.10	4	0.10	0.10	0.10

Table 2.33. Percent exceedance of appropriate water quality standards for agricultural and industrial chemicals in Lake Borgne.

Toxic Substance		Aquatic Life Protection						Human Health Protection	
		Freshwater		Marine Water		Brackish Water		Drinking	Non-Drinking Water Supply
	N	Acute	Chronic	Acute	Chronic	Acute	Chronic	Water Supply	
VINYL CHLORIDE	4							100	

d. Trace metals and selected trace inorganics. Several trace metals have been detected in Lake Borgne, the general summary statistics for those metals for which the state of Louisiana have established criteria are in Table 2.34. Detected concentrations of selected trace metals and

metalloids were compared to the Louisiana fresh, marine and brackish criteria. No trace metals exceeded the numerical criteria established in Table 2.2A.

Table 2.34. Lake Borgne Group Trace metals and selected trace inorganics Summary Statistics from 1990-2010

Trace metals and selected trace inorganics	Units	MEAN	NOBS	MAX	MEDIAN	MIN
Arsenic	UG/L	0.56	6	1.04	0.52	0.21
Cadmium	UG/L	0.02	6	0.03	0.02	0.01
Chromium	UG/L	0.15	6	0.20	0.20	0.04
Copper	UG/L	1.52	6	3.50	1.09	0.92
Lead	UG/L	0.04	6	0.10	0.03	0.01
Nickel	UG/L	1.39	6	1.80	1.38	0.92
Zinc	UG/L	1.77	6	3.50	1.62	0.53

10. Biloxi Marsh- Existing Water Quality. The Biloxi Marsh is comprised of predominantly marine wetlands (i.e., salt marsh vegetation) southeast of Lake Borgne. The marine standards and criteria were used to gage existing water quality. Six water quality sites were combined to characterize the Biloxi Marsh, all sites were collected by the LDEQ (Figure 2.1).

a. General. The general water quality statistics for Biloxi Marsh over the time period of 1990 to 2010 from aggregated samples are presented in Table 2.35. DO concentrations were relatively constant with values ranging from 4.35 to 11.33 mg/l. Measured DO in the Biloxi Marsh averaged 7.3 mg/L during the period of 1999- 2010. During this period, violations of the state DO standard of 4.0 mg/L were not observed in the 138 observations reported. The State of Louisiana has not published numerical standards for chloride (CL), sulfate (SO_4)and total dissolved solids (TDS). A pH range of 6.5 to 9.0 and temperature criteria of 35°C has been established by the State of Louisiana for this water segment (Table 2.1). Data were not available for chloride at the stations and time period of this investigation. The average water temperate was 23°C with a maximum of 32°C. The average sulfate concentration was 1,569 mg/L, values were reported up to 3,837 mg/L. The pH averaged 7.7 with a range from 6.25 to 8.58. TDS averaged 18,130 mg/L with a maximum value of 36,860 mg/L. The specific conductance averaged 27,210 umhos/cm with a range of 21 to 43,500 umhos/cm. The Biloxi Marsh fluctuates from a brackish to marine water body.

The average NO_x concentration in the Biloxi Marsh was 0.106 mg/L with values ranging from 0.03 to 0.8 mg/L. The average total organic carbon was 6.6 mg/l with a maximum of 10.3 mg/L. The suspended sediment concentration averaged 30 mg/L and the turbidity averaged 15 NTU during the period 1999 through 2010. The maximum turbidity level was 60 NTU. The maximum turbidity levels established by the state of Louisiana for estuarine lakes, bays, bayous and canals is 50 NTU. The Biloxi Marsh exceeded these criteria in 3% of the 138 samples collected.

Table 2.35. The Biloxi Marsh Group General Summary Statistics from 1990-2010

General	Units	MEAN	NOBS	MAX	MEDIAN	MIN
DISSOLVED OXYGEN	MG/L	7.26	138	11.33	6.81	4.35
WATER TEMPERATURE	C	22.78	138	31.86	24.68	3.15
SULFATE	MG/L	1,569	138	3,837	1,455	186.00
TOTAL DISSOLVED SOLIDS	MG/L	18,130	138	36,860	18,220	7,700
pH	SU	7.77	138	8.58	7.80	6.25
SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	27,210	138	43,500	27,240	21.30
NITRATE+NITRITE NITROGEN	MG/L	0.11	72	0.80	0.05	0.03
TOTAL ORGANIC CARBON	MG/L	6.57	76	10.30	6.45	0.52
TURBIDITY	NTU	14.82	138	60.00	12.00	1.50
TOTAL SUSPENDED SOLIDS	MG/L	29.91	137	133.00	22.50	0.30

b. Bacteriological. The sanitary quality of the waters in the Biloxi Marsh, as characterized by observed fecal coliform bacteria densities, is presented in Tables 2.36 The average fecal coliform concentration was 11 CFU/100mL and the oyster propagation standard was exceeded in 4% of the 144 samples collected (Table 2.37).

Table 2.36. Lake Borgne Group Bacteriological Summary Statistics from 1990-2010

Bacteriological	Units	MEAN	NOBS	MAX	MEDIAN	MIN
FECAL COLIFORM	CFU/100 ML	11	144	310	10	1

Table 2.37. Percent of measured fecal coliform values which exceed primary contact, secondary contact and oyster propagation standards in the Lake Borgne.

Group	Primary Contact	Secondary Contact	Oyster Propagation
Central Wetlands Area	0	0	4

c. Agricultural and industrial chemicals. Several pesticides have been detected in the Biloxi Marsh. Table 2.38 provides the general summary statistics for those pesticides for which the state of Louisiana have established criteria. Twenty-one samples were available for most of the parameters, with the majority of the data points listed as 0.10 µg/L. Pesticide concentrations were compared to freshwater, brackish and marine aquatic life criteria (Table 2.39). Additionally, pesticide concentrations were compared to the human health drinking water and non-drinking water standards.

No pesticide concentrations exceeded the acute or chronic aquatic life criteria for freshwater, marine or brackish water in the Biloxi Marsh. Vinyl chloride was found to exceed the drinking water supply in 100% of the samples. However, the QA/QC review of the data reported suggest that the MDL for vinyl chloride may be greater than the standard criteria as all values were reported as 0.10 µg/L. It is important to note that Biloxi Marsh is not designated for drinking water.

Table 2.38. Biloxi Marsh Group Agricultural and Industrial chemicals Summary Statistics from 1990-2010

Agricultural and Industrial chemicals	Units	MEAN	NOBS	MAX	MEDIAN	MIN
1,1,1-Trichloroethane	UG/L	0.10	21	0.10	0.10	0.10
1,1,2,2-Tetrachloroethane	UG/L	0.10	21	0.10	0.10	0.10
1,1,2-Trichloroethane	UG/L	0.10	21	0.10	0.10	0.10
1,2-Dichloroethane (EDC)	UG/L	0.10	21	0.10	0.10	0.10
1,-3-Dichloropropene	UG/L	0.10	21	0.10	0.10	0.10
Benzene	UG/L	0.10	21	0.10	0.10	0.10
Bromodichloromethane	UG/L	0.10	21	0.10	0.10	0.10
Bromoform (Tribromomethane)	UG/L	0.10	21	0.10	0.10	0.10
Carbon Tetrachloride (Tetrachloromethane)	UG/L	0.10	21	0.10	0.10	0.10
Chloroform (Trichloromethane)	UG/L	0.10	21	0.10	0.10	0.10
Dibromochloromethane	UG/L	0.10	21	0.10	0.10	0.10
Ethylbenzene	UG/L	0.10	21	0.10	0.10	0.10
Methyl chloride (Chloromethane)	UG/L	0.17	23	0.70	0.10	0.10
Methylene chloride (Dichloromethane)	UG/L	0.10	21	0.10	0.10	0.10
Toluene	UG/L	0.14	21	0.90	0.10	0.10
Trichloroethylene	UG/L	0.10	21	0.10	0.10	0.10
Vinyl Chloride (Chloroethylene)	UG/L	0.10	21	0.10	0.10	0.10

Table 2.39. Percent exceedance of appropriate water quality standard for agricultural and industrial chemicals in the Biloxi Marsh.

Toxic Substance		Aquatic Life Protection						Human Health Protection	
		Freshwater		Marine Water		Brackish Water		Drinking	Non-Drinking Water Supply
	N	Acute	Chronic	Acute	Chronic	Acute	Chronic	Water Supply	
VINYL CHLORIDE	21							100	

d. Trace metals and selected trace inorganics. Several trace metals have been detected in the Biloxi Marsh, the general summary statistics for those metals for which the state of Louisiana have established criteria are in Table 2.40. Detected concentrations of selected trace metals and metalloids were compared to the Louisiana fresh, marine and brackish criteria.

In the Biloxi Marsh, only mercury exceeded the chronic freshwater, marine and brackish aquatic life criteria. Based upon a review of the frequency distribution of mercury data, it appears that the MDL for the technique used to calculate mercury concentration may be greater than the criteria established for freshwater, marine and brackish chronic toxicity. A value of 0.05 µg/L was reported for all six data points reported.

Table 2.40. Lake Borgne Group Trace metals and selected trace inorganics Summary Statistics from 1990-2010

Trace metals and selected trace inorganics	Units	MEAN	NOBS	MAX	MEDIAN	MIN
Arsenic	UG/L	0.73	35	1.70	0.65	0.12
Cadmium	UG/L	0.03	35	0.13	0.03	0.01
Chromium	UG/L	0.16	18	0.38	0.20	0.02
Copper	UG/L	1.05	35	1.75	1.00	0.69
Lead	UG/L	0.11	28	1.48	0.03	0.02
Mercury	UG/L	0.05	21	0.05	0.05	0.05
Nickel	UG/L	1.44	35	2.10	1.50	0.74
Zinc	UG/L	2.02	36	14.25	1.05	0.16

Table 2.41. Percent exceedance of appropriate water quality standards for trace metals in the Biloxi Marsh.

Toxic Substance		Aquatic Life Protection						Human Health Protection
	N	Freshwater		Marine Water		Brackish Water		Drinking Water Supply
		Acute	Chronic	Acute	Chronic	Acute	Chronic	
Arsenic	35	0	0	0	0	0	0	0
Chromium III	18	0	0	0	0			0
Chromium VI	18	0	0	0	0	0	0	0
Copper	35	0	0	0	0			0
Mercury	6	0	100	0	100	0	100	0
Lead	28	0	0	0	0			0
Nickel	35	0	0	0	0			0
Zinc	36	0	0	0	0			0

PART THREE
POTENTIAL WATER QUALITY IMPACTS OF FRESHWATER DIVERSION

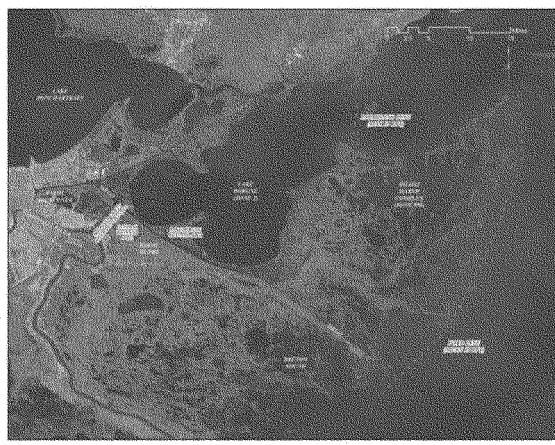
This report examines the potential water quality impacts to MRGO, Lake Borgne, Biloxi Marsh, and West Mississippi Sound associated with the implementation of a salinity reduction project that incorporates the diversion of Mississippi River water near Violet and the closure of the inlet connecting MRGO and Lake Borgne near Bayou Dupre.

Methods

Conceptual Framework

The method for predicting water quality responses of Lake Borgne, Biloxi Marsh and West Mississippi Sound was done by first computing the probable loads of various constituents from the Mississippi River. The loads were then attenuated (to various degrees) as they travel through two wetland complexes, the Central Wetlands Area (CWA) and a region referred to as the Lake Borgne Wetlands Area (LBWA; see Figure 3.1). The CWA is bounded by Paris Road to the north, the MRGO levee and canal to the east, the Violet canal and Bayou Dupre to the south, and the 40 Arpent Canal to the west. The area encompasses approximately 10,380 acres, most of which is brackish marsh. The LBWA is located east of MRGO between Bayou Villere and the channel that connects MRGO and Lake Borgne northeast of Alluvial City, and comprises 11,209 acres of wetlands. The wetlands in both the CWA and LBWA have degraded due to numerous man-made and natural processes. Water diverted into these wetlands have anticipated reductions in nitrogen, phosphorus, and total suspended solids through multiple pathways (i.e., burial, plant uptake by both emergent and potential submergent vegetation, denitrification, etc. as outlined in Mitsch et al. 2001, Richardson and Nichols 1995).

Figure 3.1. Map outlining locations of proposed diversion at Violet, Louisiana, along with the CWA, LBWA, Lake Borgne, Biloxi Marsh, and the Ford and Palmisano 15 ppt salinity isopleth lines.



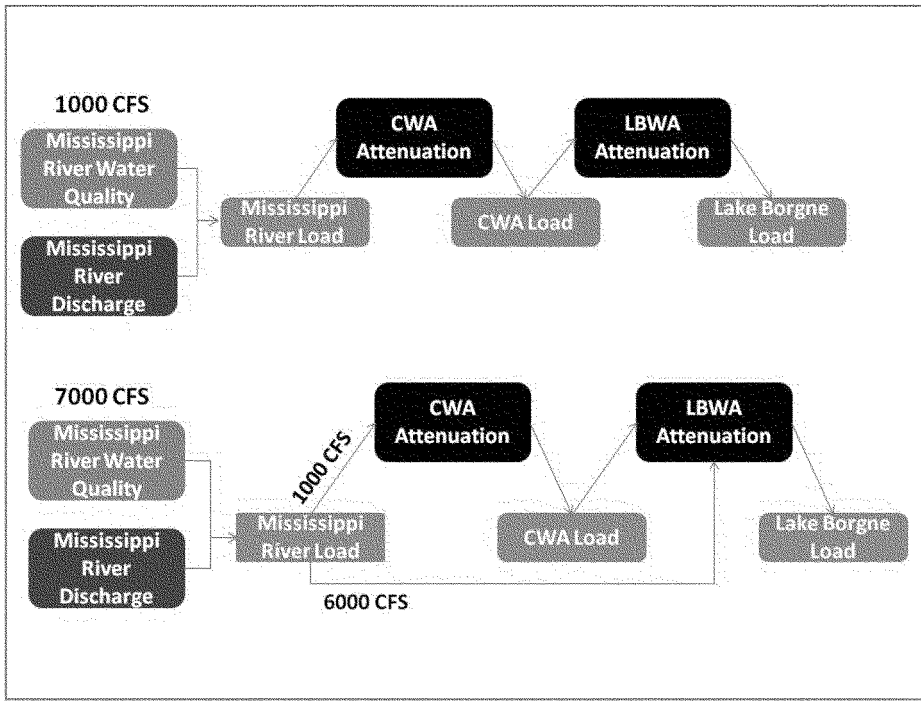
The quantity and quality of Mississippi River water to be diverted, by month, was used to calculate a constituent load for nitrate plus nitrite (NOx), total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS). These constituents are the primary ones used to categorize the eutrophication status of most US estuaries (Bricker et al. 2007).

These constituent loads were then modified by attenuation via the CWA for flows of 1,000 cfs, followed by attenuation via the LBWA. For flows of 7,000 cfs, travel time through the CWA would be such that little effective treatment would be expected for the additional 6,000 cfs flows. For both scenarios, water leaving the CWA and going to Lake Borgne might also be attenuated via the LBWA.

The quantities that would be incorporated into a final diversion schedule could vary from the values listed above; it could be decided that the "proper" diversion amount should be 6,000 or 8,000 cfs, rather than the 7,000 cfs assumed in this scenario. However, differences in diverted quantities, as long as they are within a range of perhaps 10 to 20 percent of the modeled flows, should have similar impacts. Estimates of potential changes in water quality are based on a series of assumptions of presumed rates and efficiencies, and end-point values should be considered a reasonable estimate of water quality responses. An adaptive management framework that includes ongoing water quality monitoring, regular reporting and analysis, and careful consideration of expected vs. observed responses should be incorporated into future work efforts.

The conceptual framework for assessing monthly loads to Lake Borgne, and then to Biloxi Marsh, is shown in Figure 3.2.

Figure 3.2. Conceptual framework for developing constituent loads into Lake Borgne and Biloxi Marsh.

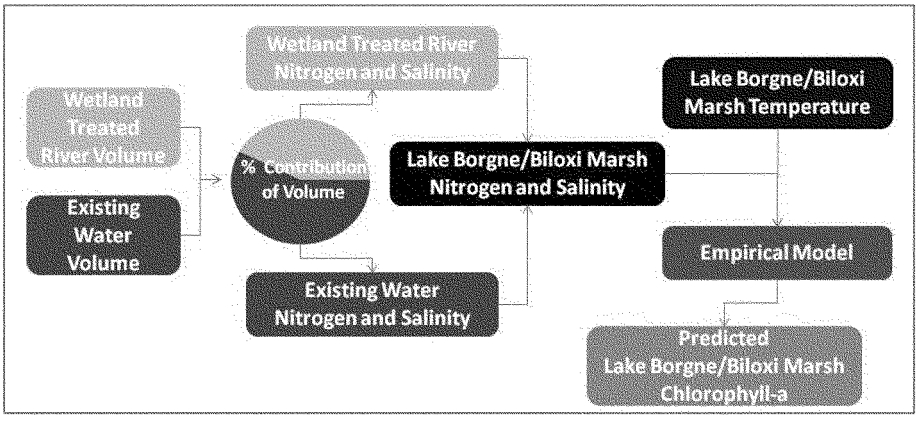


After the concentrations and constituent loads of Mississippi River water were estimated after being processed via transport through these two wetland systems (to varying degrees), the salinity values from the UNO Mass Balance Model were compared for each month for Lake Borgne (Zone 2) Biloxi Marsh (Zone 998- which is an area-weighted estimate for the Biloxi Marsh region) and West Mississippi sound (Zone 14). Water chemistry of the wetland-treated river water was then used in combination with ambient water quality data from Lake Borgne obtained from the Louisiana Department of Environmental Quality (LADEQ) and LDWF to predict concentrations of TN, TP and TSS for each zone, by month, for both the Future without Project (FWOP) scenario (i.e., status quo) and Future with Project (FWP) scenario. A similarly extensive water quality data set was not found for Biloxi Marsh or West Mississippi Sound; estimated water quality responses in those two areas should be considered to be more preliminary in nature.

The FWP scenario involves the closure of the MRGO to Lake Borgne connection northeast of Bayou Dupre (near the Martello Castle), the diversion of 7,000 cfs in April and May, and the diversion of 1,000 cfs in other months. As a simple example, if Lake Borgne's salinity was to be reduced by 50% during the month of May (on average) when comparing FWOP and FWP scenarios, then ½ the water in Lake Borgne would be comprised of ambient water from Lake Borgne, and the other ½ would be

comprised of Mississippi River water processed through one or both of the wetland systems. At this point, a prediction of phytoplankton levels (quantified as concentrations of chlorophyll-a) based on the combination of TN levels, salinity, and water temperature can be made. Figure 3.3 outlines the conceptual framework for estimating water quality responses of Lake Borgne and the Biloxi Marsh to diversion quantities.

Figure 3.3. Conceptual framework for predicting water quality responses of Lake Borgne and Biloxi Marsh to potential diversion scenarios.



Levels of chlorophyll-a are often used as a leading indicator of the relative trophic status of estuaries (e.g., Smith et al. 1981; Valiela et al. 1990; Bricker et al. 2007). Chlorophyll-a levels have been used alone or in combination with other biological indicators for setting water quality targets for biological resources (e.g., Tomasko et al. 2001; Buddemeier et al. 2007). Therefore, it is important to be able to predict a potential response of chlorophyll-a within Lake Borgne, Biloxi Marsh and Mississippi Sound based on changes in salinity and TN levels for the FWP scenario. An abundance of literature is available from Lake Pontchartrain related to its responses to diversions of Mississippi River water through the Bonnet Carre spillway (Lane et al. 2001; Georgiou et al. 2009) as well as assessments of the responses of Breton Sound to diversions at Caernarvon (Lane et al. 2007). These studies were used, in conjunction with ambient water quality data from Lake Borgne, to develop an empirical model to predict chlorophyll-a responses to TN, temperature, and salinity.

Data Sources

Data used in assessing potential impacts of withdrawing water from the Mississippi River and diverting through the CWA into Lake Borgne were obtained from the US Army Corps of Engineers (USACE) and the US Geological Survey (USGS) online databases (Table 1). Daily Mississippi River at Tarbert Landing gaged flows over the historic period-of-record (1956-2009) were used to determine average monthly means (Table 1).

Selected physical and chemical water quality parameters used to determine potential loadings and Lake Borgne responses were based on monthly averages (Table 3.2) of data from a selected series of monitoring locations (Table 3.1).

- Mississippi River at Belle Chasse, LA
- Mississippi River near St. Francisville, LA
- Mississippi River at Baton Rouge, LA
- Mississippi River at Luling, LA

Table 3.1. Sources used for Mississippi River flow and water temperature data and USGS water quality data used to develop monthly and annual loadings.

USACE ID	USACE Site Name	Latitude	Longitude	Historic Period	Interval
01100	Mississippi River at Tarbert Landing, MS	31° 00' 30"	91° 37 25"	1956-2009	Daily
01300	Mississippi River at New Orleans (Carrollton)	29° 56' 5"	90° 8' 10"	2001-2009	Hourly
USGS Site ID	**USGS Site Name**	**Latitude**	**Longitude**	**Historic Period**	**Sampling Events**
07374525	Mississippi River at Belle Chasse, LA	29°51'25"	89°58'40"	1976-2009	844
07373420	Mississippi River near ST. Francisville, LA	30°45'30"	91°23'45"	1943-2009	1660
07374000	Mississippi River at Baton Rouge, LA	30°26'44.4	91°11'29.6"	1975-2009	551
07374400	Mississippi River at Luling, LA	29°56'19	90°21'49	1957-1999	1343

Water quality data used in these analyses were limited to the most recent 20-year period in order to reduce potential discrepancies due to changes in historical and more recent analytical methods and detection limits, while still allowing sufficient numbers of water quality samples per month for further analysis.

Table 3.2. Monthly means of river flow and key water quality parameters used in load estimates.

Month	River Flow (cfs)	Temp (deg C)	TN (mg/l)	TP (mg/l)	NOX (mg/l)	TSS (mg/l)	TKN (mg/l)
January	531,157	6.7	2.087	0.231	1.180	150.6	0.650
February	599,740	7.9	2.139	0.25	1.505	148.1	0.711
March	713,412	10.7	2.093	0.235	1.417	145.3	0.659
April	763,646	15.7	2.264	0.218	1.592	194.2	0.649
May	719,761	21.2	2.455	0.21	2.047	110.7	0.610
June	592,080	26.1	2.643	0.224	1.738	155.4	0.632
July	418,916	28.6	2.727	0.236	2.333	149.0	0.596
August	302,441	29.4	1.863	0.202	1.612	129.3	0.573
September	250,242	27.5	1.426	0.179	1.250	68.6	0.508
October	276,478	21.6	1.364	0.186	0.884	158.6	0.505
November	326,252	15.5	1.784	0.198	1.143	87.8	0.552
December	478,150	10.6	1.995	0.206	1.391	160.4	0.640

These water quality data were then used to develop monthly constituent loads into the CWA, and loads were attenuated based on an approach outlined below.

Estimated removal efficiencies were determined for two flow levels (1,000 cfs and 7,000 cfs). Loading rates of Nitrate+Nitrite (NOx), Total Nitrogen (TN), Total Phosphorus (TP) and Total Suspended Sediments (TSS) were calculated for each month using average values (most data are from monthly sampling programs) for the Mississippi River from 1990-2009 (Table 2). The percent removal of TN and TP by the wetlands was estimated based on published constituent removal rates, which vary as a function of the inverse of loading rates (Richardson and Nichols, 1985). The percent reduction of NOx was calculated using the logarithmic decay regression established by Mitsch et al., 2001 relating the annual loading rate to percent removal ($y=-0.45*\text{Log}(x) + 1.23$). TSS deposition was determined using the average daily depositional load calculated in Breton Sound during periods of discharge through the Caernarvon diversion (Wheelock 2003, Cable et al. 2007). Estimated TSS deposition ranged between 3.1 and 4.7 $g/m^2/d$ (Cable et al. 2007). Under the 1,000 CFS flow regime, the output concentration for each parameter from the CWA was calculated to provide a loading estimate to MRGO, and then to the LBWA, with these loads then being delivered to Lake Borgne. During the 7,000 CFS flow regime, the first 1,000 cfs flow was attenuated as described above, while it was assumed that there was no reduction in nutrients or sediments for the additional 6,000 cfs flow during these high flow periods. The total 7,000 cfs flow was then assessed with the scenario that treatment would occur as these flows were routed into the MRGO and then into Lake Borgne via the LBWA complex. Estimated loads of TN, TP, NOx and TSS are shown in Tables XX to XX in Appendix XX.

Water quality data for Lake Borgne, as available through the USGS and LADEQ websites, were supplemented with additional water quality data from the LDWF. As these data sets did not contain information on chlorophyll-a, an empirical model could not be directly developed for Lake Borgne or the Biloxi Marsh (or West Mississippi Sound) using data from those locations. However, a multi-year data set for Breton Sound at Station 18 (Black Bay) was similar to ambient water quality conditions (as far as temperature and salinity) in Lake Borgne. While it would have been preferable

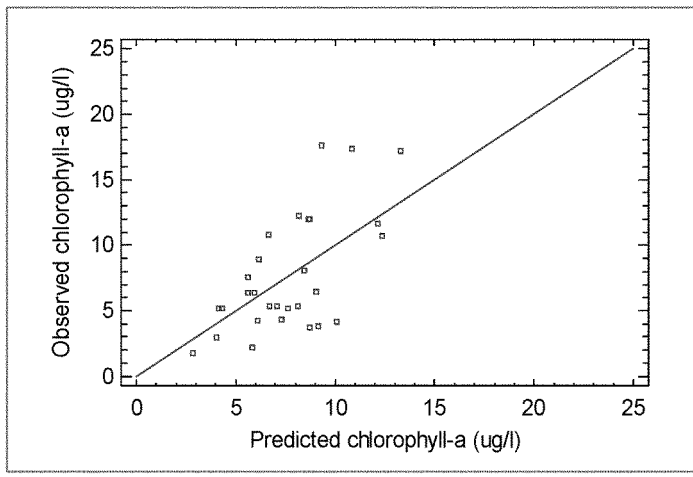
to have an empirically-derived eutrophication model developed from data sets from Lake Borgne and/or Biloxi Marsh, sufficient data sets did not exist. Thus, the Breton Sound data set was used to develop an empirical model to predict chlorophyll-a as a function of TN, water temperature and salinity. The plot of predicted vs. observed values is shown in Figure 3.4. The resultant multiple regression equation was statistically significant at $p < 0.001$.

The equation used to predict levels of chlorophyll-a in Lake Borgne (Zone 2) Biloxi Marsh (Zone 998) and West Mississippi Sound (between Bay St. Louis and the Biloxi Marsh; Zone 14) under both FWOP and FWP scenarios is:

$$\text{Chl-a} = 1.42519 + 1.9377*\text{TN} + 0.370629*\text{Temp} - 0.448084*\text{Sal}; \text{ where}$$

Chl-a is chlorophyll-a (in µg / liter),
TN is total nitrogen (in mg / liter),
Temp is water temperature (in °C), and
Sal is salinity (in ppt).

Figure 3.4 . Predicted vs. observed chlorophyll-a.



Results and Discussion

Tables XX to XX in Appendix XX show the estimated differences in salinity, total nitrogen (TN), chlorophyll-a, total phosphorus (TP) and total suspended solids (TSS) for Lake Borgne, Biloxi Marsh, and West Mississippi Sound, respectively, for Future Without Project (FWOP) and Future With Project (FWP) scenarios. The following text summarizes findings for those water quality parameters of greatest importance, as relates to estuarine eutrophication processes (i.e., Bricker et al. 2007).

Salinities in Lake Borgne (Zone 2) are lower than those in Biloxi Marsh (Zone 998) and they would be altered more than salinities in Biloxi Marsh and West Mississippi Sound, when comparing FWOP to FWP scenarios (Figures 5, 6 and 7, respectively).

Figure 3.5. Average monthly salinity values for Lake Borgne (Zone 2) for Future without Project (FWOP) and Future with Project (FWP) scenarios.

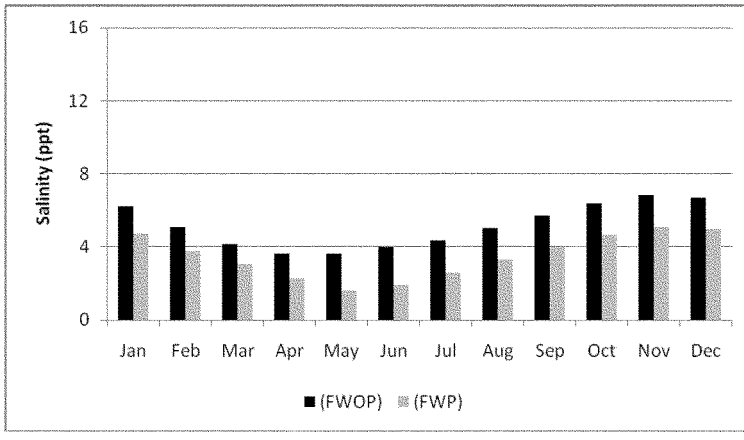


Figure 3.6. Average monthly salinity values for Biloxi Marsh (Zone 998) for Future without Project (FWOP) and Future with Project (FWP) scenarios.

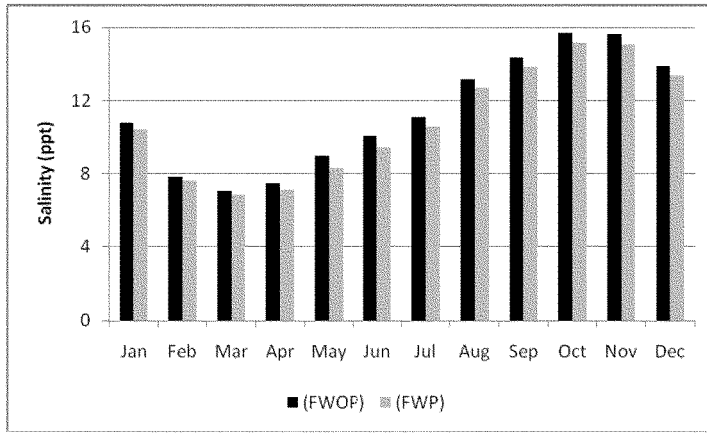
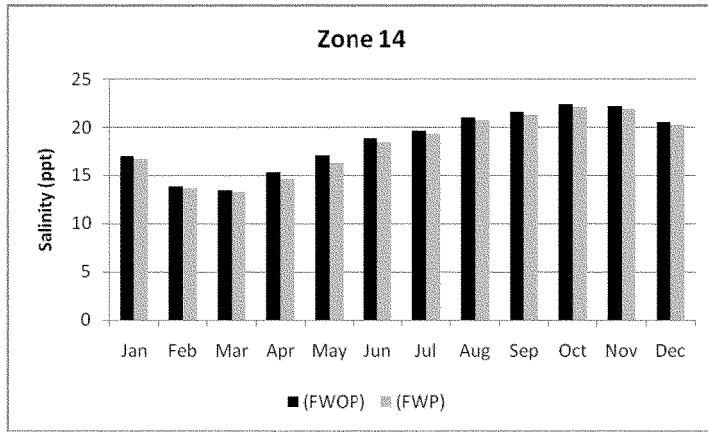


Figure 3.7. Average monthly salinity values for West Mississippi Sound (Zone 14) for Future without Project (FWOP) and Future with Project (FWP) scenarios.



With water diverted from the Mississippi River near Violet, a greater amount of dilution of ambient salinities would occur in the adjacent Lake Borgne region than in the more distant Biloxi Marsh (Figures 5 and 6, respectively). Salinity levels in West Mississippi Sound are higher than those in Biloxi Marsh, and much higher than values in Lake Borgne (not the change in scale of the y-axis); these salinity values are not likely to be changed to any significant degree, comparing FWOP and FWP scenarios (Figure 3.7).

Levels of TN and TSS would also be expected to be altered more in Lake Borgne (Zone 2) than in Biloxi Marsh (Zone 998) or West Mississippi Sound (Zone 14) when comparing FWOP to FWP scenarios (Figures 8 through 13, respectively). The differences in TN and TSS in Lake Borgne, comparing FWOP to FWP scenarios, is greatest in the months of April and May, when the volume of water diverted is sufficiently large that wetland treatment is very much curtailed.

For Biloxi Marsh and West Mississippi Sound, anticipated reductions in salinities in months other than April, May and June are less than 5 percent, comparing FWP and FWOP scenarios. Under these scenarios, during months other than April to June, estimates of changes in levels of TN, TP and chlorophyll-a are within the range of error associated with the use of predictive water quality models.

Figure 3.8. Average monthly total nitrogen (TN) values for Lake Borgne (Zone 2) for Future without Project (FWOP) and Future with Project (FWP) scenarios.

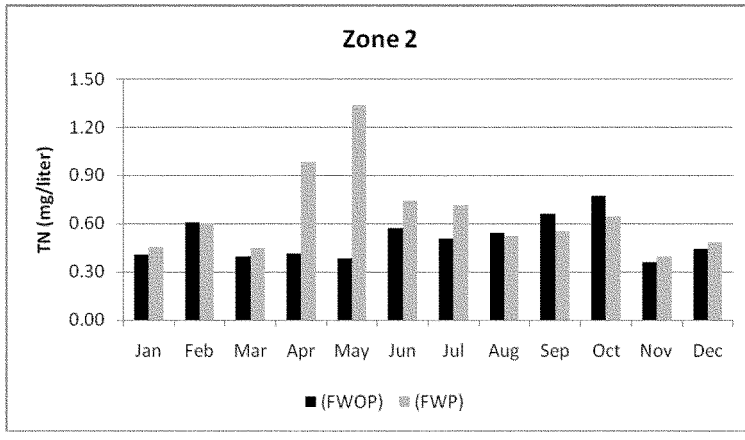


Figure 3.9. Average monthly total nitrogen (TN) values for Biloxi Marsh (Zone 998) for Future without Project (FWOP) and Future with Project (FWP) scenarios.

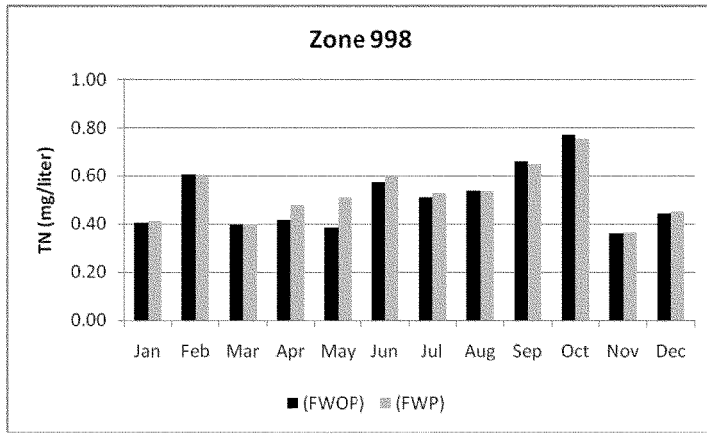


Figure 3.10. Average monthly total nitrogen (TN) values for West Mississippi Sound (Zone 14) for Future without Project (FWOP) and Future with Project (FWP) scenarios.

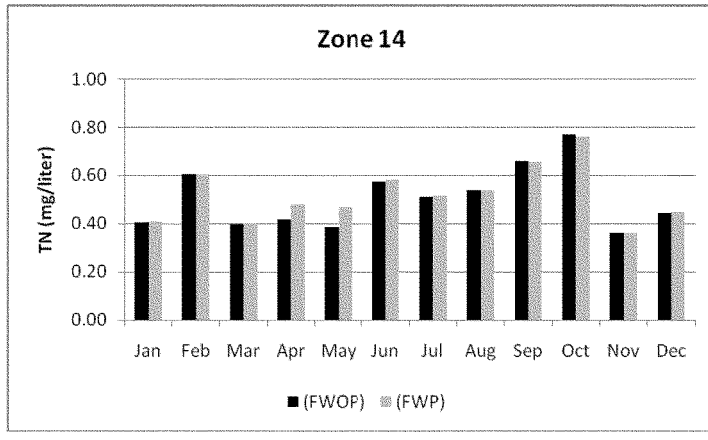


Figure 3.11. Average monthly total suspended solids (TSS) values for Lake Borgne (Zone 2) for Future without Project (FWOP) and Future with Project (FWP) scenarios.

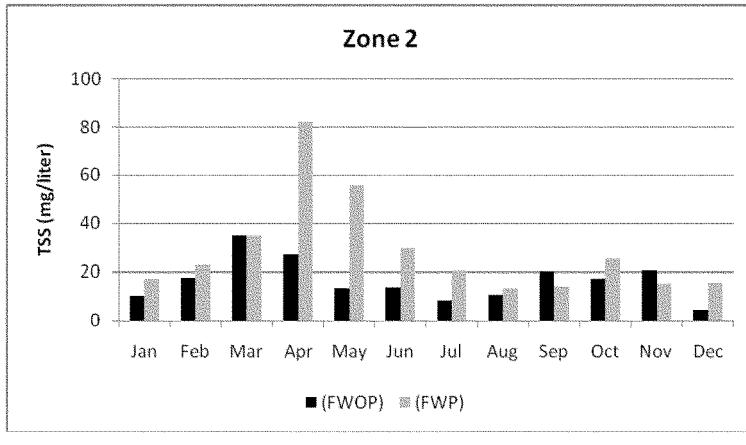


Figure 3.12. Average monthly total suspended solids (TSS) values for Biloxi Marsh (Zone 998) for Future without Project (FWOP) and Future with Project (FWP) scenarios.

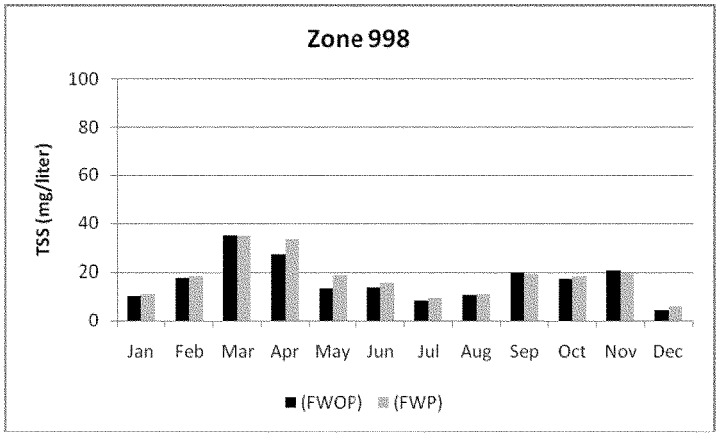
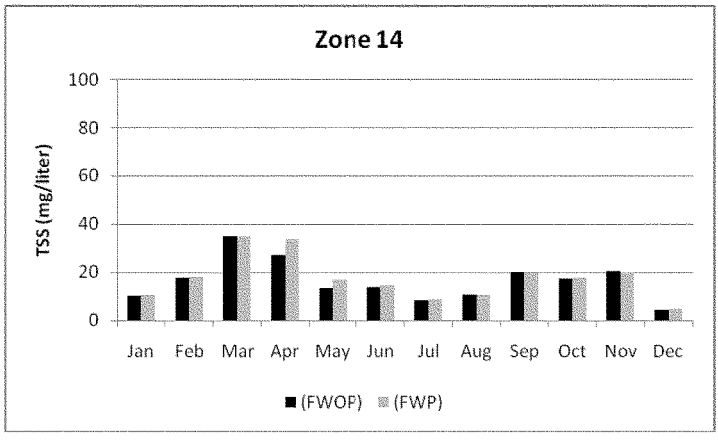


Figure 3.13. Average monthly total suspended solids (TSS) values for West Mississippi Sound (Zone 14) for Future without Project (FWOP) and Future with Project (FWP) scenarios.



These results suggest a pattern wherein the need to reduce salinities in the Biloxi Marsh area will result in more changes to Lake Borgne than in Biloxi Marsh or West Mississippi Sound. While expected changes in levels of TN in Lake Borgne are not inconsequential, changes in TN concentrations are not likely to lead to a similar rate of change in levels of chlorophyll-a due to moderating effects of flushing and turbidity. Lake Borgne is shallower than Lake Pontchartrain (average depths of 2.0 to 2.7 m and 3.4 to 3.7 m, respectively; McCorquodale et al. 2009) , and it has

a tidal range approximately twice that of Lake Pontchartrain; thus Lake Borgne has a much shorter residence time than Lake Pontchartrain (17 days vs. > 100 days, respectively; Bricker et al. 2007; McCorquodale et al. 2009). As such, the responses of Lake Borgne to nutrient increases associated with a diversion at Violet are not likely to be as extreme as those found for Lake Pontchartrain in response to releases from the Bonnet Carre spillway (e.g., Lane et al. 2001; Georgiou et al. 2009). Water quality in West Mississippi Sound would not be expected to change in any significant way with a diversion near Violet, due mostly to the minor modifications in salinity that would are expected in this region with the FWP scenario (see Figure 3.7) and the influence of the more locally-relevant Pearl River.

Figure 3.14 suggests a rather modest increase in levels of chlorophyll-a in Lake Borgne is expected, even in the months of April and May when diversion amounts are greatest. In Biloxi Marsh, changes in levels of chlorophyll-a are expected to be sufficiently minor that they might not be detected with water quality monitoring programs (Figure 3.15). In Western Mississippi Sound, even smaller changes in chlorophyll-a are expected; however the algorithm for predicting levels of chlorophyll-a may underestimate values in West Mississippi Sound in the colder winter months (Figure 3.16).

Figure 3.14. Average monthly chlorophyll-a concentrations for Lake Borgne (Zone 2) for Future without Project (FWOP) and Future with Project (FWP) scenarios.

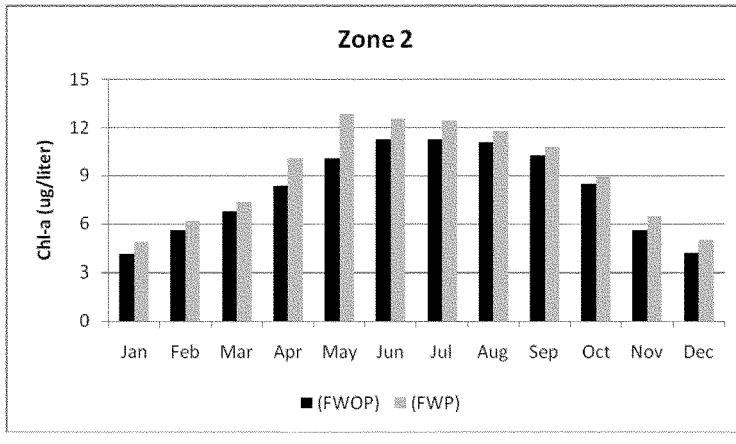


Figure 3.15. Average monthly chlorophyll-a concentrations for Biloxi Marsh (Zone 998) for Future without Project (FWOP) and Future with Project (FWP) scenarios.

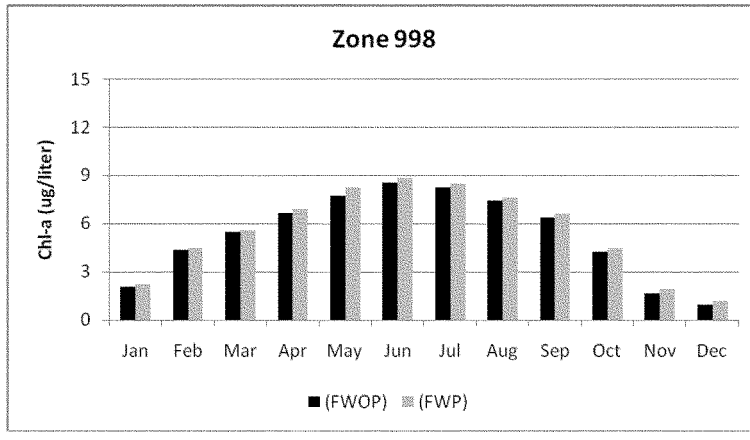
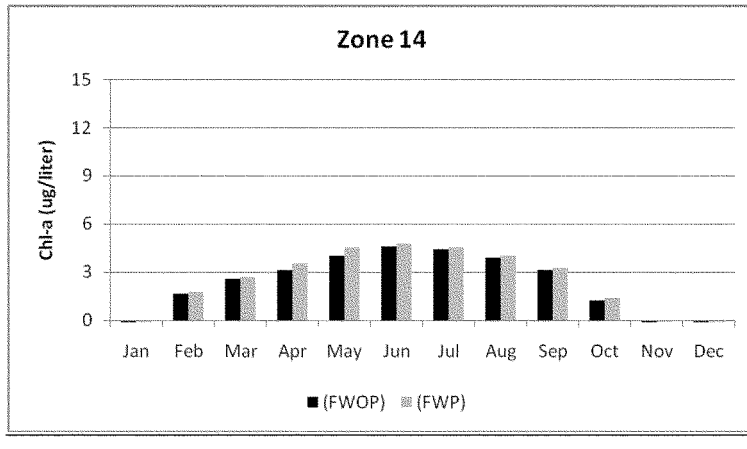


Figure 3.16. Average monthly chlorophyll-a concentrations for West Mississippi Sound (Zone 14) for Future without Project (FWOP) and Future with Project (FWP) scenarios.



Bacteria

Bacterial densities in the Mississippi River were discussed in the second portion of this report. When the diversion structure is operating, significant quantities of relatively high bacterial density freshwater would be introduced into the Central Wetlands, and then into MRGO and eventually into Lake Borgne and the Biloxi Marsh. Dilution, bacterial sedimentation, predation,

and the effect of increased salinities would reduce bacterial abundance by some not yet quantified degree. However, it is likely that there could be an increased risk associated with the consumption of raw oysters in those areas nearest the diversion structure.

Agricultural and industrial chemicals.

Long-lasting organochlorine insecticides such as DDT, dieldrin, and endrin, are still detected within the Mississippi River. However, the ability to predict the amount of time that levels exceed state water quality standards is compromised by a frequent finding of laboratory detection limits being higher than existing standards. If the diversion project near Violet is implemented, the occurrence and variety of pesticides and other organic compounds would likely increase in the Central Wetlands, MRGO, and Lake Borgne. This could lead to a possibility of bioaccumulation of these compounds in various filter feeders such as oysters, particularly in the areas nearest the diversion itself. Chemical spills within the Mississippi River should be detected by the Lower Mississippi River Early Warning Organic Compound Detection System (EVOCS) and the diversion structure could be closed until any potential spill passes by Violet, thus preventing accidental spills from entering the Central Wetlands and MRGO via the diversion structure.

To assess potential impacts of the changes in heavy metal concentrations that could result from freshwater diversion, data were compared to various appropriate water quality standards. Various metals exceeded both the acute and chronic saltwater aquatic life criteria. Within the Mississippi River, lead, mercury, copper and chromium (VI) consistently exceed the freshwater chronic criteria. These data also indicate potential problems associated with recurrent high concentrations of copper and chromium which exceed the acute criteria. Based upon a review of the frequency distribution of mercury data, it appears that the minimum detection limit for the technique used to calculate mercury concentration may be greater than the criteria established for freshwater, marine and brackish chronic toxicity.

In the Central Wetlands, mercury and lead exceeded the chronic freshwater aquatic life criteria (100 and 1%, respectively). Additionally, mercury exceeded the marine and brackish chronic criteria in the Central Wetlands. As was found for the Mississippi River, it appears that the minimum detection limit for the technique used to calculate mercury concentration may be greater than the criteria established for freshwater, marine and brackish chronic toxicity. Metals were not found to exceed water quality standards within Lake Borgne, the Biloxi Marsh, or West Mississippi Sound.

Dissolved Oxygen

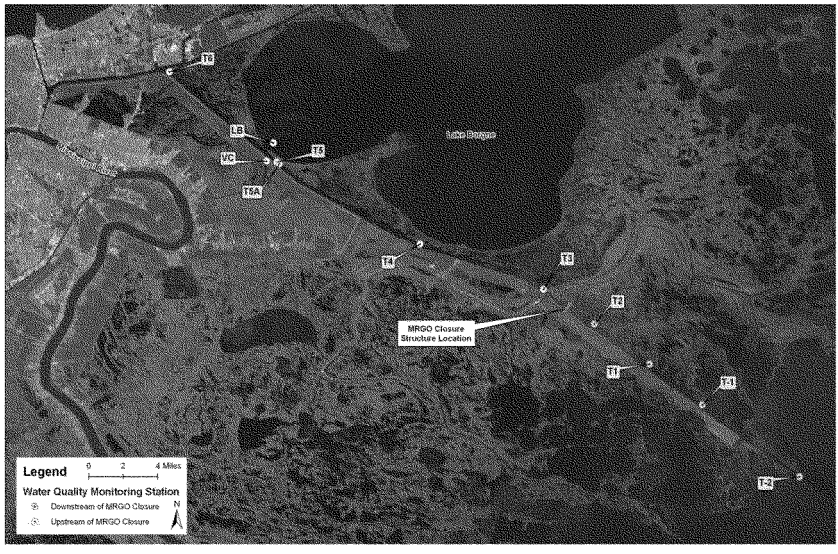
MRGO Dissolved Oxygen Analysis

In January 2009, construction began on a closure structure across the MRGO channel just downstream of Bayou La Loutre. Upon completion of the project in July 2009, the project was turned over to the Louisiana Coastal Protection and Restoration Authority for long-term operation, maintenance, repair, rehabilitation, and replacement responsibilities.

Concerns regarding a potential decline in dissolved oxygen (DO) values in the MRGO due to the closure of the canal are addressed here. Synoptic data were provided by the USGS for nine sampling transects along MRGO, a station in the Violet Canal (VC) and in Lake Borgne (LB; Figure 3.17). For each transect, data were collected from multiple profiles across the canal. Water depth (feet), water temperature (degrees C), salinity (ppt), conductivity ($\mu S\ cm^{-1}$), dissolved oxygen (mg/L), dissolved oxygen saturation (%), and pH were reported at each depth sampled. For the purposes of this assessment, sampling events were divided into pre construction (Prior to January 2009), during construction (January 2009 to July 7, 2009), and post construction (after July 7, 2009) time periods for analysis and interpretation. There were four stations located in MRGO downstream (toward the Gulf of Mexico) of the closure; stations T-2, T-1, T2 and T1 (the similar station identifications can be confusing to readers), and four stations located in MRGO upstream of the closure (T3, T4, T5, T5a, and T6). Additional sampling locations are in the Violet Canal (VC) and far western Lake Borgne (LB), close to the Martello Castle.

Water temperature, salinity, and water depth have been shown to directly impact DO concentrations within estuarine and marine systems. For example, the synergistic affects of salinity stratification, water depth and water temperature combine to produce DO sags in Charlotte Harbor, Florida (Turner et al. 2006). In Charlotte Harbor, DO levels in the bottom layers of the estuary drop below about 2 mg/L under the following conditions: 1) salinity stratification exceeds 10 ppt, and 2) water temperature exceeds 20° C. Salinity stratification occurs when the inflow of less dense freshwater is sufficiently large that it forms a distinct layer on top of the saltier (and thus denser) ambient waters of the estuary. Stratification thus isolates bottom waters from being re-oxygenated via the atmosphere. Additionally, bottom water under conditions of stratification can often have insufficient light for photosynthesis. DO levels drop as respiration and organic decomposition processes exceed infusion of DO from atmospheric mixing and/or photosynthesis. Temperature plays a vital role, due to the direct affects of water temperature (warmer water holds less oxygen at saturation) and the indirect affects wherein bacterial metabolism increases with temperature (i.e., higher respiration rates at higher water temperatures). Higher salinities in bottom waters could also affect DO levels, as more saline water holds less oxygen at saturation than freshwater. This effort conducted a characterization of DO levels in MRGO based on evaluating changes in water temperature, salinity and DO levels with increasing water depth for pre-closure, during construction, and post-construction time periods for the MRGO. These data were then used to suggest changes in DO levels that might occur with the additional activities of a freshwater diversion in the area of Violet.

Figure 3.17. Location of synoptic stations along MRGO.



Figures 3.18 to 3.28 plot water temperature vs. water depth at these stations. Overall, there is evidence of a strong effect of season on water temperatures at all stations, but not an affect of depth. That is, deeper waters do not appear to be, on average, either warmer or colder than shallow waters at these locations. Water temperatures are generally lower than 20°C during the months of November to March and warmer than 20°C during the spring to late fall.

Figure 3.18. Change in temperature with increasing depth at station T-2.

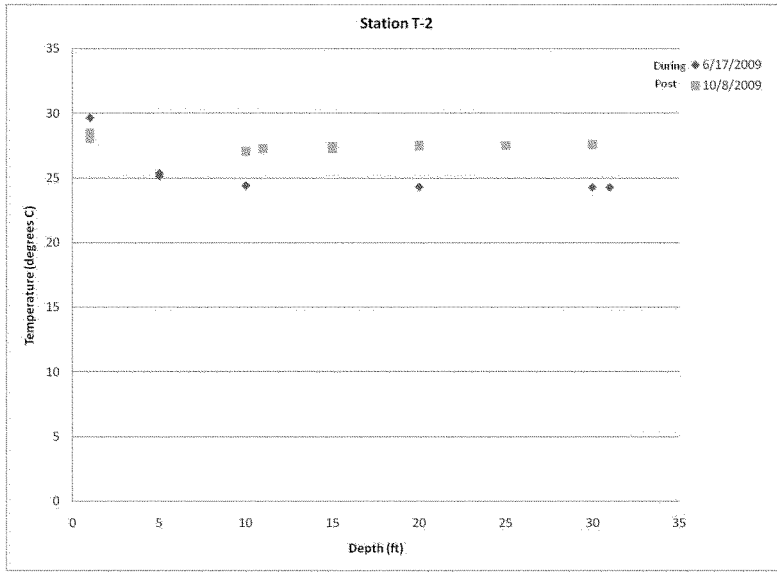


Figure 3.19. Change in temperature with increasing depth at station T-1.

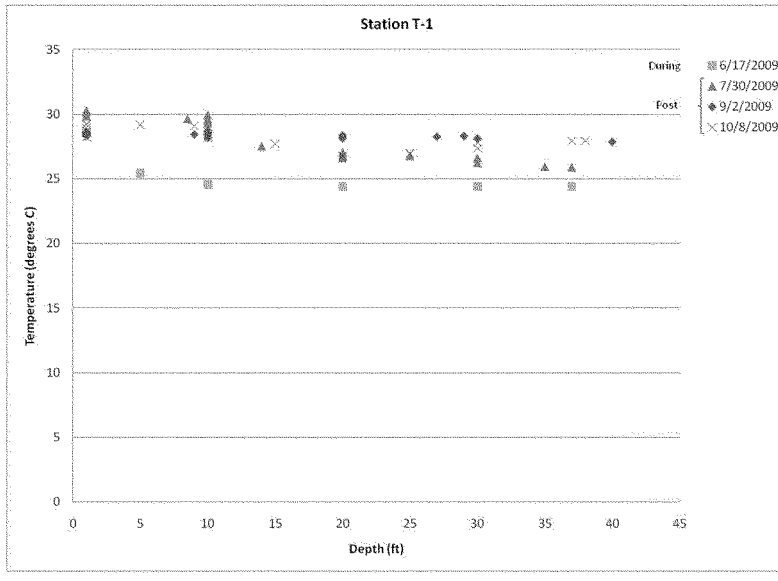


Figure 3.20. Change in temperature with increasing depth at station T1.

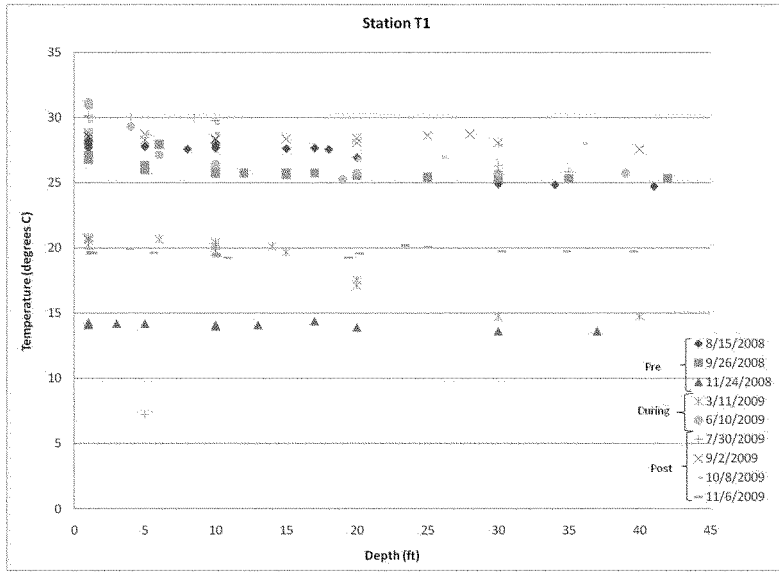


Figure 3.21. Change in temperature with increasing depth at station T2.

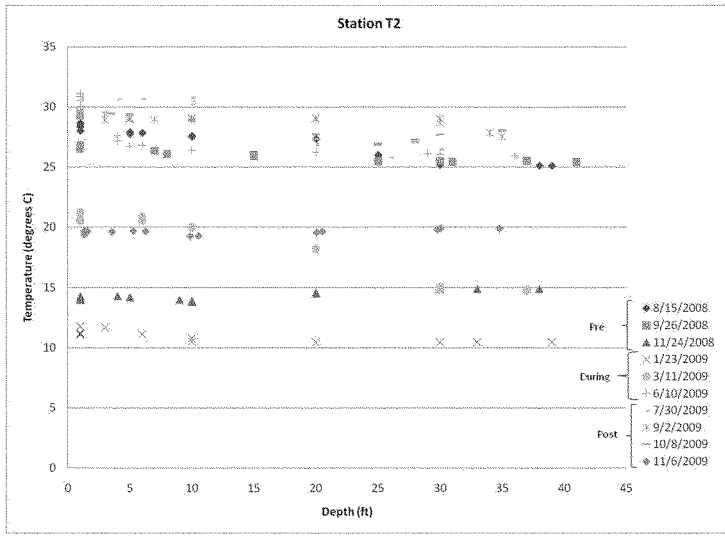


Figure 3.22. Change in temperature with increasing depth at station T3.

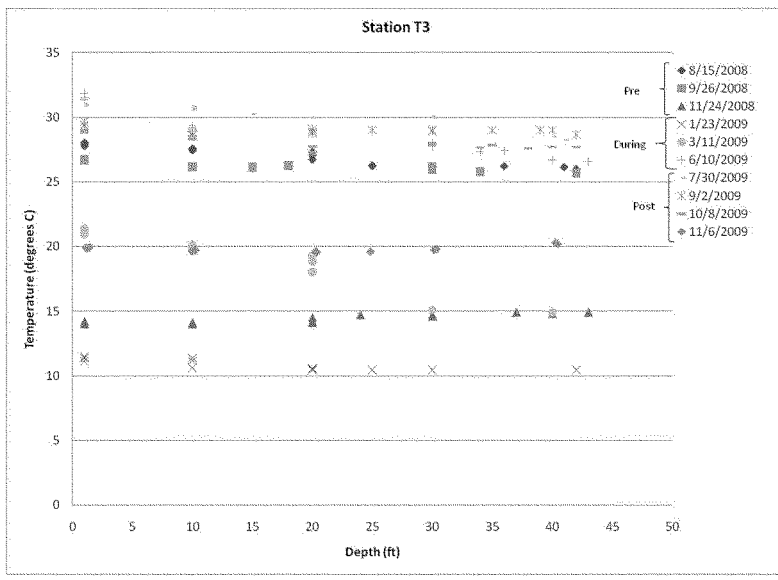


Figure 3.23. Change in temperature with increasing depth at station T4.

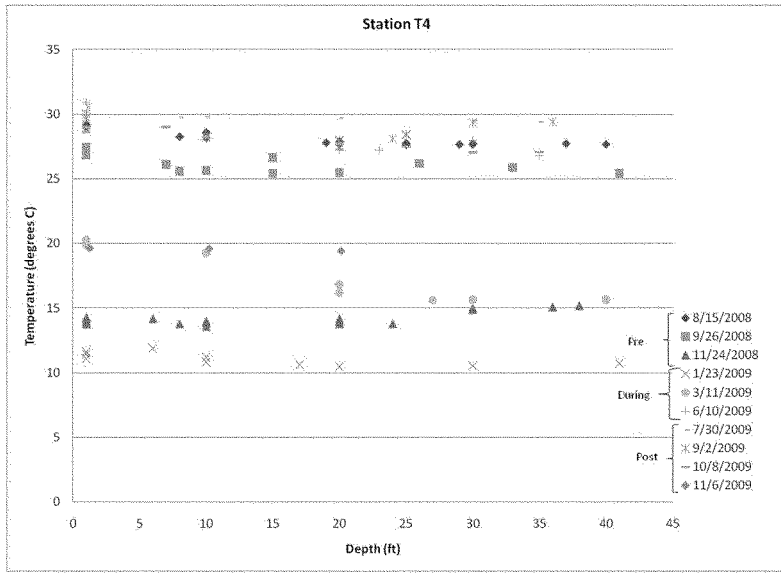


Figure 3.24. Change in temperature with increasing depth at station T5.

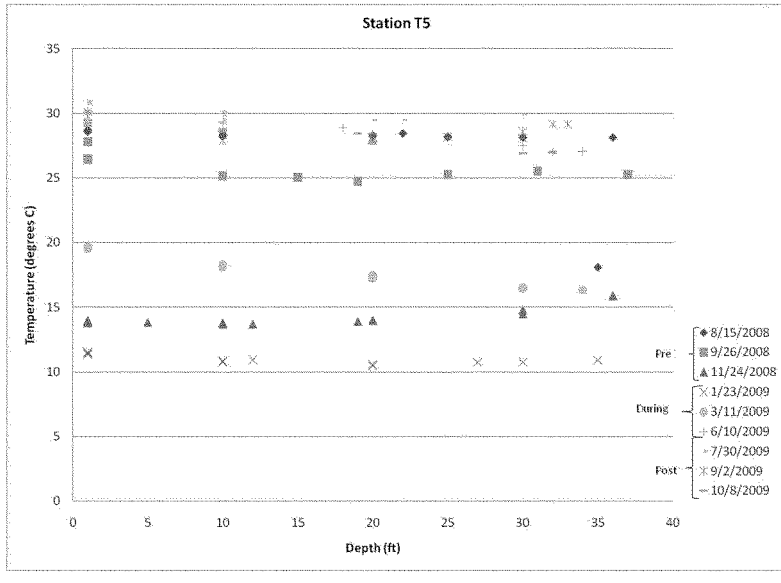


Figure 3.25. Change in temperature with increasing depth at station T5A.

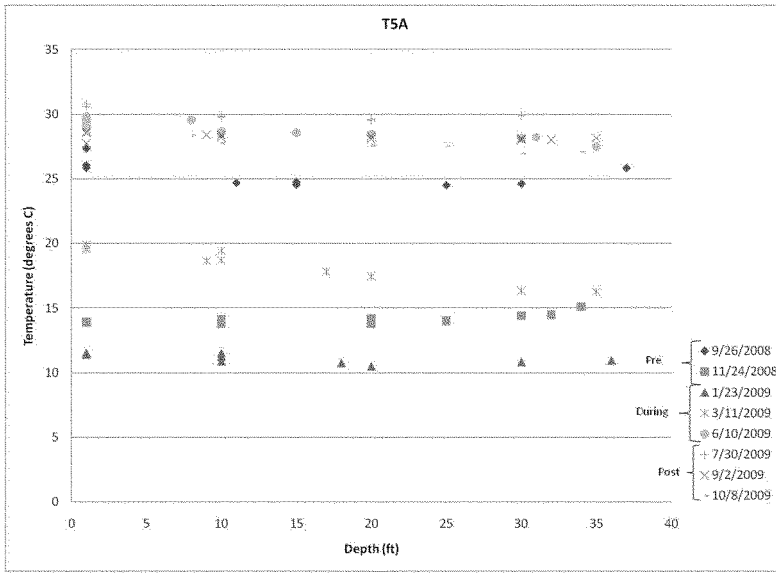


Figure 3.26. Change in temperature with increasing depth at station T6.

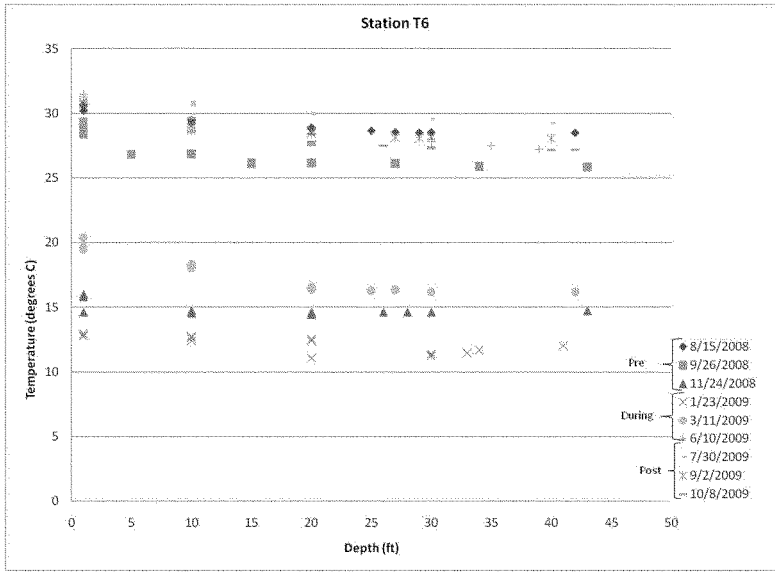


Figure 3.27. Change in temperature with increasing depth at station LB.

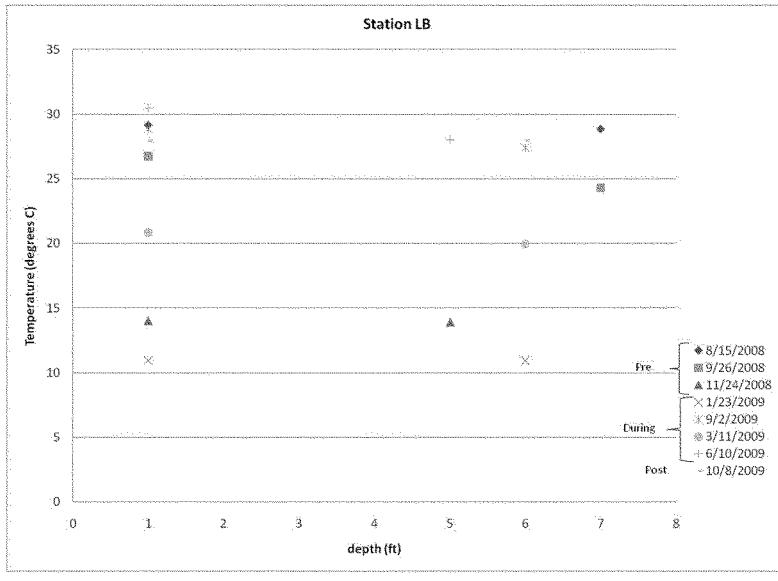
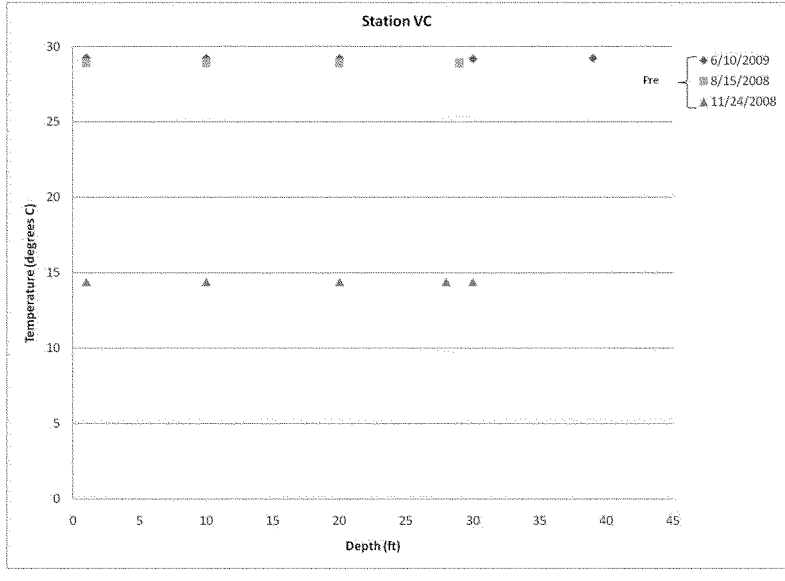


Figure 3.28. Change in temperature with increasing depth at station VC.



Figures 3.29 to 3.39 depict the pattern of salinity vs. depth at these same stations. In contrast to water temperature, salinity mostly increased with increasing water depth, with the exception of stations located in the Violet Canal and Lake Borgne. These results suggest that salinity stratification is occurring, to varying degrees, within MRGO, but not within Lake Borgne or the Violet Canal. Overall, salinities appear to be higher for sampling events post-closure, compared to pre-closure, which is consistent with the intent of the closure to aid in reducing salinities in upstream areas. However, salinities upstream of the closure can still reach relatively high salinities (i.e., 10 to 15 ppt) due perhaps to the multiple connections between MRGO and Lake Borgne.

Figure 3.29. Change in salinity with increasing depth at station T-2.

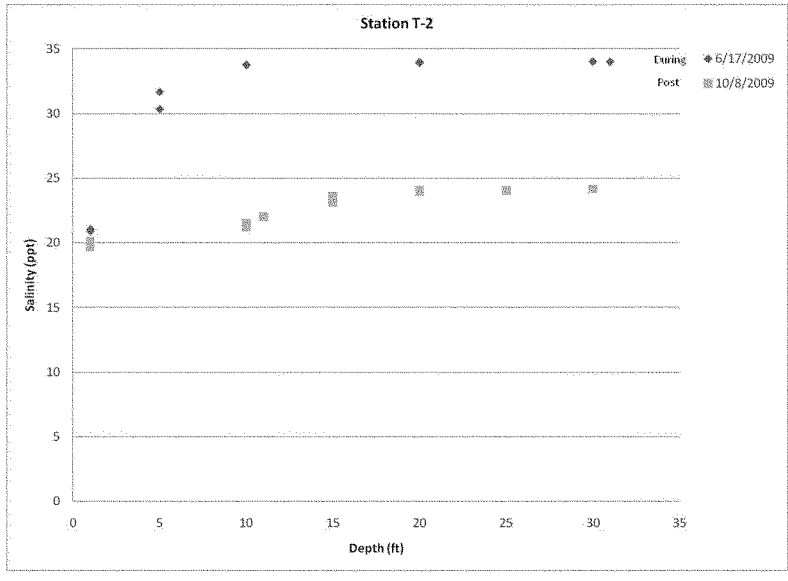


Figure 3.30. Change in salinity with increasing depth at station T-1.

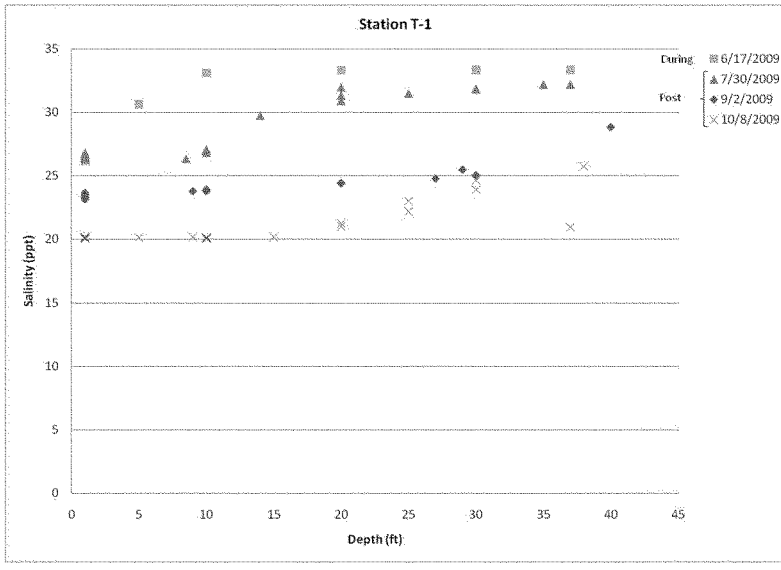


Figure 3.31. Change in salinity with increasing depth at station T1.

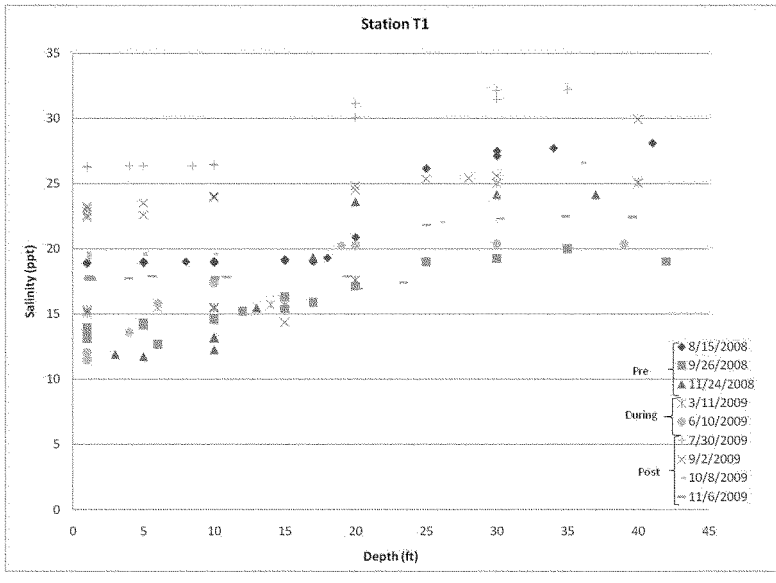


Figure 3.32. Change in salinity with increasing depth at station T2.

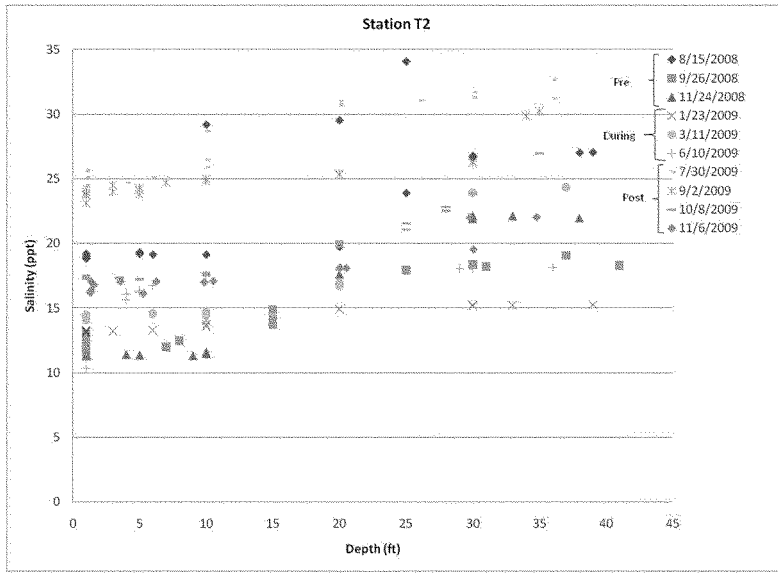


Figure 3.33. Change in salinity with increasing depth at station T3.

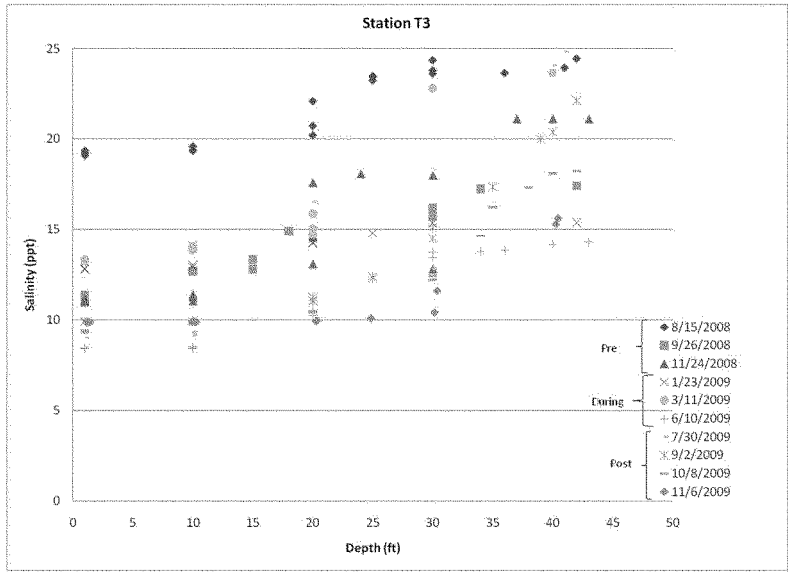


Figure 3.34. Change in salinity with increasing depth at station T4.

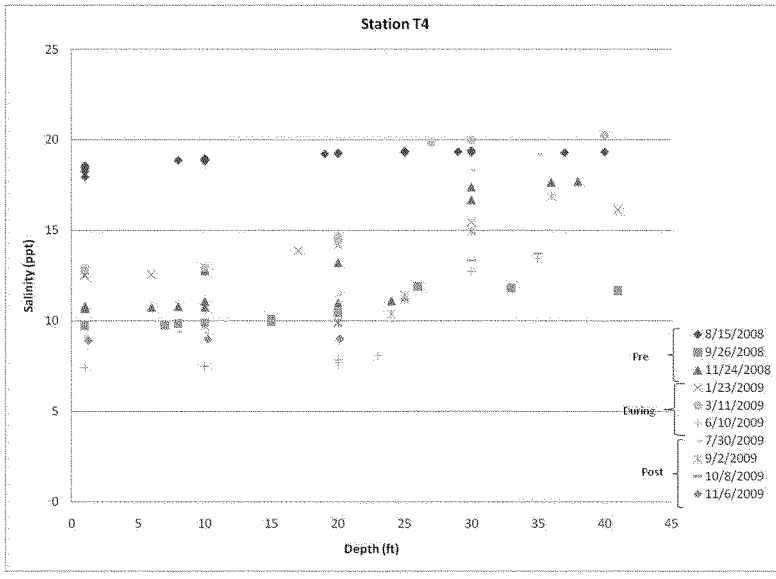


Figure 3.35. Change in salinity with increasing depth at station T5.

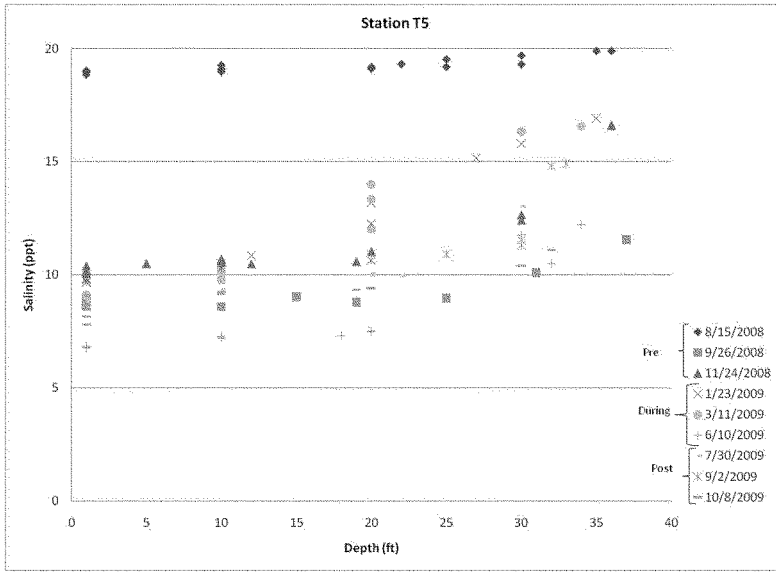


Figure 3.36. Change in salinity with increasing depth at station T5A.

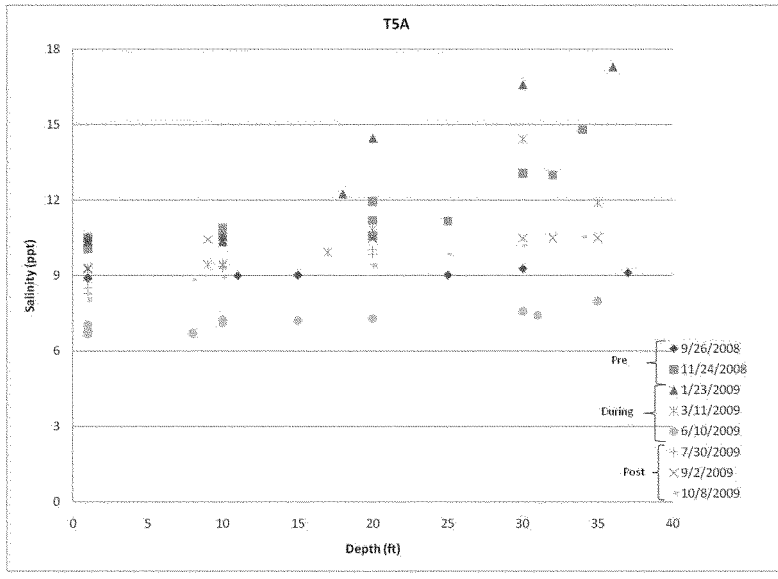


Figure 3.37. Change in salinity with increasing depth at station T6.

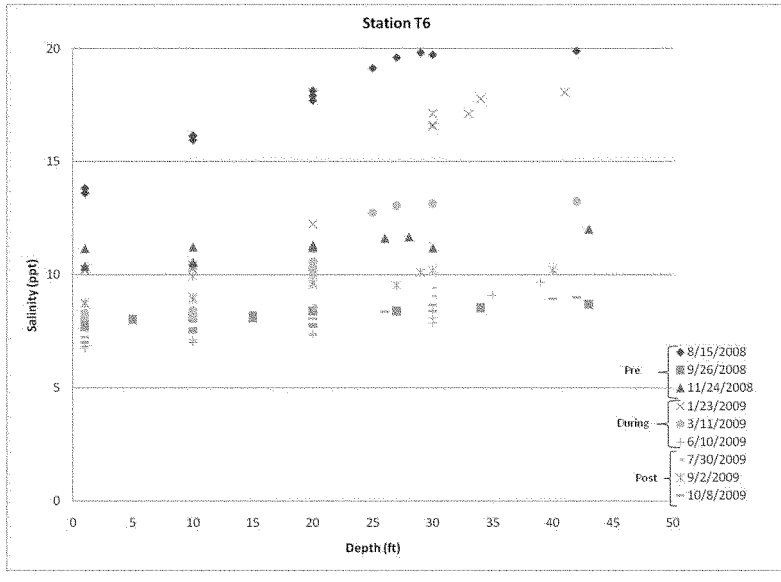


Figure 3.38. Change in salinity with increasing depth at station LB.

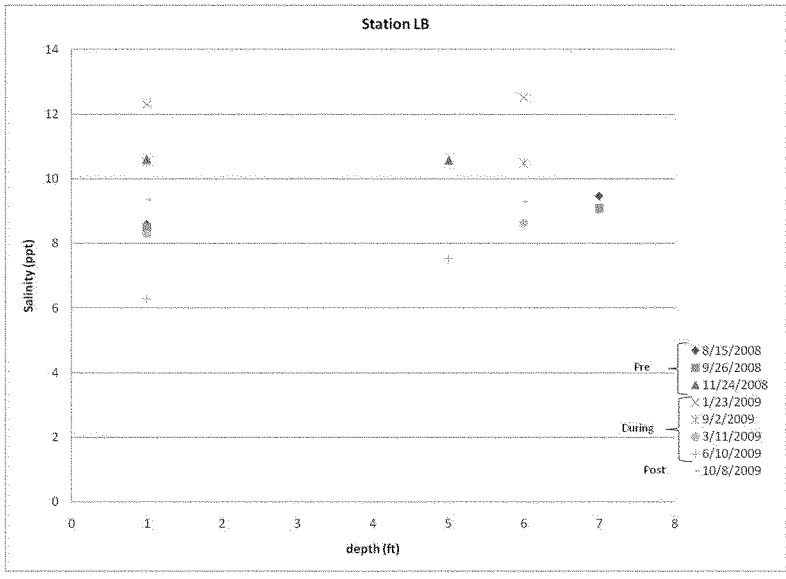
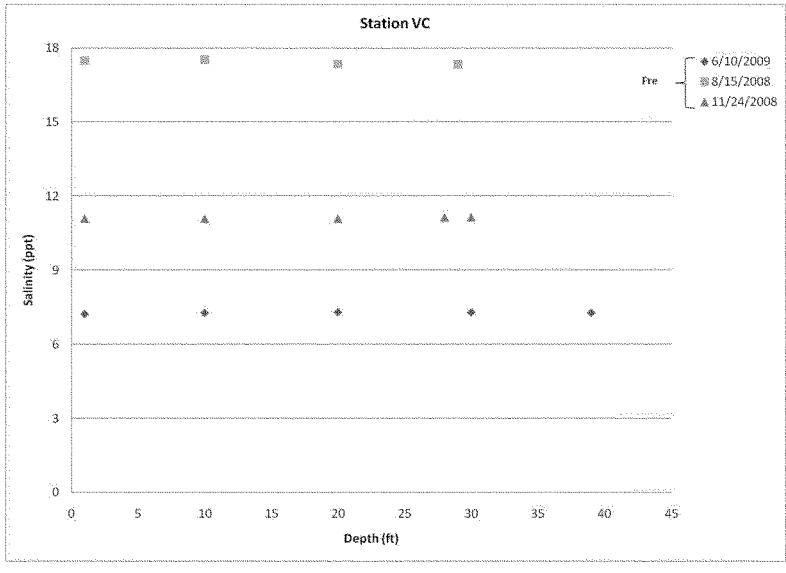


Figure 3.39. Change in salinity with increasing depth at station VC.



Figures 3.40 to 3.50 depict the changes in DO levels at sampling locations. The state of Louisiana's water quality standard for DO in estuarine waters is 4.0 mg/L. Additionally, Turner

et al. (2006) and others have suggested that DO levels below 2.0 mg/L are more relevant in terms of impacts to biological processes; both levels are relevant for examining the results shown here. Overall, DO concentrations consistently decline with increasing water depth, with the exception of stations located in Lake Borgne and the Violet Canal. Stations located downstream of the closure also showed the pattern of decreased DO with depth, even at stations located more than 5 miles downstream of the closure. At stations nearest the closure, an examination of the data suggests that DO levels did not drop below 2 or 4 mg/L prior to closure of MRGO, this phenomenon is examined in greater detail, as described below.

An evaluation of the percent of dissolved oxygen concentrations which fell below 4.0 and 2.0 mg/l prior to construction (Prior to January 2009), during construction (January 2009 to July 7, 2009), and after the completion of construction (after July 7, 2009) was completed, with the results shown in Table 3.2. Only one dissolved oxygen value fell below the 4.0 mg/L standard prior to the construction of the barrier on MRGO; in contrast, greater than 33% of the samples fell below 2.0 mg/L downstream of the barrier during and post construction. Additionally, post-construction bottom-water dissolved oxygen concentrations were consistently below 4.0 and 2.0 mg/L at the upstream locations, particularly at station T3.

Figure 3.40. Change in dissolved oxygen with increasing depth at station T-2.

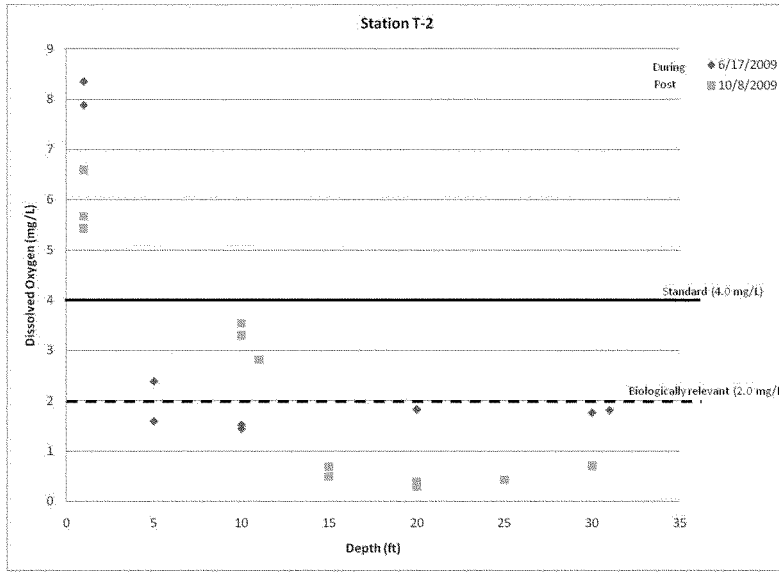


Figure 3.41. Change in dissolved oxygen with increasing depth at station T-1.

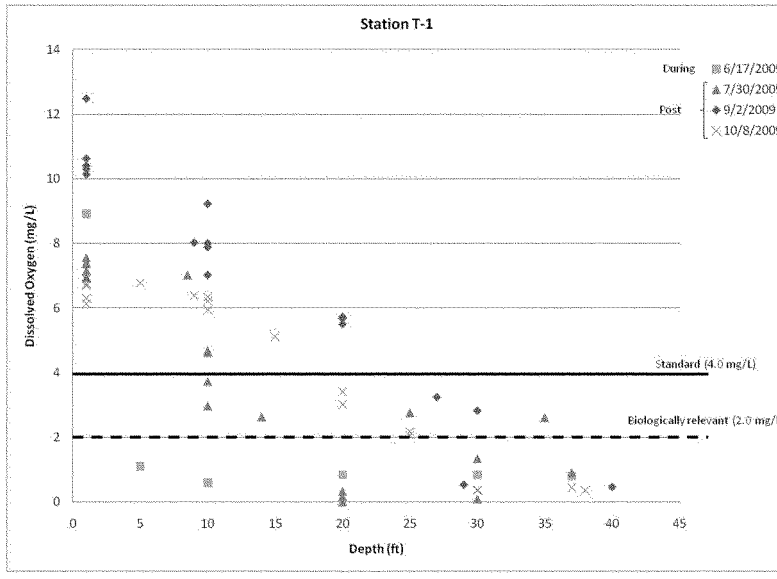


Figure 3.42. Change in dissolved oxygen with increasing depth at station T1.

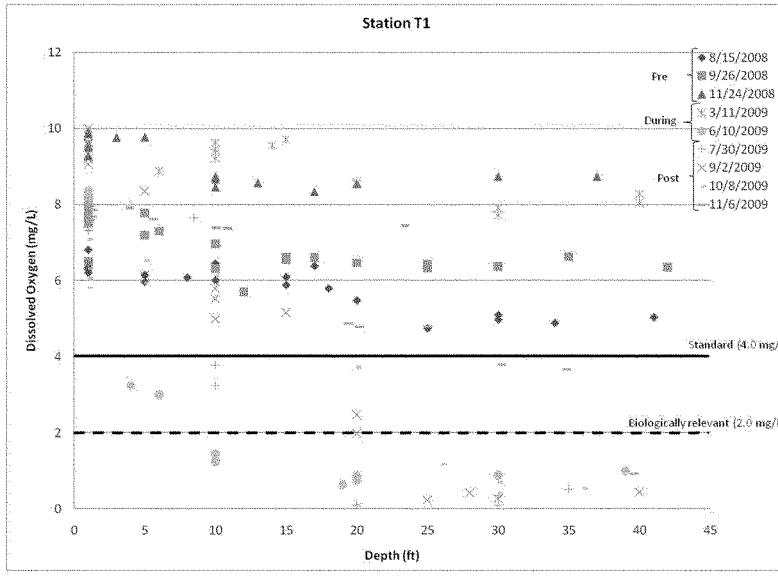


Figure 3.43. Change in dissolved oxygen with increasing depth at station T2.

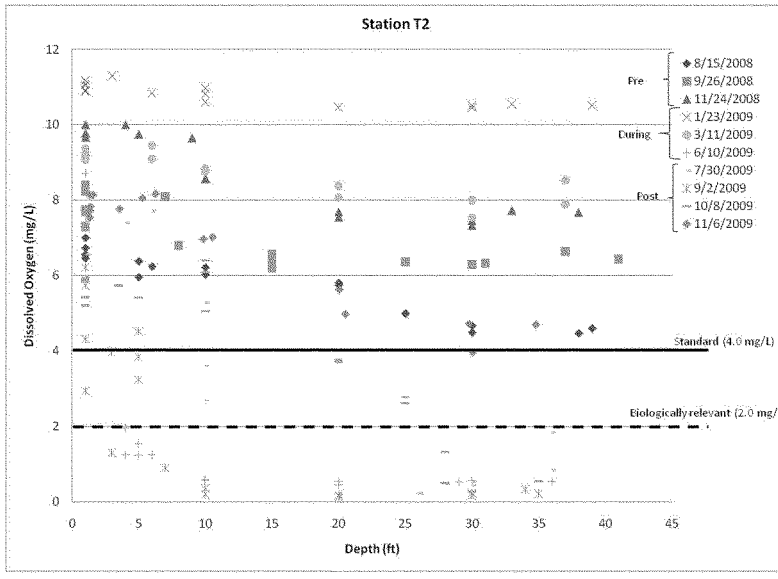


Figure 3.44. Change in dissolved oxygen with increasing depth at station T3.

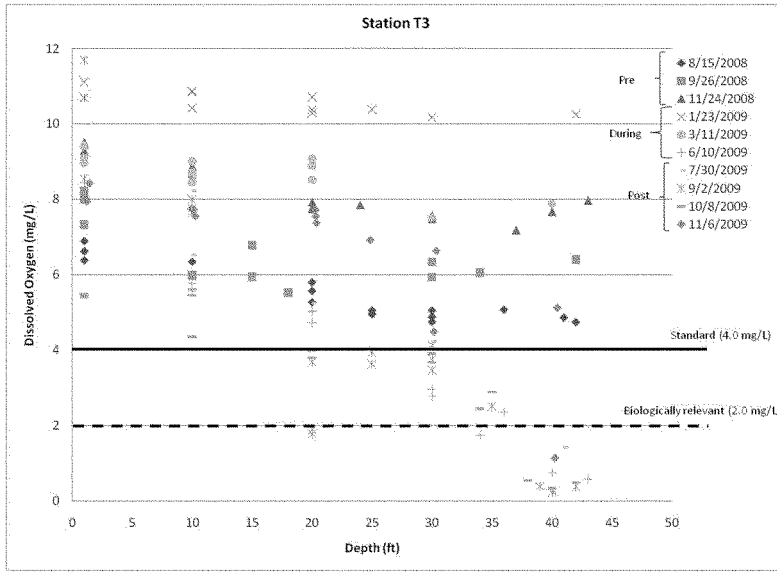


Figure 3.45. Change in dissolved oxygen with increasing depth at station T4.

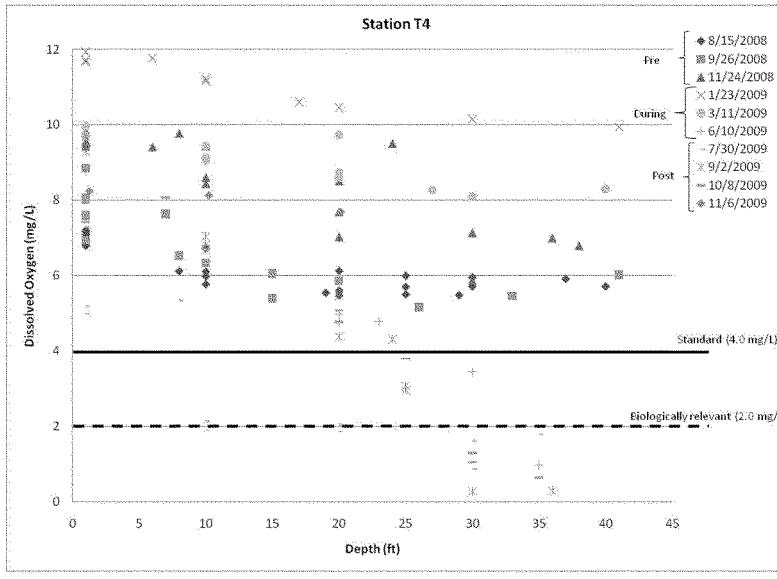


Figure 3.46. Change in dissolved oxygen with increasing depth at station T5.

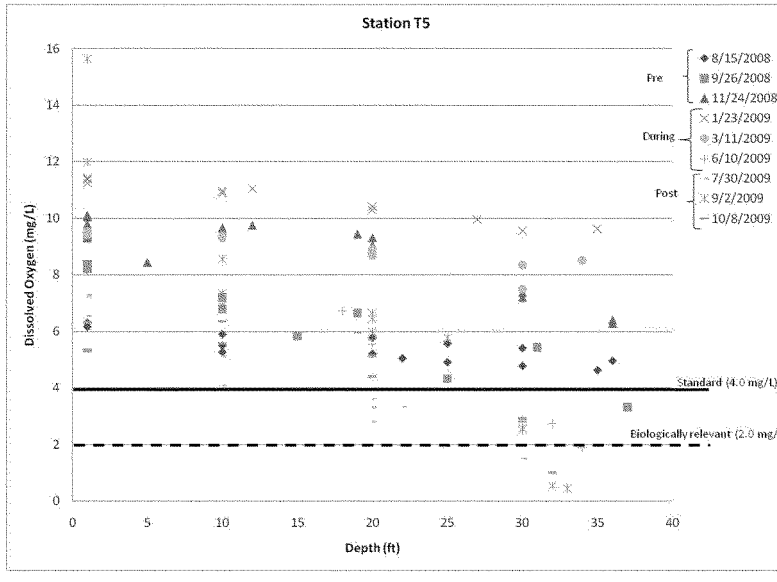


Figure 3.47. Change in dissolved oxygen with increasing depth at station T5A.

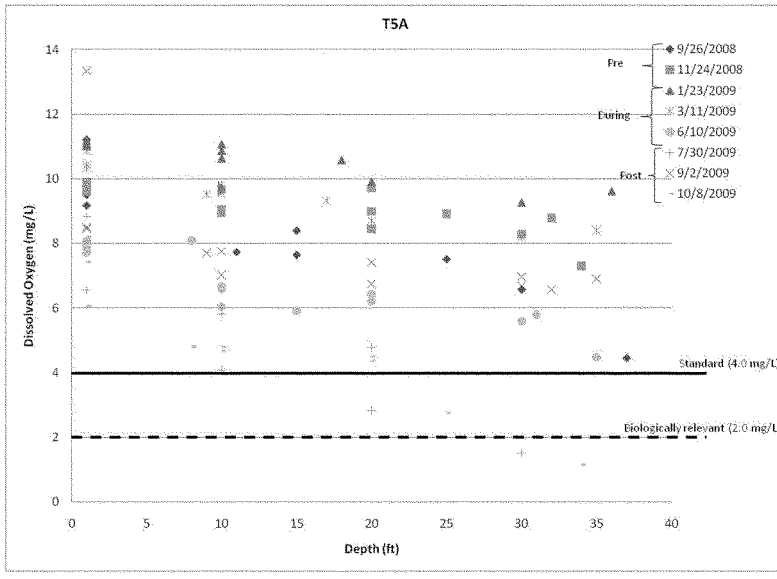


Figure 3.48. Change in dissolved oxygen with increasing depth at station T6.

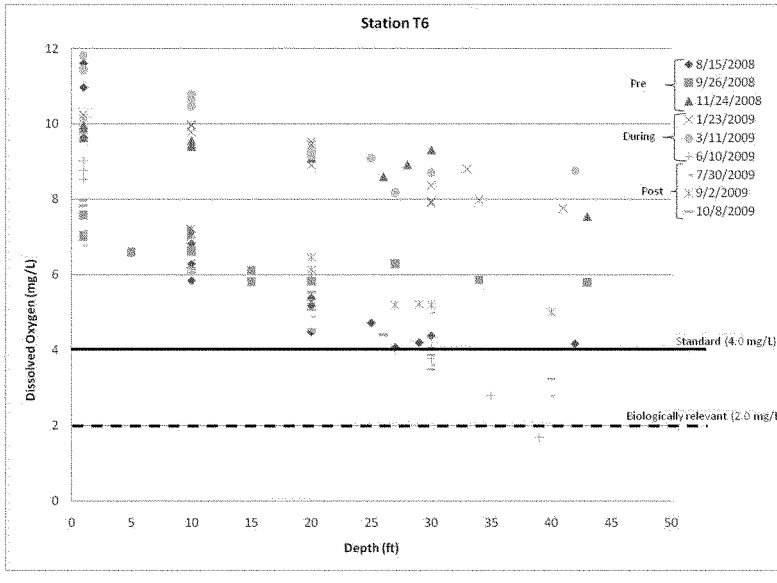


Figure 3.49. Change in dissolved oxygen with increasing depth at station LB.

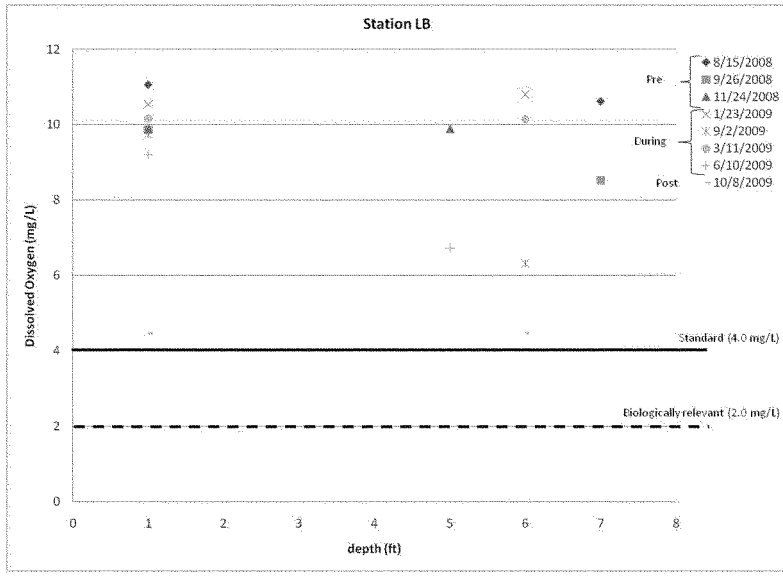


Figure 3.50. Change in dissolved oxygen with increasing depth at station VC.

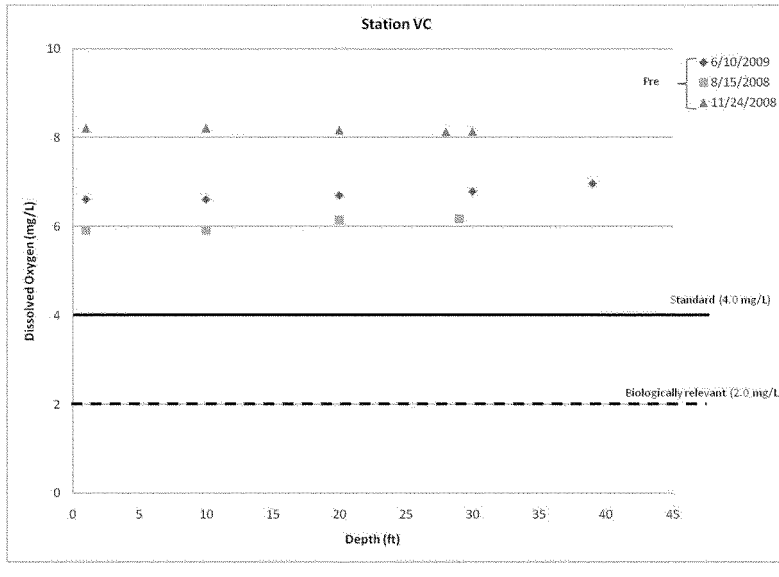


Table 3.2. Number and Percent Exceedances of dissolved oxygen values below 4.0 and 2.0 mg/L in Pre, During and Post construction time periods for each station (green stations are downstream and yellow stations are upstream of the MRGO closure). Limited data were available for stations LB and VC and are not included in the table.

Group = PRE					
		<4.0 mg/L		<2.0 mg/L	
Station	N	# Exceedances	% Exceedances	# Exceedances	% Exceedances
T1	56	0	0.00%	0	0.00%
T2	49	0	0.00%	0	0.00%
T3	44	0	0.00%	0	0.00%
T4	54	0	0.00%	0	0.00%
T5	42	1	2.38%	0	0.00%
T5A	22	0	0.00%	0	0.00%
T6	38	0	0.00%	0	0.00%
Group = DURING					
		<4.0 mg/L		<2.0 mg/L	
Station	N	# Exceedances	% Exceedances	# Exceedances	% Exceedances
T-2	10	8	80.00%	7	70.00%
T-1	6	5	83.33%	5	83.33%
T1	40	16	40.00%	14	35.00%
T2	57	20	35.09%	19	33.33%
T3	38	6	15.79%	3	7.89%
T4	34	2	5.88%	1	2.94%
T5	35	3	8.57%	1	2.86%
T5A	36	0	0.00%	0	0.00%
T6	47	3	6.38%	1	2.13%
Group = POST					
		<4.0 mg/L		<2.0 mg/L	
Station	N	# Exceedances	% Exceedances	# Exceedances	% Exceedances
T-2	12	9	75.00%	6	50.00%
T-1	55	23	41.82%	21	38.18%
T1	120	45	37.50%	27	22.50%
T2	83	43	51.81%	28	33.73%
T3	60	25	41.67%	11	18.33%
T4	40	15	37.50%	10	25.00%
T5	37	13	35.14%	4	10.81%
T5A	32	5	15.63%	3	9.38%
T6	38	5	13.16%	0	0.00%

A more comprehensive evaluation of the impact of water depth on dissolved oxygen concentrations was then completed using Statgraphics Centurion XV Version 15.1.03. Regression analysis was performed, comparing water depth and dissolved oxygen for each time period (pre, during and post closure) wherein the best-fit model (linear or exponential) was selected based upon the greatest amount of variability explained (i.e., the highest r^2 value) upon

examining the relationships between water depth and DO (Figure 3.35 to 42). All best-fit equation lines are shown, but statistical significance should be attributed only to those lines where the p value is < 0.05. These results show that the closure of the MRGO resulted in a much greater probability of experiencing low DO values at depths greater than 20 feet, particularly during months when water temperatures exceed 20° C. Only station LB does not reflect a significant decline in DO with increasing depth which is likely due to both the limited dataset available and the shallower water depths at the sampling site visited.

Figure 3.51. Effect of water depth on dissolved oxygen at Station T1 over different periods

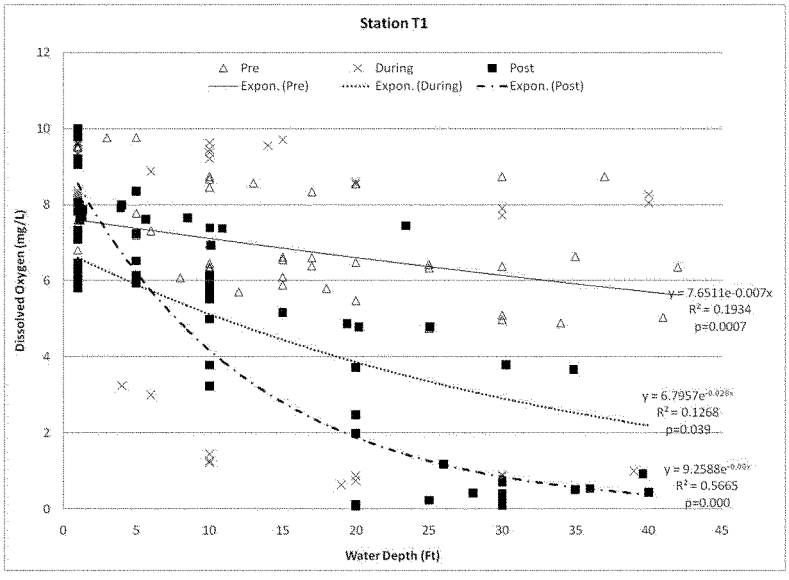


Figure 3.52. Effect of water depth on dissolved oxygen at Station T2 over different periods.

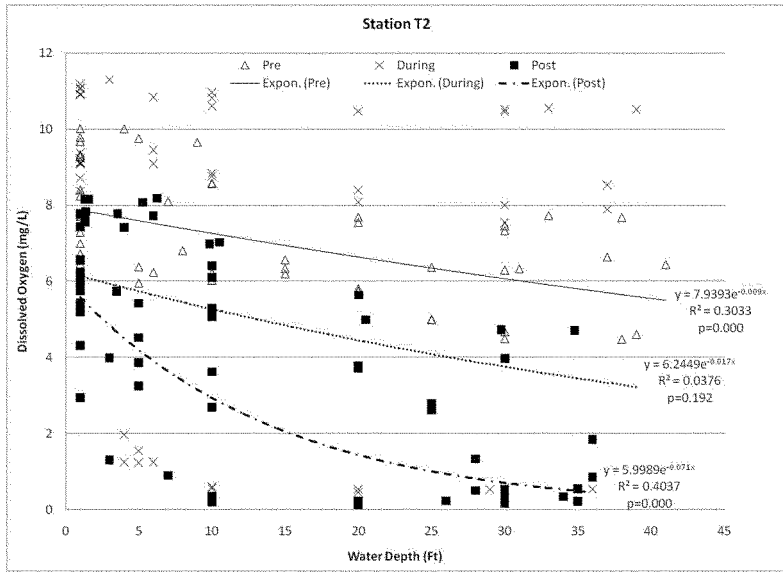


Figure 3.53. Effect of water depth on dissolved oxygen at Station T3 over different periods

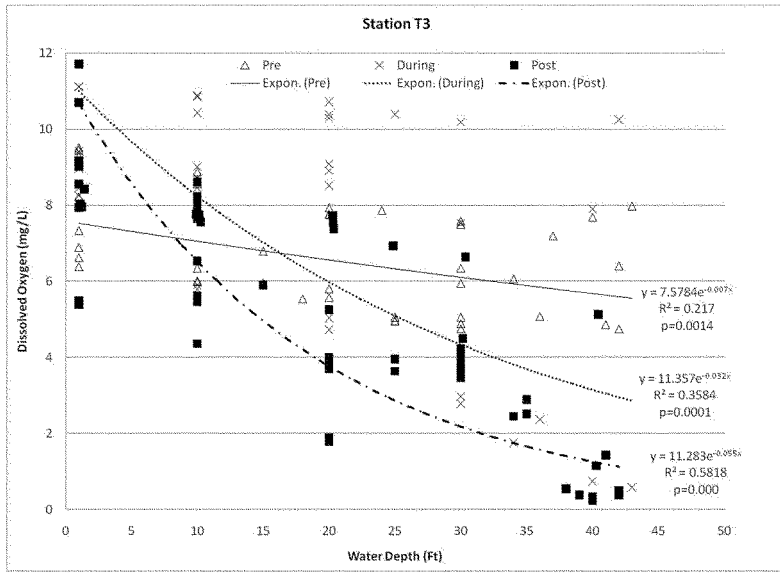


Figure 3.54. Effect of water depth on dissolved oxygen at Station T4 over different periods

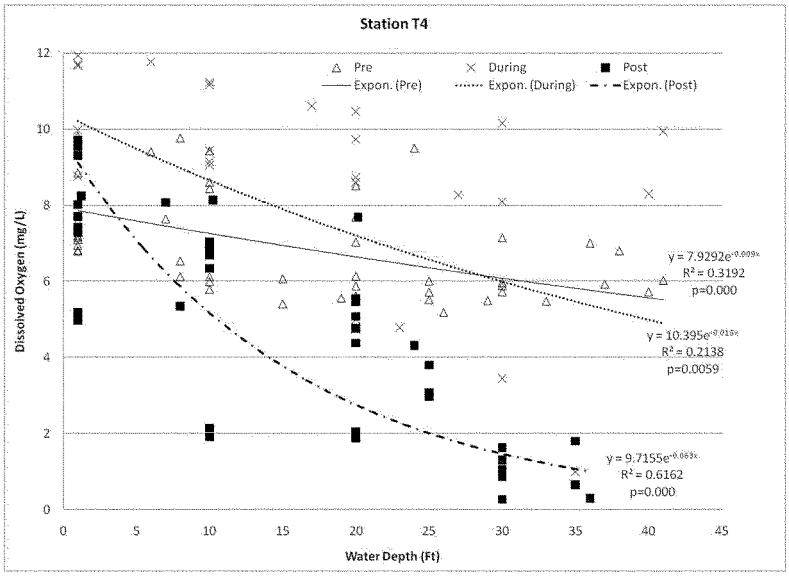


Figure 3.55. Effect of water depth on dissolved oxygen at Station T5 over different periods

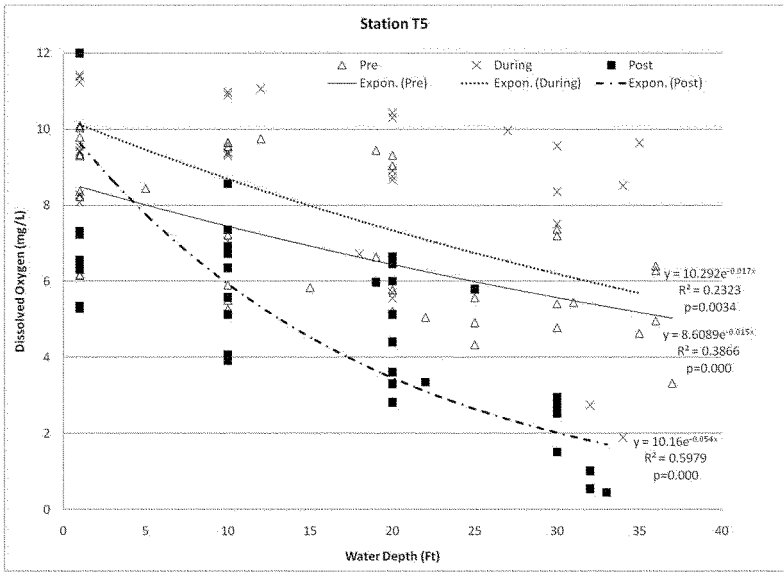


Figure 3.56. Effect of water depth on dissolved oxygen at Station T5 over different periods

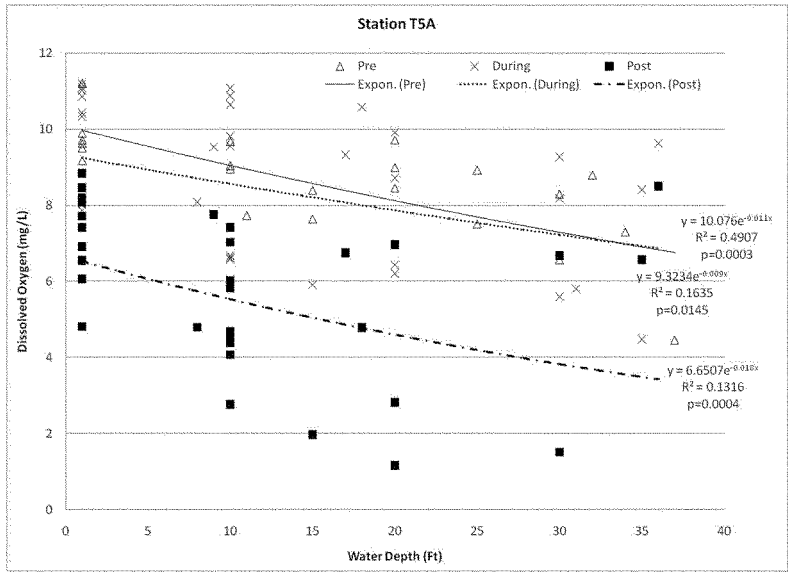


Figure 3.57. Effect of water depth on dissolved oxygen at Station 6 over different periods

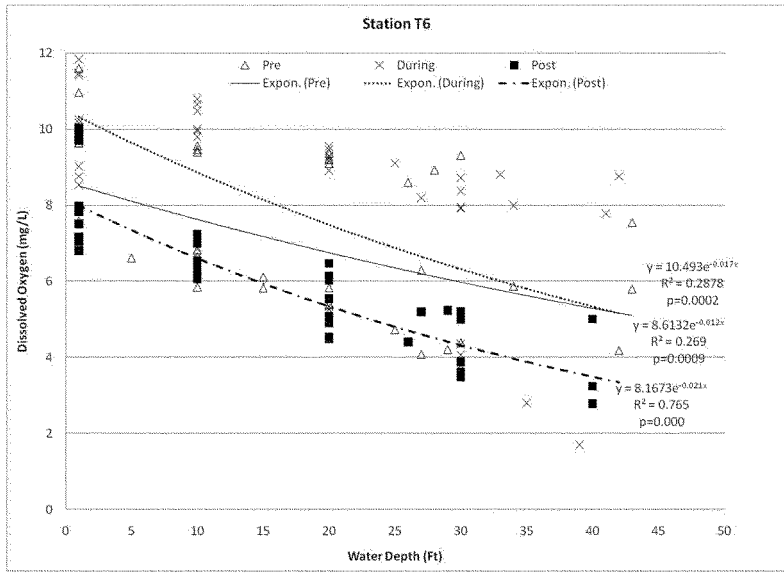
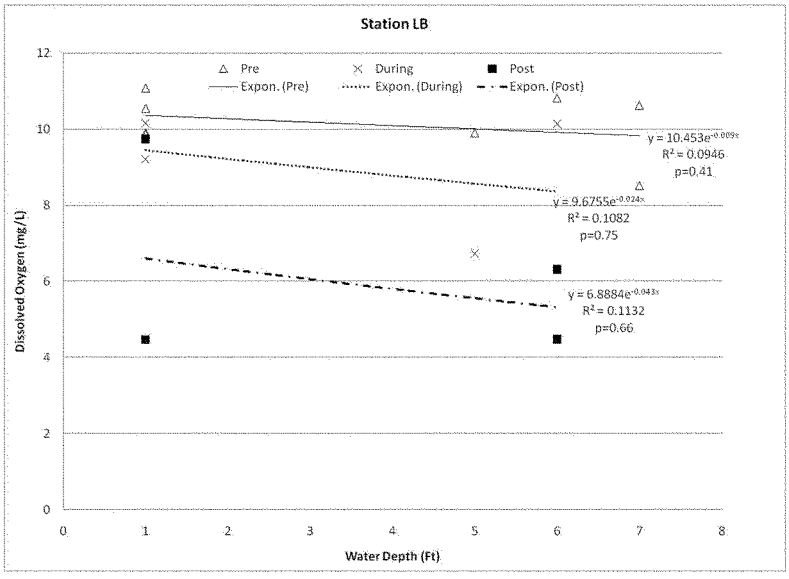


Figure 3.58. Effect of water depth on dissolved oxygen at Station LB over different periods



Data collected post-construction of the closure were then reviewed to determine at what water depth values typically dropped below 4.0 mg/L (Figure 3.59). Based upon a statistically significant linear model ($p < 0.01$) DO levels are typically below 4.0 mg/L at water depths greater than approximately 20 feet since the closure of MRGO. For locations where water depths exceed 20 feet, and after the closure of MRGO, the percent of DO values less than 4.0 mg/L varies from a low of 25% of values (station T6) to a high of 100% of values (station T-2). In general, DO values appear to be more severely depressed at stations downstream of the closure than upstream of the closure.

Figure 3.59. Post construction linear regression between dissolved oxygen and water depth.

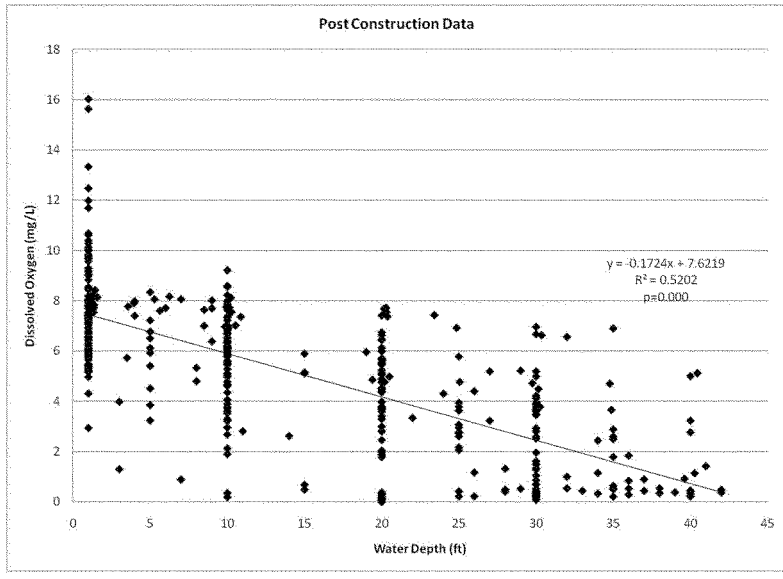
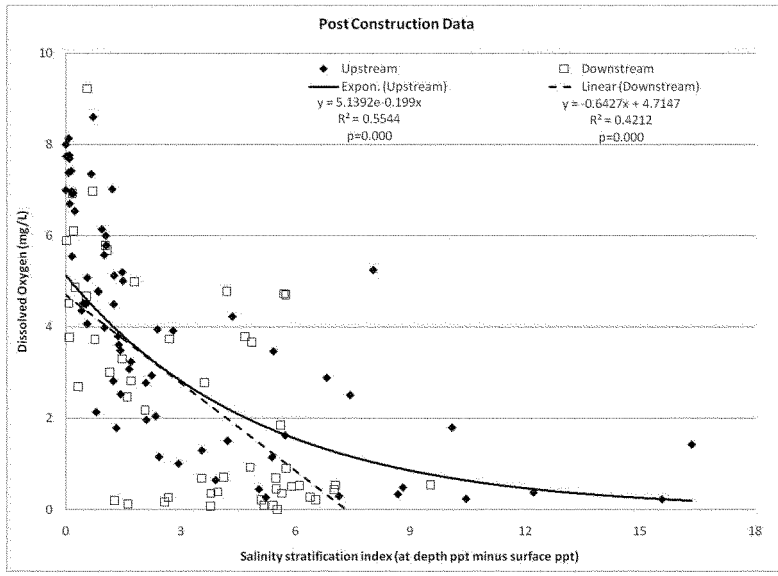

Post Construction Data
Dissolved Oxygen (mg/L)
Water Depth (ft)
y = -0.1724x + 7.6219
R² = 0.5202
p=0.000
0
2
4
6
8
10
12
14
16
18
0
5
10
15
20
25
30
35
40
45

Table 3.2. Number and Percent Exceedances of dissolved oxygen values below 4.0 during the post-construction time period for each station with a water depth greater than or equal to 20 feet (green stations are downstream and yellow stations are upstream of the MRGO closure). Limited data were available for stations LB and VC and are not included in the table.

Group = POST			
<4.0 mg/L with n≥20 feet			
Station	N	# Exceedances	% Exceedances
T-2	4	4	100.00%
T-1	23	20	89.96%
T1	46	40	86.96%
T2	32	28	87.50%
T3	35	25	71.43%
T4	20	13	65.00%
T5	18	12	66.67%
T5A	14	5	35.71%
T6	20	5	25.00%

As it is became evident that water depth significantly impacts DO within MRGO, the role of salinity stratification was then examined. To evaluate potential salinity stratification within the canal, a stratification index was calculated for each depth at each station, with the following efforts restricted to the post-closure time period. The sampling profile for each transect which had the greatest range of water depths was selected for further analysis. The difference in salinity between the various profile depths and at the surface was calculated to determine the salinity stratification index. For example, if a measurement was taken every 10 feet within the profile and the greatest depth was 30 feet, then a stratification index was calculated for the 30, 20 and 10 foot measurements. The effect of salinity stratification on DO was then determined by using a simple regression for each respective depth at all stations upstream or downstream of the closure (Figure 3.60). A highly significant relationship was observed at both the upstream stations (exponential; r^2=0.55; p=0.000) and downstream stations (linear; r^2=0.42; p=0.000).

Figure 3.60. Regression between dissolved oxygen and the salinity stratification index for both the upstream and downstream stations after the closure was completed



After the closure of MRGO, DO values appear to be influenced both by water depth and salinity stratification. Additionally, an influence of water temperature is observed, as would be expected with warmer waters in the spring to late fall months. However, temperature stratification is not seen with depth. A statistically significant multiple regression model based on water depth, water temperature and salinity stratification was found to be able to predict dissolved oxygen upstream of the closure (equation 1: r^2= 0.61; p=0.000). Water depth explained the majority of the variability in levels of DO, followed by the influence of water temperature; salinity stratification explained the least amount of variability in DO values.

Equation 1: Where DO= dissolved oxygen (mg/L), WT= water temperature (degrees C), WD= water depth (ft), and SSI= salinity stratification index

$$DO= 12.8606 - (0.210453* WT) - (0.111159 * WD) - (0.202889 *SSI)$$

The results shown in this analysis suggest that salinity stratification due to freshwater diversions would not initiate a DO problem in MRGO, as DO levels during the post-closure period are already typically less than 4 mg/L at most locations in MRGO at depths greater than 20 feet (especially during the spring to late fall time period). Low levels of DO are found both

downstream and upstream of the closure, with less evidence of DO problems in both Violet Canal and Lake Borgne.

The most likely scenario to produce problematic DO conditions is in areas with water depths greater than 20 feet during the spring to late fall. For Lake Borgne, the combination of its shallow depths and greater degree of flushing would likely result in it being less susceptible to DO problems, even with freshwater diversions, compared to MRGO.

Summary

These results suggest that the implementation of the FWP scenario should result in minimal to non-detectable adverse impacts to water quality in Biloxi Marsh and West Mississippi Sound, even though sufficient flows would occur to meet or maximize the ability to meet the Chatry et al. (1983) salinity targets for oyster development in Biloxi Marsh. In West Mississippi Sound, changes in salinity would be in the range of an approximate 1 ppt decline; changes in TN, TSS and chlorophyll-a would be expected to be minor to non-detectable.

Within the Central Wetlands themselves, diversion quantities are likely to create conditions wherein salinities would be similar to the Mississippi River itself. During the months with inflows of 1,000 cfs (June to March) the quantity diverted would be approximately 2,000 acre-feet per day; a volume capable of covering the Central Wetlands to a water depth of up to 2 inches each day. The distribution of water within the Central Wetlands would vary based on the final design of spreader canals and other features, but the quantity of water available, even during the low-flow months, is sufficient to flood the area with a volume of water capable of reducing salinity stress for remnant Cypress trees and other salinity-sensitive species. The Central Wetlands currently has a median salinity value of 9.28 ppt (n = 240); freshwater inflows are thus needed to create a more appropriate salinity regime for historically occurring vegetation (including Cypress trees). The water diverted into the Central Wetlands from the Mississippi River has an elevated level of total suspended solids (TSS), with monthly means that range between 68.6 and 194.2 mg / liter. The diverted water is likely to create a visible plume of turbid water within the channels of the Central Wetlands, where the median TSS value is 18.8 mg / liter (n = 248). However, the enhancement of wetlands via diversions involves an anticipated increase in sediment loads; the sediments themselves are an important component of the restorative value of diversions (Caffrey et al. 2002).

Within the MRGO, diversions of Mississippi River water through the Central Wetlands would likely result in noticeable increases in turbidity, especially during the 7,000 cfs flows during the months of April and May. The median TSS value within MRGO is 19.3 mg / liter (n = 23) a value much lower than values within the Mississippi River (monthly means between 68.6 and 194.2 mg / liter). Water temperatures in the Mississippi River tend to be cooler than those in the MRGO, with median values over the period of record of 22.8 and 18.5 degrees Celsius, respectively. The cooler waters of the Mississippi River, combined with the elevated level of TSS, combine to increase the density of diverted water. However, the difference between the amount of total dissolved solids (TDS) in the Mississippi River (median value of 268 mg / liter) and the MRGO (median value of 15,440 mg / liter) is greater than differences in density due to temperature and TSS. Therefore it is likely that differences in salt content are sufficiently large that diverted water from the Mississippi River may form a localized layer of freshwater on top of the saltier waters of the MRGO, especially during high inflow months of April and May. Consequently, it is possible that salinity-based stratification of the water column could occur within the MRGO, but DO problems in MRGO would not be initiated by a freshwater diversion, as they appear to have already been initiated by the closure of MRGO. Based

on the available information, it would appear that Lake Borgne is shallow enough that hypoxic conditions, which are limited to water depths greater than 20 feet in MRGO, would be unlikely to occur due to stratification. As phytoplankton levels are not anticipated to increase dramatically in Lake Borgne due to growth limitations associated with turbidity and the lake's relatively short residence time, it is likely that DO problems would not occur in Lake Borgne in response to a freshwater diversion at Violet.

In Lake Borgne, the FWP scenario would likely result in changes in TSS levels that would be detectable, and likely visible to the public, in the months of April and May. These increases are smaller in the Lake Borgne closed scenario (i.e., with the opening between MRGO and Lake Borgne near Martello Castle closed) than in the Lake Borgne open scenario, due to additional treatment of diverted water through the LBWA complex. Although levels of TSS and TN would likely increase substantially in Lake Borgne with diversions (especially in April and May) changes in levels of chlorophyll-a would be much more modest, due to the already turbid nature of Lake Borgne (which reduces light availability needed for algal growth) and the shallow and well-flushed nature of the system. The estimated increase in TSS in Lake Borgne from 10 to 30 mg / liter (FWOP) up to 60 to 80 mg / liter (in April and May - FWP) would not be expected to impact the oyster reefs in Lake Borgne in a negative fashion, as studies have indicated that the growth of oyster eggs and/or larvae is not reduced until silt concentrations reach levels of 180 mg / liter (Davis and Hidu, 1969). In Delaware Bay, oyster beds are found in areas with TSS concentrations ranging between 20 and 80 mg / liter (Stanley et al., 1986), values that encompass the range of estimates for the FWP scenario in Lake Borgne. However, declines in salinity, comparing FWOP and FWP scenarios, would likely result in reductions in oyster abundance in Lake Borgne, as seasonal minimums would drop below threshold values identified by Chatry et al. (1983). The Salinity Working Group (2009) also concluded the FWP scenario would adversely impact commercial oyster harvests in Lake Borgne due to salinity depression.

Associated with the Caernarvon diversion project, while local impacts to oyster populations had occurred, regional oyster production increased by 50% (Caffey et al. 2002) without evidence of concurrent eutrophication of the Breton Sound estuary (Lane et al. 2007). While the Caernarvon diversion cannot be directly compared to the proposed Violet diversion project (due to differences in the sizes of their wetland treatment areas) the proposed Violet diversion project would likely bring about similar benefits due to increased freshwater and sediment inputs into the Lake Borgne and Biloxi Marsh ecosystem.

Along the Louisiana coast, the only region to show evidence of significant recent increases in wetland acreage is within the Atchafalaya/Vermilion Basin, where significant land gains have occurred at the Atchafalaya and Wax Lake outlet deltas, which are managed to optimize freshwater and sediment inputs to coastal regions (Lake Pontchartrain Basin Foundation 2008).

Despite the overall ecological benefits associated with freshwater diversion projects such as that anticipated for Violet, a number of water quality related impacts can be identified. These include the following: 1) a decrease in salinities in Lake Borgne sufficient to impact oyster production, 2) the lowering of water temperatures in the Central Wetlands and MRGO (and perhaps even Lake Borgne) due to the cooler temperatures of diverted Mississippi River water, 3) elevated levels of metals, bacteria and various organochlorine compounds in areas nearest the diversion, and 4) continued hypoxic conditions in MRGO (associated with the closure of MRGO).

The impact, if any, of these potential stressors would increase with proximity to the diversion itself, and the size and intensity of the impact would be maximal during times of maximum discharge rates (i.e., April and May).

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APPENDIX A

Station List

Source	Site Number	Site Name
LDEQ	1086	Bayou Loutre near Mississippi River Gulf Outlet
LDEQ	1087	Eloi Bay near Mississippi River Gulf Outlet marker #76,
LDEQ	1088	Morgan Harbor, Louisiana
LDEQ	1089	Bay Boudreau 5.18 nautical miles from Morgan Harbor
LDEQ	1090	Point Lydia, Louisiana
LDEQ	1091	Drum Bay, Louisiana
LDEQ	307	Bayou Bienvenue north of Chalmette, Louisiana
LDEQ	1065	New Canal near Bayou Pirogue, Louisiana
LDEQ	1066	Bayou Pirogue near New Canal
LDEQ	1067	Bayou Terre Beau near New Canal, Louisiana
LDEQ	1068	Violet Canal near New Canal
LDEQ	1069	Bayou Dupre adjacent to Toca loading dock
LDEQ	1070	Bayou Bashman near Bayou Dupre
LDEQ	1071	Bayou Chaperon near Bayou Bienvenue
LDEQ	1074	Lake Borgne near mouth of Blind Rigolets
LDEQ	1062	Bayou Bienvenue, Louisiana
LDEQ	1063	Bayou Bienvenue, Louisiana
LDEQ	1064	Intracoastal Waterway at New Orleans Public Service gas
LDEQ	49	Mississippi River near Pointe a la Hache, Louisiana
LDEQ	50	Mississippi River at Pointe a la Hache, Louisiana
LDEQ	51	Mississippi River at Belle Chasse, Louisiana
LDEQ	52	Mississippi River near Belle Chase, Louisiana
LDEQ	320	Mississippi River east of Belle Chasse, Louisiana
LDEQ	322	Mississippi River west of Point a la Hache, Louisiana
USGS	7374400	Mississippi River at Luling
USGS	7374525	Mississippi River at Belle Chasse, Louisiana
LDEQ	1085	Mississippi River Gulf Outlet at marker #94

APPENDIX B

General summary statistics for each parameter by site

Group Name
Biloxi_Marsh
Biloxi_Marsh
Biloxi_Marsh
Biloxi_Marsh
Biloxi_Marsh
Biloxi_Marsh
Central_Wetlands_Area
Central_Wetlands_Area
Central_Wetlands_Area
Central_Wetlands_Area
Central_Wetlands_Area
Central_Wetlands_Area
Central_Wetlands_Area
Central_Wetlands_Area
Lake_Borgne
Lake_Borgne_Wetland_Area
Lake_Borgne_Wetland_Area
Lake_Borgne_Wetland_Area
Mississippi_River
Mississippi_River
Mississippi_River
Mississippi_River
Mississippi_River
Mississippi_River
Mississippi_River
Mississippi_River
MRGO

Summary statistics of sampled water quality

Parameter=1,1,1-TRICHLOROETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	1,1,1-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	1,1,1-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	1,1,1-TRICHLOROETHANE	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	1,1,1-TRICHLOROETHANE	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	1,1,1-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	1,1,1-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	1,1,1-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	1,1,1-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	1,1,1-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	1,1,1-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	1,1,1-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	1,1,1-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	1,1,1-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	1,1,1-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	1,1,1-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	1,1,1-TRICHLOROETHANE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	1,1,1-TRICHLOROETHANE	UG/L	112	0.183	6.3	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	1,1,1-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	1,1,1-TRICHLOROETHANE	UG/L	81	0.100	0.1	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	1,1,1-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	1,1,1-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=1,1,1-TRICHLOROETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	1,1,1-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	1,1,1-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=1,1,2,2-TETRACHLOROETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	1,1,2,2-TETRACHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	1,1,2,2-TETRACHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	1,1,2,2-TETRACHLOROETHANE	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	1,1,2,2-TETRACHLOROETHANE	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	1,1,2,2-TETRACHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	1,1,2,2-TETRACHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	1,1,2,2-TETRACHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	1,1,2,2-TETRACHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	1,1,2,2-TETRACHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	1,1,2,2-TETRACHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	1,1,2,2-TETRACHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	1,1,2,2-TETRACHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	1,1,2,2-TETRACHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	1,1,2,2-TETRACHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	1,1,2,2-TETRACHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	1,1,2,2-TETRACHLOROETHANE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	1,1,2,2-TETRACHLOROETHANE	UG/L	112	0.112	1.0	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	1,1,2,2-TETRACHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	1,1,2,2-TETRACHLOROETHANE	UG/L	81	0.101	0.2	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	1,1,2,2-TETRACHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	1,1,2,2-TETRACHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=1,1,2,2-TETRACHLOROETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	1,1,2,2-TETRACHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	1,1,2,2-TETRACHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=1,1,2-TRICHLOROETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	1,1,2-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	1,1,2-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	1,1,2-TRICHLOROETHANE	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	1,1,2-TRICHLOROETHANE	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	1,1,2-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	1,1,2-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	1,1,2-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	1,1,2-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	1,1,2-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	1,1,2-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	1,1,2-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	1,1,2-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	1,1,2-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	1,1,2-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	1,1,2-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	1,1,2-TRICHLOROETHANE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	1,1,2-TRICHLOROETHANE	UG/L	112	0.112	1.0	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	1,1,2-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	1,1,2-TRICHLOROETHANE	UG/L	81	0.100	0.1	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	1,1,2-TRICHLOROETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	1,1,2-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=1,1,2-TRICHLOROETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	1,1,2-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	1,1,2-TRICHLOROETHANE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=1,2-DICHLOROETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	1,2-DICHLOROETHANE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	1,2-DICHLOROETHANE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	1,2-DICHLOROETHANE	UG/L	10	0.145	0.55	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	1,2-DICHLOROETHANE	UG/L	2	0.100	0.10	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	1,2-DICHLOROETHANE	UG/L	4	0.235	0.64	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	1,2-DICHLOROETHANE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	1,2-DICHLOROETHANE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	1,2-DICHLOROETHANE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	1,2-DICHLOROETHANE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	1,2-DICHLOROETHANE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	1,2-DICHLOROETHANE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	1,2-DICHLOROETHANE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	1,2-DICHLOROETHANE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	1,2-DICHLOROETHANE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	1,2-DICHLOROETHANE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	1,2-DICHLOROETHANE	UG/L	2	8.700	17.30	8.7	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	1,2-DICHLOROETHANE	UG/L	112	0.166	4.80	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	1,2-DICHLOROETHANE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	1,2-DICHLOROETHANE	UG/L	81	0.143	2.70	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	1,2-DICHLOROETHANE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	1,2-DICHLOROETHANE	UG/L	4	0.100	0.10	0.1	0.1

Summary statistics of sampled water quality

Parameter=1,2-DICHLOROETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	1,2-DICHLOROETHANE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	1,2-DICHLOROETHANE	UG/L	4	0.100	0.10	0.1	0.1

Summary statistics of sampled water quality

Parameter=2,4-DICHLOROPHENOL

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	2,4-DICHLOROPHENOL	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	2,4-DICHLOROPHENOL	UG/L	29	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	2,4-DICHLOROPHENOL	UG/L	77	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=2,4-Dichlorophenoxyacetic acid (2,4-D)

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
USGS	Mississippi River at Luling, LA	7374400	2,4-Dichlorophenoxyacetic acid (2,4-D)		31	0.045	0.5	0.01	0.01

Summary statistics of sampled water quality

Parameter=2-CHLOROPHENOL

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	2-CHLOROPHENOL	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	2-CHLOROPHENOL	UG/L	28	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	2-CHLOROPHENOL	UG/L	51	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=4,4 -DDT

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	4,4 -DDT	UG/L	23	2.464	11.25	0.10	0.05
USGS	Mississippi River at Luling, LA	7374400	4,4 -DDT	UG/L	6	0.010	0.01	0.01	0.01
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	4,4 -DDT	UG/L	30	0.104	0.20	0.10	0.10
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	4,4 -DDT	UG/L	78	0.100	0.10	0.10	0.10

Summary statistics of sampled water quality

Parameter=4,4'-DDD

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	4,4'-DDD	UG/L	23	0.960	10.72	0.075	0.05
USGS	Mississippi River at Luling, LA	7374400	4,4'-DDD	UG/L	6	0.010	0.01	0.010	0.01
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	4,4'-DDD	UG/L	29	0.100	0.11	0.100	0.10
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	4,4'-DDD	UG/L	78	0.100	0.10	0.100	0.10

Summary statistics of sampled water quality

Parameter=4,4'-DDE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	4,4'-DDE	UG/L	23	3.408	9.94	0.10	0.05
USGS	Mississippi River at Luling, LA	7374400	4,4'-DDE	UG/L	6	0.010	0.01	0.01	0.01
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	4,4'-DDE	UG/L	29	0.100	0.11	0.10	0.10
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	4,4'-DDE	UG/L	78	0.100	0.10	0.10	0.10

Summary statistics of sampled water quality

Parameter=ALDRIN

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	ALDRIN	UG/L	23	3.506	8.25	0.075	0.05
USGS	Mississippi River at Luling, LA	7374400	ALDRIN	UG/L	6	0.010	0.01	0.010	0.01
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	ALDRIN	UG/L	29	0.095	0.10	0.100	0.05
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	ALDRIN	UG/L	78	0.100	0.10	0.100	0.10

Summary statistics of sampled water quality

Parameter=ALKALINITY

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	ALKALINITY	MG/L	23	82.439	124.0	87.60	35.5
LDEQ	Bayou Bashman near Bayou Dupre	1070	ALKALINITY	MG/L	24	71.592	101.0	66.15	43.3
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	ALKALINITY	MG/L	80	72.909	101.0	72.00	35.5
LDEQ	Bayou Bienvenue, Louisiana	1062	ALKALINITY	MG/L	36	61.528	87.1	58.90	39.3
LDEQ	Bayou Bienvenue, Louisiana	1063	ALKALINITY	MG/L	36	62.697	87.8	60.65	41.7
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	ALKALINITY	MG/L	24	75.687	107.0	74.05	49.7
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	ALKALINITY	MG/L	24	76.508	99.8	81.80	44.4
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	ALKALINITY	MG/L	23	85.835	103.0	85.00	54.1
LDEQ	Bayou Pirogue near New Canal	1066	ALKALINITY	MG/L	24	89.850	191.0	82.10	57.6
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	ALKALINITY	MG/L	24	85.571	133.0	86.30	55.3
LDEQ	Drum Bay, Louisiana	1091	ALKALINITY	MG/L	23	87.743	125.0	92.40	36.6
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	ALKALINITY	MG/L	23	90.617	115.0	87.70	59.0
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	ALKALINITY	MG/L	36	66.106	118.0	60.25	47.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	ALKALINITY	MG/L	24	38.408	67.3	36.35	17.9
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	ALKALINITY	MG/L	23	79.487	109.0	79.20	50.4
USGS	Mississippi River at Belle Chasse, LA	7374525	ALKALINITY	MG/L	46	113.130	152.0	110.50	85.0
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	ALKALINITY	MG/L	60	117.455	169.0	117.50	72.6
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	ALKALINITY	MG/L	12	104.667	138.0	106.00	73.7
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	ALKALINITY	MG/L	176	111.169	181.0	110.00	71.8
LDEQ	Mississippi River near Belle Chase, Louisiana	52	ALKALINITY	MG/L	21	107.052	138.0	108.00	72.6
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	ALKALINITY	MG/L	12	105.025	139.0	107.50	73.9
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	ALKALINITY	MG/L	88	108.040	151.0	107.50	28.3

Summary statistics of sampled water quality

Parameter=ALKALINITY

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Morgan Harbor, Louisiana	1088	ALKALINITY	MG/L	23	85.483	120.0	90.00	41.9
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	ALKALINITY	MG/L	24	90.329	240.0	85.95	46.6
LDEQ	Point Lydia, Louisiana	1090	ALKALINITY	MG/L	23	95.217	124.0	101.00	44.2
LDEQ	Violet Canal near New Canal	1068	ALKALINITY	MG/L	24	95.083	153.0	94.00	59.5

Summary statistics of sampled water quality

Parameter=AMMONIA NITROGEN

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	AMMONIA NITROGEN	MG/L	12	0.124	0.37	0.100	0.10
LDEQ	Bayou Bashman near Bayou Dupre	1070	AMMONIA NITROGEN	MG/L	13	0.128	0.23	0.110	0.10
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	AMMONIA NITROGEN	MG/L	18	0.194	0.99	0.125	0.10
LDEQ	Bayou Bienvenue, Louisiana	1062	AMMONIA NITROGEN	MG/L	17	0.141	0.32	0.100	0.10
LDEQ	Bayou Bienvenue, Louisiana	1063	AMMONIA NITROGEN	MG/L	18	0.224	1.30	0.120	0.10
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	AMMONIA NITROGEN	MG/L	13	0.119	0.22	0.100	0.10
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	AMMONIA NITROGEN	MG/L	14	0.116	0.22	0.100	0.10
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	AMMONIA NITROGEN	MG/L	12	0.226	1.12	0.100	0.10
LDEQ	Bayou Pirogue near New Canal	1066	AMMONIA NITROGEN	MG/L	18	0.122	0.18	0.100	0.10
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	AMMONIA NITROGEN	MG/L	17	0.134	0.32	0.100	0.10
LDEQ	Drum Bay, Louisiana	1091	AMMONIA NITROGEN	MG/L	11	0.135	0.48	0.100	0.10
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	AMMONIA NITROGEN	MG/L	12	0.162	0.84	0.100	0.10
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	AMMONIA NITROGEN	MG/L	18	0.194	0.44	0.170	0.10
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	AMMONIA NITROGEN	MG/L	11	0.100	0.10	0.100	0.10
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	AMMONIA NITROGEN	MG/L	11	0.159	0.70	0.100	0.10
USGS	Mississippi River at Belle Chasse, LA	7374525	AMMONIA NITROGEN	MG/L	25	0.058	0.14	0.060	0.01
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	AMMONIA NITROGEN	MG/L	6	0.183	0.30	0.170	0.12
USGS	Mississippi River at Luling, LA	7374400	AMMONIA NITROGEN	MG/L	47	0.033	0.12	0.030	0.01
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	AMMONIA NITROGEN	MG/L	39	0.114	0.23	0.100	0.10
LDEQ	Morgan Harbor, Louisiana	1088	AMMONIA NITROGEN	MG/L	11	0.134	0.47	0.100	0.10
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	AMMONIA NITROGEN	MG/L	17	0.124	0.22	0.110	0.10

Summary statistics of sampled water quality

Parameter=AMMONIA NITROGEN

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	AMMONIA NITROGEN	MG/L	11	0.108	0.19	0.100	0.10
LDEQ	Violet Canal near New Canal	1068	AMMONIA NITROGEN	MG/L	13	0.123	0.21	0.100	0.10

Summary statistics of sampled water quality

Parameter=ARSENIC

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	ARSENIC	UG/L	6	0.740	1.29	0.665	0.16
LDEQ	Bayou Bashman near Bayou Dupre	1070	ARSENIC	UG/L	6	0.925	1.72	0.905	0.30
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	ARSENIC	UG/L	53	1.983	6.70	1.300	0.30
LDEQ	Bayou Bienvenue, Louisiana	1062	ARSENIC	UG/L	9	0.929	1.54	0.940	0.27
LDEQ	Bayou Bienvenue, Louisiana	1063	ARSENIC	UG/L	9	0.992	2.90	0.710	0.31
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	ARSENIC	UG/L	6	0.915	1.48	0.945	0.31
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	ARSENIC	UG/L	6	0.915	1.38	0.970	0.38
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	ARSENIC	UG/L	6	0.553	0.96	0.525	0.35
LDEQ	Bayou Pirogue near New Canal	1066	ARSENIC	UG/L	6	0.970	1.72	1.000	0.23
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	ARSENIC	UG/L	6	0.963	2.12	0.815	0.31
LDEQ	Drum Bay, Louisiana	1091	ARSENIC	UG/L	5	0.838	1.52	0.750	0.23
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	ARSENIC	UG/L	6	0.645	1.14	0.615	0.28
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	ARSENIC	UG/L	9	0.791	1.39	0.810	0.34
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	ARSENIC	UG/L	6	0.557	1.04	0.515	0.21
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	ARSENIC	UG/L	6	0.695	1.53	0.630	0.21
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	ARSENIC	UG/L	29	2.459	9.70	1.900	1.03
USGS	Mississippi River at Luling, LA	7374400	ARSENIC	UG/L	59	2.915	6.00	3.000	1.00
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	ARSENIC	UG/L	12	3.483	10.10	2.550	1.30
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	ARSENIC	UG/L	116	2.349	5.00	1.800	0.50
LDEQ	Mississippi River near Belle Chase, Louisiana	52	ARSENIC	UG/L	22	2.536	10.70	1.650	1.30
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	ARSENIC	UG/L	11	3.482	10.50	2.500	1.30
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	ARSENIC	UG/L	88	2.276	5.00	1.700	0.50

Summary statistics of sampled water quality

Parameter=ARSENIC

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Morgan Harbor, Louisiana	1088	ARSENIC	UG/L	6	0.668	1.08	0.685	0.12
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	ARSENIC	UG/L	6	0.982	1.66	0.985	0.28
LDEQ	Point Lydia, Louisiana	1090	ARSENIC	UG/L	6	0.957	1.70	0.845	0.15
LDEQ	Violet Canal near New Canal	1068	ARSENIC	UG/L	6	1.190	1.80	1.175	0.82

Summary statistics of sampled water quality

Parameter=BENZENE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	BENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	BENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	BENZENE	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	BENZENE	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	BENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	BENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	BENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	BENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	BENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	BENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	BENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	BENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	BENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	BENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	BENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	BENZENE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	BENZENE	UG/L	112	0.110	1.0	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	BENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	BENZENE	UG/L	81	0.100	0.1	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	BENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	BENZENE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=BENZENE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	BENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	BENZENE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=BENZIDINE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	BENZIDINE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	BENZIDINE	UG/L	29	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	BENZIDINE	UG/L	78	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=BROMODICHLOROMETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	BROMODICHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	BROMODICHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	BROMODICHLOROMETHANE	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	BROMODICHLOROMETHANE	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	BROMODICHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	BROMODICHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	BROMODICHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	BROMODICHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	BROMODICHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	BROMODICHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	BROMODICHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	BROMODICHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	BROMODICHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	BROMODICHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	BROMODICHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	BROMODICHLOROMETHANE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	BROMODICHLOROMETHANE	UG/L	113	0.119	1.0	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	BROMODICHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	BROMODICHLOROMETHANE	UG/L	81	0.100	0.1	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	BROMODICHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	BROMODICHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=BROMODICHLOROMETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	BROMODICHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	BROMODICHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=BROMOFORM

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	BROMOFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	BROMOFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	BROMOFORM	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	BROMOFORM	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	BROMOFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	BROMOFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	BROMOFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	BROMOFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	BROMOFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	BROMOFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	BROMOFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	BROMOFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	BROMOFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	BROMOFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	BROMOFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	BROMOFORM	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	BROMOFORM	UG/L	114	0.154	2.6	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	BROMOFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	BROMOFORM	UG/L	81	0.100	0.1	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	BROMOFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	BROMOFORM	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=BROMOFORM

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	BROMOFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	BROMOFORM	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=CADMIUM

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	CADMIUM	UG/L	6	0.035	0.08	0.025	0.02
LDEQ	Bayou Bashman near Bayou Dupre	1070	CADMIUM	UG/L	6	0.017	0.02	0.020	0.01
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	CADMIUM	UG/L	51	0.334	1.03	0.200	0.01
LDEQ	Bayou Bienvenue, Louisiana	1062	CADMIUM	UG/L	8	0.020	0.06	0.015	0.01
LDEQ	Bayou Bienvenue, Louisiana	1063	CADMIUM	UG/L	8	0.021	0.04	0.020	0.01
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	CADMIUM	UG/L	5	0.012	0.02	0.010	0.01
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	CADMIUM	UG/L	6	0.013	0.02	0.010	0.01
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	CADMIUM	UG/L	6	0.027	0.04	0.020	0.02
LDEQ	Bayou Pirogue near New Canal	1066	CADMIUM	UG/L	5	0.014	0.02	0.010	0.01
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	CADMIUM	UG/L	6	0.013	0.02	0.010	0.01
LDEQ	Drum Bay, Louisiana	1091	CADMIUM	UG/L	5	0.024	0.03	0.030	0.01
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	CADMIUM	UG/L	6	0.048	0.13	0.035	0.02
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	CADMIUM	UG/L	8	0.019	0.02	0.020	0.01
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	CADMIUM	UG/L	6	0.020	0.03	0.020	0.01
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	CADMIUM	UG/L	6	0.067	0.28	0.025	0.02
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	CADMIUM	UG/L	26	0.118	0.50	0.075	0.03
USGS	Mississippi River at Luling, LA	7374400	CADMIUM	UG/L	58	1.052	4.00	1.000	1.00
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	CADMIUM	UG/L	12	0.225	0.70	0.200	0.10
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	CADMIUM	UG/L	116	0.277	1.20	0.200	0.01
LDEQ	Mississippi River near Belle Chase, Louisiana	52	CADMIUM	UG/L	22	0.264	1.10	0.150	0.10
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	CADMIUM	UG/L	12	0.225	0.60	0.150	0.10
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	CADMIUM	UG/L	88	0.330	2.62	0.200	0.10

Summary statistics of sampled water quality

Parameter=CADMIUM

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Morgan Harbor, Louisiana	1088	CADMIUM	UG/L	6	0.037	0.06	0.035	0.02
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	CADMIUM	UG/L	6	0.018	0.03	0.015	0.01
LDEQ	Point Lydia, Louisiana	1090	CADMIUM	UG/L	6	0.030	0.05	0.030	0.01
LDEQ	Violet Canal near New Canal	1068	CADMIUM	UG/L	5	0.016	0.03	0.010	0.01

Summary statistics of sampled water quality

Parameter=CARBON TETRACHLORIDE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	CARBON TETRACHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	CARBON TETRACHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	CARBON TETRACHLORIDE	UG/L	9	0.100	0.10	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	CARBON TETRACHLORIDE	UG/L	3	0.490	1.27	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	CARBON TETRACHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	CARBON TETRACHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	CARBON TETRACHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	CARBON TETRACHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	CARBON TETRACHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	CARBON TETRACHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	CARBON TETRACHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	CARBON TETRACHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	CARBON TETRACHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	CARBON TETRACHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	CARBON TETRACHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	CARBON TETRACHLORIDE	UG/L	1	0.100	0.10	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	CARBON TETRACHLORIDE	UG/L	111	0.100	0.10	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	CARBON TETRACHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	CARBON TETRACHLORIDE	UG/L	81	0.100	0.10	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	CARBON TETRACHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	CARBON TETRACHLORIDE	UG/L	4	0.100	0.10	0.1	0.1

Summary statistics of sampled water quality

Parameter=CARBON TETRACHLORIDE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	CARBON TETRACHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	CARBON TETRACHLORIDE	UG/L	4	0.100	0.10	0.1	0.1

Summary statistics of sampled water quality

Parameter=CHLORDANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	CHLORDANE	UG/L	19	0.186	0.2	0.200	0.10
USGS	Mississippi River at Luling, LA	7374400	CHLORDANE	UG/L	6	0.055	0.1	0.055	0.01
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	CHLORDANE	UG/L	29	0.128	0.5	0.100	0.10
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	CHLORDANE	UG/L	78	0.100	0.1	0.100	0.10

Summary statistics of sampled water quality

Parameter=CHLOROFORM

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	CHLOROFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	CHLOROFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	CHLOROFORM	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	CHLOROFORM	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	CHLOROFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	CHLOROFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	CHLOROFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	CHLOROFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	CHLOROFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	CHLOROFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	CHLOROFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	CHLOROFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	CHLOROFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	CHLOROFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	CHLOROFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	CHLOROFORM	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	CHLOROFORM	UG/L	112	0.114	1.0	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	CHLOROFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	CHLOROFORM	UG/L	81	0.105	0.5	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	CHLOROFORM	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	CHLOROFORM	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=CHLOROFORM

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	CHLOROFORM	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	CHLOROFORM	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=CHLOROMETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	CHLOROMETHANE	UG/L	3	0.100	0.1	0.10	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	CHLOROMETHANE	UG/L	5	0.300	0.7	0.10	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	CHLOROMETHANE	UG/L	10	0.150	0.6	0.10	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	CHLOROMETHANE	UG/L	3	0.300	0.7	0.10	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	CHLOROMETHANE	UG/L	4	0.275	0.8	0.10	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	CHLOROMETHANE	UG/L	4	0.200	0.5	0.10	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	CHLOROMETHANE	UG/L	5	0.320	1.2	0.10	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	CHLOROMETHANE	UG/L	4	0.375	0.7	0.35	0.1
LDEQ	Bayou Pirogue near New Canal	1066	CHLOROMETHANE	UG/L	5	0.360	0.9	0.10	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	CHLOROMETHANE	UG/L	5	0.280	1.0	0.10	0.1
LDEQ	Drum Bay, Louisiana	1091	CHLOROMETHANE	UG/L	4	0.100	0.1	0.10	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	CHLOROMETHANE	UG/L	4	0.100	0.1	0.10	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	CHLOROMETHANE	UG/L	5	0.360	0.8	0.10	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	CHLOROMETHANE	UG/L	4	0.100	0.1	0.10	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	CHLOROMETHANE	UG/L	4	0.325	0.6	0.30	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	CHLOROMETHANE	UG/L	4	1.175	2.0	1.30	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	CHLOROMETHANE	UG/L	113	0.121	2.0	0.10	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	CHLOROMETHANE	UG/L	3	0.100	0.1	0.10	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	CHLOROMETHANE	UG/L	81	0.100	0.1	0.10	0.1
LDEQ	Morgan Harbor, Louisiana	1088	CHLOROMETHANE	UG/L	4	0.200	0.5	0.10	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	CHLOROMETHANE	UG/L	5	0.200	0.6	0.10	0.1

Summary statistics of sampled water quality

Parameter=CHLOROMETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	CHLOROMETHANE	UG/L	4	0.100	0.1	0.10	0.1
LDEQ	Violet Canal near New Canal	1068	CHLOROMETHANE	UG/L	4	0.100	0.1	0.10	0.1

Summary statistics of sampled water quality

Parameter=CHROMIUM

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	CHROMIUM	UG/L	2	0.035	0.05	0.035	0.02
LDEQ	Bayou Bashman near Bayou Dupre	1070	CHROMIUM	UG/L	2	0.200	0.37	0.200	0.03
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	CHROMIUM	UG/L	50	0.711	2.80	0.350	0.02
LDEQ	Bayou Bienvenue, Louisiana	1062	CHROMIUM	UG/L	5	0.166	0.20	0.200	0.03
LDEQ	Bayou Bienvenue, Louisiana	1063	CHROMIUM	UG/L	6	0.173	0.22	0.200	0.02
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	CHROMIUM	UG/L	2	0.200	0.37	0.200	0.03
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	CHROMIUM	UG/L	2	0.200	0.37	0.200	0.03
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	CHROMIUM	UG/L	5	0.168	0.20	0.200	0.04
LDEQ	Bayou Pirogue near New Canal	1066	CHROMIUM	UG/L	3	0.143	0.21	0.200	0.02
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	CHROMIUM	UG/L	2	0.115	0.20	0.115	0.03
LDEQ	Drum Bay, Louisiana	1091	CHROMIUM	UG/L	1	0.200	0.20	0.200	0.20
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	CHROMIUM	UG/L	5	0.182	0.20	0.200	0.11
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	CHROMIUM	UG/L	6	0.175	0.20	0.200	0.05
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	CHROMIUM	UG/L	6	0.152	0.20	0.200	0.04
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	CHROMIUM	UG/L	5	0.246	0.43	0.200	0.20
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	CHROMIUM	UG/L	24	6.516	44.00	1.390	0.09
USGS	Mississippi River at Luling, LA	7374400	CHROMIUM	UG/L	59	5.564	14.00	5.000	1.00
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	CHROMIUM	UG/L	12	12.733	43.20	9.800	1.20
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	CHROMIUM	UG/L	116	0.936	6.80	0.500	0.02
LDEQ	Mississippi River near Belle Chase, Louisiana	52	CHROMIUM	UG/L	22	5.927	27.40	1.650	0.30
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	CHROMIUM	UG/L	12	11.200	35.10	7.400	1.20
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	CHROMIUM	UG/L	88	0.873	4.50	0.500	0.20

Summary statistics of sampled water quality

Parameter=CHROMIUM

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Morgan Harbor, Louisiana	1088	CHROMIUM	UG/L	2	0.125	0.20	0.125	0.05
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	CHROMIUM	UG/L	3	0.177	0.29	0.200	0.04
LDEQ	Point Lydia, Louisiana	1090	CHROMIUM	UG/L	3	0.210	0.38	0.200	0.05
LDEQ	Violet Canal near New Canal	1068	CHROMIUM	UG/L	3	0.263	0.55	0.200	0.04

Summary statistics of sampled water quality

Parameter=CIS-1,3-DICHLOROPROPENE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	CIS-1,3-DICHLOROPROPENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	CIS-1,3-DICHLOROPROPENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	CIS-1,3-DICHLOROPROPENE	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	CIS-1,3-DICHLOROPROPENE	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	CIS-1,3-DICHLOROPROPENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	CIS-1,3-DICHLOROPROPENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	CIS-1,3-DICHLOROPROPENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	CIS-1,3-DICHLOROPROPENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	CIS-1,3-DICHLOROPROPENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	CIS-1,3-DICHLOROPROPENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	CIS-1,3-DICHLOROPROPENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	CIS-1,3-DICHLOROPROPENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	CIS-1,3-DICHLOROPROPENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	CIS-1,3-DICHLOROPROPENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	CIS-1,3-DICHLOROPROPENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	CIS-1,3-DICHLOROPROPENE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	CIS-1,3-DICHLOROPROPENE	UG/L	113	0.112	1.0	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	CIS-1,3-DICHLOROPROPENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	CIS-1,3-DICHLOROPROPENE	UG/L	81	0.100	0.1	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	CIS-1,3-DICHLOROPROPENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	CIS-1,3-DICHLOROPROPENE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=CIS-1,3-DICHLOROPROPENE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	CIS-1,3-DICHLOROPROPENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	CIS-1,3-DICHLOROPROPENE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=COLOR

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	COLOR	PCU	11	19.545	40	15	10.0
LDEQ	Bayou Bashman near Bayou Dupre	1070	COLOR	PCU	13	32.538	80	25	15.0
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	COLOR	PCU	61	32.189	60	30	10.0
LDEQ	Bayou Bienvenue, Louisiana	1062	COLOR	PCU	17	23.471	50	21	10.0
LDEQ	Bayou Bienvenue, Louisiana	1063	COLOR	PCU	17	23.706	40	21	12.0
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	COLOR	PCU	13	33.269	55	30	11.0
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	COLOR	PCU	13	35.462	110	25	12.0
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	COLOR	PCU	15	26.333	45	25	14.0
LDEQ	Bayou Pirogue near New Canal	1066	COLOR	PCU	13	57.385	120	55	15.0
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	COLOR	PCU	13	47.308	110	50	19.0
LDEQ	Drum Bay, Louisiana	1091	COLOR	PCU	11	18.273	40	15	9.0
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	COLOR	PCU	15	18.767	38	20	11.0
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	COLOR	PCU	17	29.235	120	21	10.0
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	COLOR	PCU	17	28.824	60	22	12.0
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	COLOR	PCU	15	21.467	40	20	9.0
USGS	Mississippi River at Belle Chasse, LA	7374525	COLOR	PCU	59	13.136	50	10	0.0
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	COLOR	PCU	59	21.627	120	15	3.0
USGS	Mississippi River at Luling, LA	7374400	COLOR	PCU	72	12.500	50	10	0.0
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	COLOR	PCU	12	17.083	30	15	5.0
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	COLOR	PCU	175	22.043	70	20	5.0
LDEQ	Mississippi River near Belle Chase, Louisiana	52	COLOR	PCU	22	17.727	30	20	5.0
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	COLOR	PCU	12	19.583	30	20	10.0

Summary statistics of sampled water quality

Parameter=COLOR

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	COLOR	PCU	88	25.909	60	20	5.0
LDEQ	Morgan Harbor, Louisiana	1088	COLOR	PCU	11	18.227	35	15	8.5
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	COLOR	PCU	13	67.692	160	55	13.0
LDEQ	Point Lydia, Louisiana	1090	COLOR	PCU	11	14.818	30	15	7.0
LDEQ	Violet Canal near New Canal	1068	COLOR	PCU	13	49.923	110	30	15.0

Summary statistics of sampled water quality

Parameter=COPPER

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	COPPER	UG/L	6	1.102	1.61	1.035	0.90
LDEQ	Bayou Bashman near Bayou Dupre	1070	COPPER	UG/L	6	0.943	1.11	0.930	0.80
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	COPPER	UG/L	53	2.496	16.80	1.800	0.60
LDEQ	Bayou Bienvenue, Louisiana	1062	COPPER	UG/L	9	1.018	1.30	1.020	0.85
LDEQ	Bayou Bienvenue, Louisiana	1063	COPPER	UG/L	9	0.994	1.27	0.970	0.65
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	COPPER	UG/L	6	1.060	1.16	1.130	0.86
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	COPPER	UG/L	6	1.028	1.20	1.020	0.88
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	COPPER	UG/L	6	0.907	1.19	0.870	0.73
LDEQ	Bayou Pirogue near New Canal	1066	COPPER	UG/L	6	0.902	1.16	0.970	0.42
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	COPPER	UG/L	6	0.868	1.10	0.960	0.47
LDEQ	Drum Bay, Louisiana	1091	COPPER	UG/L	5	1.170	1.75	1.110	0.76
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	COPPER	UG/L	6	0.997	1.16	1.010	0.77
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	COPPER	UG/L	9	1.121	1.31	1.140	0.90
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	COPPER	UG/L	6	1.522	3.50	1.085	0.92
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	COPPER	UG/L	6	1.135	2.08	0.965	0.83
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	COPPER	UG/L	29	3.810	24.40	2.140	1.24
USGS	Mississippi River at Luling, LA	7374400	COPPER	UG/L	55	12.951	43.00	10.000	3.00
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	COPPER	UG/L	12	6.525	25.70	4.150	1.50
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	COPPER	UG/L	116	5.510	31.00	4.500	0.90
LDEQ	Mississippi River near Belle Chase, Louisiana	52	COPPER	UG/L	22	5.655	22.80	4.250	1.90
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	COPPER	UG/L	12	5.800	21.70	4.300	1.10
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	COPPER	UG/L	88	5.426	14.71	4.900	0.50

Summary statistics of sampled water quality

Parameter=COPPER

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Morgan Harbor, Louisiana	1088	COPPER	UG/L	6	1.045	1.31	1.000	0.78
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	COPPER	UG/L	6	1.032	1.38	1.060	0.48
LDEQ	Point Lydia, Louisiana	1090	COPPER	UG/L	6	1.108	1.65	1.145	0.69
LDEQ	Violet Canal near New Canal	1068	COPPER	UG/L	6	1.145	1.37	1.190	0.76

Summary statistics of sampled water quality

Parameter=Cyanide

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
USGS	Mississippi River at Luling, LA	7374400	Cyanide		58	0.010	0.02	0.01	0.01

Summary statistics of sampled water quality

Parameter=DIBROMOCHLOROMETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	DIBROMOCHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	DIBROMOCHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	DIBROMOCHLOROMETHANE	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	DIBROMOCHLOROMETHANE	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	DIBROMOCHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	DIBROMOCHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	DIBROMOCHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	DIBROMOCHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	DIBROMOCHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	DIBROMOCHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	DIBROMOCHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	DIBROMOCHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	DIBROMOCHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	DIBROMOCHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	DIBROMOCHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	DIBROMOCHLOROMETHANE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	DIBROMOCHLOROMETHANE	UG/L	114	0.162	2.5	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	DIBROMOCHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	DIBROMOCHLOROMETHANE	UG/L	81	0.100	0.1	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	DIBROMOCHLOROMETHANE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	DIBROMOCHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=DIBROMOCHLOROMETHANE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	DIBROMOCHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	DIBROMOCHLOROMETHANE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=DIELDRIN

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	DIELDRIN	UG/L	23	2.652	10.03	0.10	0.05
USGS	Mississippi River at Luling, LA	7374400	DIELDRIN	UG/L	6	0.010	0.01	0.01	0.01
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	DIELDRIN	UG/L	29	0.100	0.11	0.10	0.10
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	DIELDRIN	UG/L	78	0.100	0.10	0.10	0.10

Summary statistics of sampled water quality

Parameter=DISSOLVED OXYGEN

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	DISSOLVED OXYGEN	MG/L	23	7.693	11.33	7.450	5.01
LDEQ	Bayou Bashman near Bayou Dupre	1070	DISSOLVED OXYGEN	MG/L	23	5.853	10.35	5.630	2.96
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	DISSOLVED OXYGEN	MG/L	79	6.814	12.72	6.500	1.77
LDEQ	Bayou Bienvenue, Louisiana	1062	DISSOLVED OXYGEN	MG/L	36	7.718	11.33	7.550	4.52
LDEQ	Bayou Bienvenue, Louisiana	1063	DISSOLVED OXYGEN	MG/L	36	7.459	11.10	7.125	4.17
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	DISSOLVED OXYGEN	MG/L	23	6.245	11.53	5.470	2.81
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	DISSOLVED OXYGEN	MG/L	23	6.257	11.25	6.050	1.75
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	DISSOLVED OXYGEN	MG/L	23	6.783	10.72	6.370	4.62
LDEQ	Bayou Pirogue near New Canal	1066	DISSOLVED OXYGEN	MG/L	23	5.158	10.98	5.650	1.38
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	DISSOLVED OXYGEN	MG/L	23	5.520	12.73	5.620	1.71
LDEQ	Drum Bay, Louisiana	1091	DISSOLVED OXYGEN	MG/L	23	7.413	11.24	7.010	4.77
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	DISSOLVED OXYGEN	MG/L	23	7.112	10.36	6.790	4.45
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	DISSOLVED OXYGEN	MG/L	36	7.464	10.77	6.940	4.18
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	DISSOLVED OXYGEN	MG/L	23	7.844	10.71	7.610	5.67
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	DISSOLVED OXYGEN	MG/L	23	7.337	10.40	6.910	4.48
USGS	Mississippi River at Belle Chasse, LA	7374525	DISSOLVED OXYGEN	MG/L	105	8.625	13.80	8.500	5.00
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	DISSOLVED OXYGEN	MG/L	61	8.571	14.30	8.590	4.63
USGS	Mississippi River at Luling, LA	7374400	DISSOLVED OXYGEN	MG/L	72	8.647	14.00	8.100	5.00
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	DISSOLVED OXYGEN	MG/L	12	10.475	14.50	10.800	7.20
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	DISSOLVED OXYGEN	MG/L	169	8.379	17.70	7.840	5.00
LDEQ	Mississippi River near Belle Chase, Louisiana	52	DISSOLVED OXYGEN	MG/L	23	9.909	15.20	9.500	6.50
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	DISSOLVED OXYGEN	MG/L	12	9.642	14.40	9.300	6.30

Summary statistics of sampled water quality

Parameter=DISSOLVED OXYGEN

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	DISSOLVED OXYGEN	MG/L	90	8.296	12.55	8.075	0.10
LDEQ	Morgan Harbor, Louisiana	1088	DISSOLVED OXYGEN	MG/L	23	7.400	11.04	6.830	4.94
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	DISSOLVED OXYGEN	MG/L	23	5.343	9.58	5.500	1.42
LDEQ	Point Lydia, Louisiana	1090	DISSOLVED OXYGEN	MG/L	23	7.143	10.96	6.760	4.35
LDEQ	Violet Canal near New Canal	1068	DISSOLVED OXYGEN	MG/L	23	5.952	11.66	6.220	1.01

Summary statistics of sampled water quality

Parameter=DISSOLVED OXYGEN PERCENT SATURATION

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	DISSOLVED OXYGEN PERCENT SATURATION	%	23	89.902	112.0	92.30	31.44
LDEQ	Bayou Bashman near Bayou Dupre	1070	DISSOLVED OXYGEN PERCENT SATURATION	%	22	67.750	96.3	65.05	40.50
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	DISSOLVED OXYGEN PERCENT SATURATION	%	36	77.981	117.0	80.20	44.70
LDEQ	Bayou Bienvenue, Louisiana	1062	DISSOLVED OXYGEN PERCENT SATURATION	%	36	90.208	106.3	91.00	68.90
LDEQ	Bayou Bienvenue, Louisiana	1063	DISSOLVED OXYGEN PERCENT SATURATION	%	36	87.033	105.6	88.55	56.70
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	DISSOLVED OXYGEN PERCENT SATURATION	%	24	72.713	107.0	73.15	38.60
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	DISSOLVED OXYGEN PERCENT SATURATION	%	24	72.613	96.2	78.50	22.70
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	DISSOLVED OXYGEN PERCENT SATURATION	%	23	84.408	102.9	84.70	65.88
LDEQ	Bayou Pirogue near New Canal	1066	DISSOLVED OXYGEN PERCENT SATURATION	%	24	61.046	94.1	64.90	18.30
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	DISSOLVED OXYGEN PERCENT SATURATION	%	24	61.317	100.5	66.20	23.10
LDEQ	Drum Bay, Louisiana	1091	DISSOLVED OXYGEN PERCENT SATURATION	%	23	88.747	105.0	92.50	4.77
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	DISSOLVED OXYGEN PERCENT SATURATION	%	23	89.653	115.1	88.70	65.50
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	DISSOLVED OXYGEN PERCENT SATURATION	%	36	89.214	114.9	88.20	63.70
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	DISSOLVED OXYGEN PERCENT SATURATION	%	22	90.959	105.8	92.05	77.50

Summary statistics of sampled water quality

Parameter=DISSOLVED OXYGEN PERCENT SATURATION

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	DISSOLVED OXYGEN PERCENT SATURATION	%	23	90.935	142.3	90.60	66.70
USGS	Mississippi River at Belle Chasse, LA	7374525	DISSOLVED OXYGEN PERCENT SATURATION	%	89	88.337	114.0	90.00	62.00
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	DISSOLVED OXYGEN PERCENT SATURATION	%	48	84.515	99.0	85.40	61.00
USGS	Mississippi River at Luling, LA	7374400	DISSOLVED OXYGEN PERCENT SATURATION	%	59	89.746	128.0	89.00	61.00
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	DISSOLVED OXYGEN PERCENT SATURATION	%	55	84.391	108.1	83.60	66.40
LDEQ	Morgan Harbor, Louisiana	1088	DISSOLVED OXYGEN PERCENT SATURATION	%	23	91.587	108.1	92.30	70.70
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	DISSOLVED OXYGEN PERCENT SATURATION	%	24	61.887	98.5	60.25	16.20
LDEQ	Point Lydia, Louisiana	1090	DISSOLVED OXYGEN PERCENT SATURATION	%	23	88.800	101.0	89.30	63.70
LDEQ	Violet Canal near New Canal	1068	DISSOLVED OXYGEN PERCENT SATURATION	%	24	63.096	112.5	65.85	9.30

Summary statistics of sampled water quality

Parameter=ENDOSULFAN I

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	ENDOSULFAN I	UG/L	23	3.424	9.64	0.05	0.05
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	ENDOSULFAN I	UG/L	29	0.095	0.10	0.10	0.05
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	ENDOSULFAN I	UG/L	78	0.100	0.10	0.10	0.10

Summary statistics of sampled water quality

Parameter=ENDOSULFAN II

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	ENDOSULFAN II	UG/L	23	3.489	11.68	0.10	0.05
USGS	Mississippi River at Luling, LA	7374400	ENDOSULFAN II	UG/L	6	0.010	0.01	0.01	0.01
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	ENDOSULFAN II	UG/L	29	0.100	0.11	0.10	0.10
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	ENDOSULFAN II	UG/L	78	0.100	0.10	0.10	0.10

Summary statistics of sampled water quality

Parameter=ENDRIN

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	ENDRIN	UG/L	23	1.664	10.44	0.10	0.05
USGS	Mississippi River at Luling, LA	7374400	ENDRIN	UG/L	5	0.010	0.01	0.01	0.01
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	ENDRIN	UG/L	26	0.100	0.10	0.10	0.10
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	ENDRIN	UG/L	78	0.100	0.10	0.10	0.10

Summary statistics of sampled water quality

Parameter=ETHYLBENZENE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	ETHYLBENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	ETHYLBENZENE	UG/L	5	0.200	0.6	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	ETHYLBENZENE	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	ETHYLBENZENE	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	ETHYLBENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	ETHYLBENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	ETHYLBENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	ETHYLBENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	ETHYLBENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	ETHYLBENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	ETHYLBENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	ETHYLBENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	ETHYLBENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	ETHYLBENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	ETHYLBENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	ETHYLBENZENE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	ETHYLBENZENE	UG/L	112	0.108	1.0	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	ETHYLBENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	ETHYLBENZENE	UG/L	81	0.100	0.1	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	ETHYLBENZENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	ETHYLBENZENE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=ETHYLBENZENE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	ETHYLBENZENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	ETHYLBENZENE	UG/L	5	0.180	0.5	0.1	0.1

Summary statistics of sampled water quality

Parameter=FECAL COLIFORM

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	FECAL COLIFORM	CFU/100 ML	24	10.167	99	10.0	2
LDEQ	Bayou Bashman near Bayou Dupre	1070	FECAL COLIFORM	CFU/100 ML	24	36.625	230	20.5	4
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	FECAL COLIFORM	CFU/100 ML	76	114.667	1300	23.0	2
LDEQ	Bayou Bienvenue, Louisiana	1062	FECAL COLIFORM	CFU/100 ML	35	32.618	230	11.0	2
LDEQ	Bayou Bienvenue, Louisiana	1063	FECAL COLIFORM	CFU/100 ML	34	40.971	220	14.0	2
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	FECAL COLIFORM	CFU/100 ML	24	59.083	545	17.5	2
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	FECAL COLIFORM	CFU/100 ML	24	46.792	300	18.0	4
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	FECAL COLIFORM	CFU/100 ML	24	13.917	54	10.0	1
LDEQ	Bayou Pirogue near New Canal	1066	FECAL COLIFORM	CFU/100 ML	24	123.458	700	80.0	10
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	FECAL COLIFORM	CFU/100 ML	24	75.750	410	58.5	4
LDEQ	Drum Bay, Louisiana	1091	FECAL COLIFORM	CFU/100 ML	24	6.375	10	8.5	2
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	FECAL COLIFORM	CFU/100 ML	24	5.708	10	2.5	2
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	FECAL COLIFORM	CFU/100 ML	33	32.594	350	10.0	2
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	FECAL COLIFORM	CFU/100 ML	23	18.348	130	8.0	2
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	FECAL COLIFORM	CFU/100 ML	24	17.375	170	10.0	2
USGS	Mississippi River at Belle Chasse, LA	7374525	FECAL COLIFORM	CFU/100 ML	36	114.417	500	70.0	2
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	FECAL COLIFORM	CFU/100 ML	55	216.055	2400	106.0	10
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	FECAL COLIFORM	CFU/100 ML	10	307.000	800	220.0	110
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	FECAL COLIFORM	CFU/100 ML	174	270.494	2400	170.0	11
LDEQ	Mississippi River near Belle Chase, Louisiana	52	FECAL COLIFORM	CFU/100 ML	10	936.000	4300	230.0	140
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	FECAL COLIFORM	CFU/100 ML	10	1322.000	9000	235.0	40
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	FECAL COLIFORM	CFU/100 ML	85	285.059	1700	220.0	20

Summary statistics of sampled water quality

Parameter=FECAL COLIFORM

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Morgan Harbor, Louisiana	1088	FECAL COLIFORM	CFU/100 ML	24	22.208	310	6.0	2
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	FECAL COLIFORM	CFU/100 ML	24	129.625	800	71.0	10
LDEQ	Point Lydia, Louisiana	1090	FECAL COLIFORM	CFU/100 ML	24	8.667	72	7.0	2
LDEQ	Violet Canal near New Canal	1068	FECAL COLIFORM	CFU/100 ML	24	101.083	430	45.5	2

Summary statistics of sampled water quality

Parameter=GAMMA BHC (GAMMA HEXACHLOROCYCLOHEXANE)

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	GAMMA BHC (GAMMA HEXACHLOROCYCLOHEXANE)	UG/L	23	1.411	6.82	0.05	0.05
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	GAMMA BHC (GAMMA HEXACHLOROCYCLOHEXANE)	UG/L	26	0.100	0.10	0.10	0.10
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	GAMMA BHC (GAMMA HEXACHLOROCYCLOHEXANE)	UG/L	78	0.100	0.10	0.10	0.10

Summary statistics of sampled water quality

Parameter=HARDNESS (AS CACO3)

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	HARDNESS (AS CACO3)	MG/L	23	3071.978	5256	3102.0	1397.0
LDEQ	Bayou Bashman near Bayou Dupre	1070	HARDNESS (AS CACO3)	MG/L	24	2132.625	3875	2005.0	669.0
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	HARDNESS (AS CACO3)	MG/L	80	1777.890	3303	1756.0	330.0
LDEQ	Bayou Bienvenue, Louisiana	1062	HARDNESS (AS CACO3)	MG/L	36	1818.528	3303	1771.0	530.0
LDEQ	Bayou Bienvenue, Louisiana	1063	HARDNESS (AS CACO3)	MG/L	35	1843.286	3305	1784.0	470.0
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	HARDNESS (AS CACO3)	MG/L	23	1936.087	2934	1930.0	547.0
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	HARDNESS (AS CACO3)	MG/L	24	1995.125	3732	1953.0	414.0
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	HARDNESS (AS CACO3)	MG/L	23	3223.261	4606	3167.0	1954.0
LDEQ	Bayou Pirogue near New Canal	1066	HARDNESS (AS CACO3)	MG/L	24	1948.625	3347	1855.0	505.0
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	HARDNESS (AS CACO3)	MG/L	24	1958.458	3257	1909.5	574.0
LDEQ	Drum Bay, Louisiana	1091	HARDNESS (AS CACO3)	MG/L	23	3234.391	5760	3305.0	1511.0
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	HARDNESS (AS CACO3)	MG/L	23	3591.870	4716	3495.0	2316.0
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	HARDNESS (AS CACO3)	MG/L	35	1884.914	3316	1940.0	630.0
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	HARDNESS (AS CACO3)	MG/L	24	1365.083	2927	1185.5	372.0
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	HARDNESS (AS CACO3)	MG/L	23	2872.000	4189	2857.0	1976.0
USGS	Mississippi River at Belle Chasse, LA	7374525	HARDNESS (AS CACO3)	MG/L	106	143.566	190	140.0	98.0
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	HARDNESS (AS CACO3)	MG/L	60	163.500	229	164.0	111.0
USGS	Mississippi River at Luling, LA	7374400	HARDNESS (AS CACO3)	MG/L	71	148.634	210	150.0	90.0
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	HARDNESS (AS CACO3)	MG/L	12	147.000	184	148.0	113.0
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	HARDNESS (AS CACO3)	MG/L	175	153.561	222	154.0	4.7
LDEQ	Mississippi River near Belle Chase, Louisiana	52	HARDNESS (AS CACO3)	MG/L	22	148.682	183	150.0	111.0
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	HARDNESS (AS CACO3)	MG/L	12	145.917	184	145.0	111.0

Summary statistics of sampled water quality

Parameter=HARDNESS (AS CACO3)

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	HARDNESS (AS CACO3)	MG/L	88	151.407	219	149.5	103.0
LDEQ	Morgan Harbor, Louisiana	1088	HARDNESS (AS CACO3)	MG/L	23	3200.630	4931	3312.0	1563.0
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	HARDNESS (AS CACO3)	MG/L	24	1924.917	3382	1897.5	408.0
LDEQ	Point Lydia, Louisiana	1090	HARDNESS (AS CACO3)	MG/L	23	3668.087	5108	3817.0	1750.0
LDEQ	Violet Canal near New Canal	1068	HARDNESS (AS CACO3)	MG/L	24	1455.583	3328	1531.5	141.0

Summary statistics of sampled water quality

Parameter=HEPTACHLOR

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	HEPTACHLOR	UG/L	23	3.051	9.26	0.05	0.05
USGS	Mississippi River at Luling, LA	7374400	HEPTACHLOR	UG/L	6	0.010	0.01	0.01	0.01
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	HEPTACHLOR	UG/L	29	0.095	0.10	0.10	0.05
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	HEPTACHLOR	UG/L	78	0.100	0.10	0.10	0.10

Summary statistics of sampled water quality

Parameter=HEXACHLOROBENZENE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	HEXACHLOROBENZENE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	HEXACHLOROBENZENE	UG/L	29	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	HEXACHLOROBENZENE	UG/L	78	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=HEXACHLOROBUTADIENE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	HEXACHLOROBUTADIENE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	HEXACHLOROBUTADIENE	UG/L	29	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	HEXACHLOROBUTADIENE	UG/L	78	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=LEAD

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	LEAD	UG/L	5	0.096	0.28	0.060	0.02
LDEQ	Bayou Bashman near Bayou Dupre	1070	LEAD	UG/L	6	0.040	0.08	0.030	0.02
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	LEAD	UG/L	51	1.635	25.44	0.600	0.02
LDEQ	Bayou Bienvenue, Louisiana	1062	LEAD	UG/L	7	0.040	0.06	0.050	0.02
LDEQ	Bayou Bienvenue, Louisiana	1063	LEAD	UG/L	6	0.050	0.11	0.045	0.02
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	LEAD	UG/L	6	0.170	0.86	0.035	0.02
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	LEAD	UG/L	5	0.044	0.07	0.050	0.01
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	LEAD	UG/L	5	0.030	0.04	0.030	0.02
LDEQ	Bayou Pirogue near New Canal	1066	LEAD	UG/L	6	0.040	0.06	0.045	0.02
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	LEAD	UG/L	6	0.040	0.05	0.045	0.01
LDEQ	Drum Bay, Louisiana	1091	LEAD	UG/L	4	0.085	0.27	0.025	0.02
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	LEAD	UG/L	5	0.314	1.48	0.020	0.02
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	LEAD	UG/L	6	0.035	0.05	0.035	0.02
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	LEAD	UG/L	6	0.038	0.10	0.030	0.01
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	LEAD	UG/L	5	0.824	4.02	0.030	0.02
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	LEAD	UG/L	27	2.234	15.50	0.510	0.03
USGS	Mississippi River at Luling, LA	7374400	LEAD	UG/L	52	5.950	16.00	5.000	1.00
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	LEAD	UG/L	12	4.975	18.80	3.200	0.40
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	LEAD	UG/L	116	1.702	8.84	0.750	0.02
LDEQ	Mississippi River near Belle Chase, Louisiana	52	LEAD	UG/L	22	3.418	16.60	1.400	0.30
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	LEAD	UG/L	12	4.100	14.50	2.850	0.40
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	LEAD	UG/L	88	1.424	6.99	0.700	0.10

Summary statistics of sampled water quality

Parameter=LEAD

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Morgan Harbor, Louisiana	1088	LEAD	UG/L	4	0.100	0.22	0.080	0.02
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	LEAD	UG/L	6	0.050	0.09	0.045	0.03
LDEQ	Point Lydia, Louisiana	1090	LEAD	UG/L	5	0.052	0.07	0.050	0.03
LDEQ	Violet Canal near New Canal	1068	LEAD	UG/L	6	0.065	0.18	0.050	0.01

Summary statistics of sampled water quality

Parameter=MERCURY

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	MERCURY	UG/L	3	0.050	0.05	0.05	0.05
LDEQ	Bayou Bashman near Bayou Dupre	1070	MERCURY	UG/L	2	.	.	.	.
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	MERCURY	UG/L	47	0.102	0.20	0.05	0.05
LDEQ	Bayou Bienvenue, Louisiana	1062	MERCURY	UG/L	4	.	.	.	.
LDEQ	Bayou Bienvenue, Louisiana	1063	MERCURY	UG/L	4	.	.	.	.
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	MERCURY	UG/L	2	.	.	.	.
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	MERCURY	UG/L	2	.	.	.	.
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	MERCURY	UG/L	5	0.050	0.05	0.05	0.05
LDEQ	Bayou Pirogue near New Canal	1066	MERCURY	UG/L	2	.	.	.	.
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	MERCURY	UG/L	2	.	.	.	.
LDEQ	Drum Bay, Louisiana	1091	MERCURY	UG/L	2	0.050	0.05	0.05	0.05
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	MERCURY	UG/L	5	0.050	0.05	0.05	0.05
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	MERCURY	UG/L	4	.	.	.	.
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	MERCURY	UG/L	4	.	.	.	.
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	MERCURY	UG/L	5	0.050	0.05	0.05	0.05
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	MERCURY	UG/L	15	0.200	0.20	0.20	0.20
USGS	Mississippi River at Luling, LA	7374400	MERCURY	UG/L	59	0.103	0.30	0.10	0.10
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	MERCURY	UG/L	12	0.200	0.20	0.20	0.20
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	MERCURY	UG/L	116	0.097	0.20	0.05	0.05
LDEQ	Mississippi River near Belle Chase, Louisiana	52	MERCURY	UG/L	22	0.200	0.20	0.20	0.20
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	MERCURY	UG/L	12	0.200	0.20	0.20	0.20
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	MERCURY	UG/L	87	0.102	0.20	0.05	0.05

Summary statistics of sampled water quality

Parameter=MERCURY

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Morgan Harbor, Louisiana	1088	MERCURY	UG/L	3	0.050	0.05	0.05	0.05
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	MERCURY	UG/L	2	.	.	.	.
LDEQ	Point Lydia, Louisiana	1090	MERCURY	UG/L	3	0.050	0.05	0.05	0.05
LDEQ	Violet Canal near New Canal	1068	MERCURY	UG/L	2	.	.	.	.

Summary statistics of sampled water quality

Parameter=METHYLENE CHLORIDE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	METHYLENE CHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	METHYLENE CHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	METHYLENE CHLORIDE	UG/L	10	0.334	2.44	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	METHYLENE CHLORIDE	UG/L	3	0.910	2.53	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	METHYLENE CHLORIDE	UG/L	4	1.048	3.89	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	METHYLENE CHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	METHYLENE CHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	METHYLENE CHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	METHYLENE CHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	METHYLENE CHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	METHYLENE CHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	METHYLENE CHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	METHYLENE CHLORIDE	UG/L	5	0.534	2.27	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	METHYLENE CHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	METHYLENE CHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	METHYLENE CHLORIDE	UG/L	1	0.100	0.10	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	METHYLENE CHLORIDE	UG/L	112	0.138	2.00	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	METHYLENE CHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	METHYLENE CHLORIDE	UG/L	81	0.104	0.40	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	METHYLENE CHLORIDE	UG/L	3	0.100	0.10	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	METHYLENE CHLORIDE	UG/L	4	0.100	0.10	0.1	0.1

Summary statistics of sampled water quality

Parameter=METHYLENE CHLORIDE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	METHYLENE CHLORIDE	UG/L	4	0.100	0.10	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	METHYLENE CHLORIDE	UG/L	4	0.100	0.10	0.1	0.1

Summary statistics of sampled water quality

Parameter=NICKEL

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	NICKEL	UG/L	6	1.470	1.77	1.565	1.01
LDEQ	Bayou Bashman near Bayou Dupre	1070	NICKEL	UG/L	6	1.328	1.70	1.375	0.86
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	NICKEL	UG/L	53	2.004	5.00	1.590	0.06
LDEQ	Bayou Bienvenue, Louisiana	1062	NICKEL	UG/L	9	1.477	2.15	1.310	1.10
LDEQ	Bayou Bienvenue, Louisiana	1063	NICKEL	UG/L	9	1.363	1.88	1.380	1.03
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	NICKEL	UG/L	6	1.437	1.87	1.500	0.99
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	NICKEL	UG/L	6	1.327	1.71	1.355	0.99
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	NICKEL	UG/L	6	1.388	2.10	1.270	1.07
LDEQ	Bayou Pirogue near New Canal	1066	NICKEL	UG/L	6	1.373	1.65	1.450	0.93
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	NICKEL	UG/L	6	1.410	1.75	1.505	0.92
LDEQ	Drum Bay, Louisiana	1091	NICKEL	UG/L	5	1.454	1.70	1.560	1.08
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	NICKEL	UG/L	6	1.492	1.95	1.450	1.15
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	NICKEL	UG/L	9	1.378	1.77	1.260	1.16
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	NICKEL	UG/L	6	1.387	1.80	1.375	0.92
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	NICKEL	UG/L	6	1.392	1.79	1.385	1.01
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	NICKEL	UG/L	17	1.436	2.92	1.440	0.05
USGS	Mississippi River at Luling, LA	7374400	NICKEL	UG/L	52	6.029	16.00	5.550	2.00
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	NICKEL	UG/L	116	2.778	7.90	2.400	0.21
LDEQ	Mississippi River near Belle Chase, Louisiana	52	NICKEL	UG/L	10	3.020	7.50	2.450	1.50
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	NICKEL	UG/L	88	3.244	12.50	2.600	0.80
LDEQ	Morgan Harbor, Louisiana	1088	NICKEL	UG/L	6	1.487	1.91	1.455	1.17
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	NICKEL	UG/L	6	1.457	1.81	1.535	0.93

Summary statistics of sampled water quality

Parameter=NICKEL

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	NICKEL	UG/L	6	1.365	1.64	1.525	0.74
LDEQ	Violet Canal near New Canal	1068	NICKEL	UG/L	6	1.502	1.91	1.660	0.97

Summary statistics of sampled water quality

Parameter=NITRATE+NITRITE NITROGEN

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	NITRATE+NITRITE NITROGEN	MG/L	12	0.081	0.24	0.050	0.03
LDEQ	Bayou Bashman near Bayou Dupre	1070	NITRATE+NITRITE NITROGEN	MG/L	19	0.114	0.42	0.080	0.05
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	NITRATE+NITRITE NITROGEN	MG/L	65	0.109	1.15	0.070	0.01
LDEQ	Bayou Bienvenue, Louisiana	1062	NITRATE+NITRITE NITROGEN	MG/L	16	0.079	0.17	0.070	0.05
LDEQ	Bayou Bienvenue, Louisiana	1063	NITRATE+NITRITE NITROGEN	MG/L	13	0.084	0.20	0.070	0.05
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	NITRATE+NITRITE NITROGEN	MG/L	16	0.077	0.14	0.075	0.03
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	NITRATE+NITRITE NITROGEN	MG/L	20	0.182	0.80	0.085	0.02
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	NITRATE+NITRITE NITROGEN	MG/L	11	0.112	0.66	0.050	0.03
LDEQ	Bayou Pirogue near New Canal	1066	NITRATE+NITRITE NITROGEN	MG/L	17	0.082	0.24	0.070	0.03
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	NITRATE+NITRITE NITROGEN	MG/L	17	0.122	0.60	0.080	0.04
LDEQ	Drum Bay, Louisiana	1091	NITRATE+NITRITE NITROGEN	MG/L	12	0.132	0.80	0.050	0.03
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	NITRATE+NITRITE NITROGEN	MG/L	11	0.073	0.27	0.050	0.03
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	NITRATE+NITRITE NITROGEN	MG/L	18	0.136	0.55	0.085	0.05
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	NITRATE+NITRITE NITROGEN	MG/L	14	0.084	0.14	0.075	0.05
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	NITRATE+NITRITE NITROGEN	MG/L	12	0.078	0.27	0.060	0.02
USGS	Mississippi River at Belle Chasse, LA	7374525	NITRATE+NITRITE NITROGEN	MG/L	21	1.681	2.80	1.600	0.81
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	NITRATE+NITRITE NITROGEN	MG/L	58	1.580	2.52	1.560	0.57
USGS	Mississippi River at Luling, LA	7374400	NITRATE+NITRITE NITROGEN	MG/L	71	1.541	3.20	1.400	0.60
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	NITRATE+NITRITE NITROGEN	MG/L	12	1.553	2.44	1.500	0.68
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	NITRATE+NITRITE NITROGEN	MG/L	174	1.529	9.38	1.360	0.02
LDEQ	Mississippi River near Belle Chase, Louisiana	52	NITRATE+NITRITE NITROGEN	MG/L	22	1.569	2.81	1.625	0.64
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	NITRATE+NITRITE NITROGEN	MG/L	12	1.569	2.46	1.525	0.68

Summary statistics of sampled water quality

Parameter=NITRATE+NITRITE NITROGEN

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	NITRATE+NITRITE NITROGEN	MG/L	88	1.461	2.69	1.395	0.06
LDEQ	Morgan Harbor, Louisiana	1088	NITRATE+NITRITE NITROGEN	MG/L	12	0.095	0.31	0.060	0.03
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	NITRATE+NITRITE NITROGEN	MG/L	18	0.096	0.36	0.065	0.02
LDEQ	Point Lydia, Louisiana	1090	NITRATE+NITRITE NITROGEN	MG/L	14	0.136	0.80	0.065	0.04
LDEQ	Violet Canal near New Canal	1068	NITRATE+NITRITE NITROGEN	MG/L	21	0.528	1.72	0.090	0.05

Summary statistics of sampled water quality

Parameter=NITROGEN, KJELDAHL

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	NITROGEN, KJELDAHL	MG/L	22	0.539	0.96	0.530	0.18
LDEQ	Bayou Bashman near Bayou Dupre	1070	NITROGEN, KJELDAHL	MG/L	23	0.601	1.13	0.600	0.10
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	NITROGEN, KJELDAHL	MG/L	73	0.735	2.77	0.660	0.01
LDEQ	Bayou Bienvenue, Louisiana	1062	NITROGEN, KJELDAHL	MG/L	28	0.586	1.23	0.570	0.12
LDEQ	Bayou Bienvenue, Louisiana	1063	NITROGEN, KJELDAHL	MG/L	28	0.679	1.50	0.650	0.20
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	NITROGEN, KJELDAHL	MG/L	24	0.710	1.41	0.625	0.41
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	NITROGEN, KJELDAHL	MG/L	24	0.660	1.46	0.570	0.21
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	NITROGEN, KJELDAHL	MG/L	22	0.613	1.12	0.605	0.15
LDEQ	Bayou Pirogue near New Canal	1066	NITROGEN, KJELDAHL	MG/L	23	0.953	1.54	0.990	0.47
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	NITROGEN, KJELDAHL	MG/L	23	0.888	1.86	0.770	0.43
LDEQ	Drum Bay, Louisiana	1091	NITROGEN, KJELDAHL	MG/L	23	0.507	1.20	0.420	0.12
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	NITROGEN, KJELDAHL	MG/L	22	0.574	0.95	0.535	0.29
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	NITROGEN, KJELDAHL	MG/L	29	0.604	1.61	0.530	0.10
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	NITROGEN, KJELDAHL	MG/L	23	0.549	2.68	0.440	0.17
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	NITROGEN, KJELDAHL	MG/L	23	0.552	0.88	0.600	0.20
USGS	Mississippi River at Belle Chasse, LA	7374525	NITROGEN, KJELDAHL	MG/L	109	0.591	1.20	0.580	0.24
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	NITROGEN, KJELDAHL	MG/L	56	0.892	10.20	0.680	0.24
USGS	Mississippi River at Luling, LA	7374400	NITROGEN, KJELDAHL	MG/L	31	0.579	1.10	0.540	0.20
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	NITROGEN, KJELDAHL	MG/L	12	0.878	2.53	0.640	0.48
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	NITROGEN, KJELDAHL	MG/L	172	0.748	2.60	0.705	0.02
LDEQ	Mississippi River near Belle Chase, Louisiana	52	NITROGEN, KJELDAHL	MG/L	22	0.854	2.28	0.800	0.49
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	NITROGEN, KJELDAHL	MG/L	12	0.745	1.57	0.555	0.44

Summary statistics of sampled water quality

Parameter=NITROGEN, KJELDAHL

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	NITROGEN, KJELDAHL	MG/L	88	0.788	2.55	0.725	0.07
LDEQ	Morgan Harbor, Louisiana	1088	NITROGEN, KJELDAHL	MG/L	22	0.505	0.99	0.445	0.20
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	NITROGEN, KJELDAHL	MG/L	23	0.893	1.90	0.830	0.44
LDEQ	Point Lydia, Louisiana	1090	NITROGEN, KJELDAHL	MG/L	22	0.584	1.13	0.600	0.15
LDEQ	Violet Canal near New Canal	1068	NITROGEN, KJELDAHL	MG/L	24	0.836	2.08	0.725	0.32

Summary statistics of sampled water quality

Parameter=PHENOL

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	PHENOL	UG/L	2	38.600	77.1	38.6	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	PHENOL	UG/L	29	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	PHENOL	UG/L	77	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=PHOSPHORUS (AS P)

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	PHOSPHORUS (AS P)	MG/L	23	0.093	0.17	0.090	0.05
LDEQ	Bayou Bashman near Bayou Dupre	1070	PHOSPHORUS (AS P)	MG/L	24	0.122	0.20	0.125	0.05
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	PHOSPHORUS (AS P)	MG/L	75	0.145	2.21	0.100	0.01
LDEQ	Bayou Bienvenue, Louisiana	1062	PHOSPHORUS (AS P)	MG/L	30	0.102	0.20	0.100	0.06
LDEQ	Bayou Bienvenue, Louisiana	1063	PHOSPHORUS (AS P)	MG/L	29	0.096	0.14	0.100	0.05
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	PHOSPHORUS (AS P)	MG/L	24	0.128	0.30	0.120	0.05
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	PHOSPHORUS (AS P)	MG/L	23	0.110	0.19	0.110	0.05
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	PHOSPHORUS (AS P)	MG/L	23	0.089	0.12	0.090	0.06
LDEQ	Bayou Pirogue near New Canal	1066	PHOSPHORUS (AS P)	MG/L	24	0.133	0.32	0.120	0.06
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	PHOSPHORUS (AS P)	MG/L	24	0.142	0.37	0.130	0.05
LDEQ	Drum Bay, Louisiana	1091	PHOSPHORUS (AS P)	MG/L	23	0.103	0.18	0.100	0.05
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	PHOSPHORUS (AS P)	MG/L	23	0.085	0.11	0.090	0.05
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	PHOSPHORUS (AS P)	MG/L	29	0.091	0.13	0.090	0.05
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	PHOSPHORUS (AS P)	MG/L	24	0.081	0.17	0.070	0.05
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	PHOSPHORUS (AS P)	MG/L	22	0.089	0.13	0.090	0.05
USGS	Mississippi River at Belle Chasse, LA	7374525	PHOSPHORUS (AS P)	MG/L	109	0.218	0.44	0.217	0.06
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	PHOSPHORUS (AS P)	MG/L	60	0.211	0.70	0.190	0.10
USGS	Mississippi River at Luling, LA	7374400	PHOSPHORUS (AS P)	MG/L	73	0.217	0.62	0.210	0.07
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	PHOSPHORUS (AS P)	MG/L	12	0.273	0.75	0.235	0.12
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	PHOSPHORUS (AS P)	MG/L	172	0.189	0.66	0.170	0.06
LDEQ	Mississippi River near Belle Chase, Louisiana	52	PHOSPHORUS (AS P)	MG/L	22	0.240	0.69	0.210	0.11
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	PHOSPHORUS (AS P)	MG/L	12	0.248	0.69	0.200	0.10

Summary statistics of sampled water quality

Parameter=PHOSPHORUS (AS P)

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	PHOSPHORUS (AS P)	MG/L	88	0.196	0.55	0.180	0.01
LDEQ	Morgan Harbor, Louisiana	1088	PHOSPHORUS (AS P)	MG/L	23	0.087	0.19	0.080	0.05
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	PHOSPHORUS (AS P)	MG/L	24	0.129	0.25	0.130	0.05
LDEQ	Point Lydia, Louisiana	1090	PHOSPHORUS (AS P)	MG/L	23	0.110	0.23	0.110	0.05
LDEQ	Violet Canal near New Canal	1068	PHOSPHORUS (AS P)	MG/L	24	0.156	0.35	0.155	0.05

Summary statistics of sampled water quality

Parameter=SALINITY

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	SALINITY		22	15.496	26.73	14.805	7.98
LDEQ	Bayou Bashman near Bayou Dupre	1070	SALINITY		24	10.764	19.27	10.200	3.40
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	SALINITY		72	9.711	18.00	9.030	3.10
LDEQ	Bayou Bienvenue, Louisiana	1062	SALINITY		35	9.438	17.60	8.890	5.10
LDEQ	Bayou Bienvenue, Louisiana	1063	SALINITY		35	9.729	17.40	8.600	4.94
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	SALINITY		24	9.738	14.30	10.100	2.90
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	SALINITY		24	10.340	19.33	10.550	2.10
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	SALINITY		23	16.128	23.54	16.100	10.80
LDEQ	Bayou Pirogue near New Canal	1066	SALINITY		24	9.746	15.86	9.570	2.40
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	SALINITY		24	9.988	15.57	9.610	3.00
LDEQ	Drum Bay, Louisiana	1091	SALINITY		23	16.636	27.33	17.200	8.90
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	SALINITY		23	18.097	23.90	17.900	12.00
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	SALINITY		35	9.893	17.60	9.100	4.89
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	SALINITY		23	7.247	15.97	6.000	2.60
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	SALINITY		23	14.708	21.70	14.100	10.20
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	SALINITY		50	0.305	1.00	0.220	0.13
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	SALINITY		3	0.467	1.00	0.200	0.20
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	SALINITY		142	0.831	1.00	1.000	0.10
LDEQ	Mississippi River near Belle Chase, Louisiana	52	SALINITY		5	0.500	1.00	0.200	0.10
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	SALINITY		3	0.467	1.00	0.200	0.20
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	SALINITY		68	0.960	1.00	1.000	0.10
LDEQ	Morgan Harbor, Louisiana	1088	SALINITY		23	16.436	24.95	15.700	8.40

Summary statistics of sampled water quality

Parameter=SALINITY

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	SALINITY		24	9.579	15.92	9.160	2.00
LDEQ	Point Lydia, Louisiana	1090	SALINITY		23	19.127	27.00	19.900	9.10
LDEQ	Violet Canal near New Canal	1068	SALINITY		24	7.805	15.86	7.670	0.31

Summary statistics of sampled water quality

Parameter=SPECIFIC CONDUCTANCE, FIELD

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	25065.217	41596	24540.0	13960.0
LDEQ	Bayou Bashman near Bayou Dupre	1070	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	17290.870	30900	16160.0	1300.0
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	79	15581.481	29450	14940.0	227.0
LDEQ	Bayou Bienvenue, Louisiana	1062	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	36	15467.861	28600	15014.5	231.0
LDEQ	Bayou Bienvenue, Louisiana	1063	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	36	16133.583	28330	14730.0	231.0
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	15926.087	23890	17100.0	1068.0
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	17165.435	30800	17780.0	3900.0
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	26460.174	36700	26534.0	18460.0
LDEQ	Bayou Pirogue near New Canal	1066	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	16139.696	24072	16300.0	4320.0
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	16532.957	23898	15600.0	5480.0
LDEQ	Drum Bay, Louisiana	1091	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	26521.565	42461	27600.0	15460.0
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	29163.739	37620	28130.0	21220.0
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	35	16363.786	28540	15750.0	21.5
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	11830.261	26100	9520.0	1256.0

Summary statistics of sampled water quality

Parameter=SPECIFIC CONDUCTANCE, FIELD

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	23970.174	34350	23410.0	16680.0
USGS	Mississippi River at Belle Chasse, LA	7374525	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	111	393.099	542	379.0	260.0
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	59	345.512	581	392.0	0.3
USGS	Mississippi River at Luling, LA	7374400	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	72	402.181	556	403.5	239.0
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	11	345.182	533	336.0	211.0
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	163	402.890	614	394.0	229.0
LDEQ	Mississippi River near Belle Chase, Louisiana	52	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	22	360.091	533	340.5	208.0
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	10	356.200	528	342.5	209.0
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	85	385.295	614	358.0	0.1
LDEQ	Morgan Harbor, Louisiana	1088	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	26410.522	39114	25800.0	14800.0
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	15390.000	23944	15600.0	1200.0
LDEQ	Point Lydia, Louisiana	1090	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	29639.187	43500	31400.0	21.3
LDEQ	Violet Canal near New Canal	1068	SPECIFIC CONDUCTANCE, FIELD	UMHOS/CM	23	12763.348	24084	13300.0	645.0

Summary statistics of sampled water quality

Parameter=SULFATE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	SULFATE	MG/L	23	1398.239	2233.0	1269.00	588.0
LDEQ	Bayou Bashman near Bayou Dupre	1070	SULFATE	MG/L	24	956.708	2687.0	859.00	362.0
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	SULFATE	MG/L	80	765.138	2413.0	727.50	141.0
LDEQ	Bayou Bienvenue, Louisiana	1062	SULFATE	MG/L	36	794.056	1453.0	771.00	390.0
LDEQ	Bayou Bienvenue, Louisiana	1063	SULFATE	MG/L	36	795.139	1342.0	772.00	376.0
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	SULFATE	MG/L	24	895.146	2102.0	834.50	289.0
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	SULFATE	MG/L	24	908.167	2756.0	878.00	202.0
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	SULFATE	MG/L	23	1492.978	2323.0	1418.00	888.0
LDEQ	Bayou Pirogue near New Canal	1066	SULFATE	MG/L	24	876.125	1598.0	781.50	222.0
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	SULFATE	MG/L	24	908.583	2490.0	855.50	332.0
LDEQ	Drum Bay, Louisiana	1091	SULFATE	MG/L	23	1592.348	2919.0	1492.00	627.0
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	SULFATE	MG/L	23	1591.957	2933.0	1552.00	186.0
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	SULFATE	MG/L	36	831.639	1691.0	751.00	375.0
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	SULFATE	MG/L	24	625.888	2033.0	497.00	1.3
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	SULFATE	MG/L	23	1709.217	8912.0	1251.00	826.0
USGS	Mississippi River at Belle Chasse, LA	7374525	SULFATE	MG/L	105	40.640	76.0	39.00	26.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	SULFATE	MG/L	60	41.438	59.6	39.80	25.0
USGS	Mississippi River at Luling, LA	7374400	SULFATE	MG/L	72	45.944	95.0	44.00	20.0
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	SULFATE	MG/L	12	42.792	59.8	37.85	31.0
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	SULFATE	MG/L	175	49.629	488.0	44.20	9.3
LDEQ	Mississippi River near Belle Chase, Louisiana	52	SULFATE	MG/L	22	45.814	62.6	45.65	30.9
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	SULFATE	MG/L	12	42.075	59.6	36.40	31.0

Summary statistics of sampled water quality

Parameter=SULFATE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	SULFATE	MG/L	89	46.378	87.0	42.50	25.5
LDEQ	Morgan Harbor, Louisiana	1088	SULFATE	MG/L	23	1595.283	3837.0	1405.00	610.5
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	SULFATE	MG/L	24	836.333	1613.0	806.00	203.0
LDEQ	Point Lydia, Louisiana	1090	SULFATE	MG/L	23	1743.435	3182.0	1588.00	483.0
LDEQ	Violet Canal near New Canal	1068	SULFATE	MG/L	24	704.471	2410.0	771.50	38.6

Summary statistics of sampled water quality

Parameter=Selenium

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
USGS	Mississippi River at Luling, LA	7374400	Selenium		59	1.017	2	1	1

Summary statistics of sampled water quality

Parameter=Silvex

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
USGS	Mississippi River at Luling, LA	7374400	Silvex		31	0.033	0.5	0.01	0.01

Summary statistics of sampled water quality

Parameter=TETRACHLOROETHYLENE (PCE)

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	TETRACHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	TETRACHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	TETRACHLOROETHYLENE (PCE)	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	TETRACHLOROETHYLENE (PCE)	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	TETRACHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	TETRACHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	TETRACHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	TETRACHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	TETRACHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	TETRACHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	TETRACHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	TETRACHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	TETRACHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	TETRACHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	TETRACHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	TETRACHLOROETHYLENE (PCE)	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	TETRACHLOROETHYLENE (PCE)	UG/L	112	0.116	1.0	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	TETRACHLOROETHYLENE (PCE)	UG/L	3	0.267	0.5	0.2	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	TETRACHLOROETHYLENE (PCE)	UG/L	81	0.110	0.9	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	TETRACHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	TETRACHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=TETRACHLOROETHYLENE (PCE)

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	TETRACHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	TETRACHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=TOLUENE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	TOLUENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	TOLUENE	UG/L	5	0.320	1.2	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	TOLUENE	UG/L	9	0.200	0.6	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	TOLUENE	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	TOLUENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	TOLUENE	UG/L	7	0.314	0.7	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	TOLUENE	UG/L	5	0.240	0.8	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	TOLUENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	TOLUENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	TOLUENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	TOLUENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	TOLUENE	UG/L	4	0.300	0.9	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	TOLUENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	TOLUENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	TOLUENE	UG/L	4	0.275	0.8	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	TOLUENE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	TOLUENE	UG/L	112	0.115	1.0	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	TOLUENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	TOLUENE	UG/L	81	0.100	0.1	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	TOLUENE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	TOLUENE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=TOLUENE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	TOLUENE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	TOLUENE	UG/L	5	0.300	1.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=TOTAL DISSOLVED SOLIDS

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	TOTAL DISSOLVED SOLIDS	MG/L	23	16134.130	28400	16700.0	7700
LDEQ	Bayou Bashman near Bayou Dupre	1070	TOTAL DISSOLVED SOLIDS	MG/L	24	11441.833	22460	10800.0	3744
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	TOTAL DISSOLVED SOLIDS	MG/L	80	9565.725	19008	9445.0	72
LDEQ	Bayou Bienvenue, Louisiana	1062	TOTAL DISSOLVED SOLIDS	MG/L	35	10299.943	18400	9900.0	5270
LDEQ	Bayou Bienvenue, Louisiana	1063	TOTAL DISSOLVED SOLIDS	MG/L	36	10140.778	18300	9730.0	5100
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	TOTAL DISSOLVED SOLIDS	MG/L	24	10121.000	15030	10010.0	2928
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	TOTAL DISSOLVED SOLIDS	MG/L	24	10436.458	18900	10510.0	2268
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	TOTAL DISSOLVED SOLIDS	MG/L	23	17680.435	23260	17060.0	10960
LDEQ	Bayou Pirogue near New Canal	1066	TOTAL DISSOLVED SOLIDS	MG/L	24	10059.000	17020	9520.0	2830
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	TOTAL DISSOLVED SOLIDS	MG/L	24	10041.917	16820	9955.0	560
LDEQ	Drum Bay, Louisiana	1091	TOTAL DISSOLVED SOLIDS	MG/L	23	17099.130	29000	18420.0	8430
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	TOTAL DISSOLVED SOLIDS	MG/L	23	20131.739	28060	19160.0	13050
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	TOTAL DISSOLVED SOLIDS	MG/L	36	10515.111	18880	10005.0	4724
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	TOTAL DISSOLVED SOLIDS	MG/L	24	7390.917	15700	6279.0	2068
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	TOTAL DISSOLVED SOLIDS	MG/L	23	15823.174	23340	15440.0	11120
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	TOTAL DISSOLVED SOLIDS	MG/L	60	270.617	430	262.0	184
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	TOTAL DISSOLVED SOLIDS	MG/L	12	276.833	342	286.5	174
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	TOTAL DISSOLVED SOLIDS	MG/L	175	270.853	630	266.0	67
LDEQ	Mississippi River near Belle Chase, Louisiana	52	TOTAL DISSOLVED SOLIDS	MG/L	22	282.136	364	294.0	178
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	TOTAL DISSOLVED SOLIDS	MG/L	11	292.273	362	280.0	232
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	TOTAL DISSOLVED SOLIDS	MG/L	89	267.034	406	264.0	144
LDEQ	Morgan Harbor, Louisiana	1088	TOTAL DISSOLVED SOLIDS	MG/L	23	18451.739	36860	18530.0	8710

Summary statistics of sampled water quality

Parameter=TOTAL DISSOLVED SOLIDS

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	TOTAL DISSOLVED SOLIDS	MG/L	24	10023.333	17440	9430.0	2268
LDEQ	Point Lydia, Louisiana	1090	TOTAL DISSOLVED SOLIDS	MG/L	23	19283.478	29600	20560.0	9000
LDEQ	Violet Canal near New Canal	1068	TOTAL DISSOLVED SOLIDS	MG/L	24	7484.250	16640	8545.0	320

Summary statistics of sampled water quality

Parameter=TOTAL ORGANIC CARBON

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	TOTAL ORGANIC CARBON	MG/L	11	6.473	8.40	6.60	5.00
LDEQ	Bayou Bashman near Bayou Dupre	1070	TOTAL ORGANIC CARBON	MG/L	12	9.033	13.30	8.05	6.50
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	TOTAL ORGANIC CARBON	MG/L	60	7.947	13.20	7.40	3.10
LDEQ	Bayou Bienvenue, Louisiana	1062	TOTAL ORGANIC CARBON	MG/L	17	6.982	8.70	6.80	2.00
LDEQ	Bayou Bienvenue, Louisiana	1063	TOTAL ORGANIC CARBON	MG/L	17	7.494	9.30	7.30	5.40
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	TOTAL ORGANIC CARBON	MG/L	12	9.463	16.05	8.80	6.65
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	TOTAL ORGANIC CARBON	MG/L	12	9.917	20.40	7.55	6.00
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	TOTAL ORGANIC CARBON	MG/L	16	8.159	10.30	8.10	6.40
LDEQ	Bayou Pirogue near New Canal	1066	TOTAL ORGANIC CARBON	MG/L	12	13.658	23.90	12.90	6.80
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	TOTAL ORGANIC CARBON	MG/L	12	11.433	21.40	9.50	6.90
LDEQ	Drum Bay, Louisiana	1091	TOTAL ORGANIC CARBON	MG/L	11	6.355	9.40	6.40	4.70
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	TOTAL ORGANIC CARBON	MG/L	16	6.069	7.80	6.15	4.70
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	TOTAL ORGANIC CARBON	MG/L	17	8.135	20.60	7.00	5.30
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	TOTAL ORGANIC CARBON	MG/L	17	7.188	9.40	7.10	5.30
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	TOTAL ORGANIC CARBON	MG/L	16	6.956	10.40	6.80	5.20
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	TOTAL ORGANIC CARBON	MG/L	19	4.737	10.80	4.30	3.50
USGS	Mississippi River at Luling, LA	7374400	TOTAL ORGANIC CARBON	MG/L	72	6.332	28.00	5.60	3.00
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	TOTAL ORGANIC CARBON	MG/L	12	4.908	10.70	4.45	3.50
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	TOTAL ORGANIC CARBON	MG/L	173	5.250	16.20	4.80	2.00
LDEQ	Mississippi River near Belle Chase, Louisiana	52	TOTAL ORGANIC CARBON	MG/L	23	5.187	9.20	5.10	3.20
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	TOTAL ORGANIC CARBON	MG/L	12	4.342	7.00	4.00	3.50
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	TOTAL ORGANIC CARBON	MG/L	88	5.705	16.90	5.05	3.20

Summary statistics of sampled water quality

Parameter=TOTAL ORGANIC CARBON

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Morgan Harbor, Louisiana	1088	TOTAL ORGANIC CARBON	MG/L	11	7.036	9.00	6.60	5.30
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	TOTAL ORGANIC CARBON	MG/L	12	14.808	25.70	13.10	6.00
LDEQ	Point Lydia, Louisiana	1090	TOTAL ORGANIC CARBON	MG/L	11	4.856	7.70	5.40	0.52
LDEQ	Violet Canal near New Canal	1068	TOTAL ORGANIC CARBON	MG/L	12	11.783	28.90	8.45	2.00

Summary statistics of sampled water quality

Parameter=TOTAL SUSPENDED SOLIDS

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	TOTAL SUSPENDED SOLIDS	MG/L	22	28.623	124.0	19.00	0.3
LDEQ	Bayou Bashman near Bayou Dupre	1070	TOTAL SUSPENDED SOLIDS	MG/L	24	23.475	134.0	18.25	4.0
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	TOTAL SUSPENDED SOLIDS	MG/L	80	26.740	260.0	20.25	4.0
LDEQ	Bayou Bienvenue, Louisiana	1062	TOTAL SUSPENDED SOLIDS	MG/L	36	25.144	78.0	21.15	5.0
LDEQ	Bayou Bienvenue, Louisiana	1063	TOTAL SUSPENDED SOLIDS	MG/L	36	22.053	81.0	20.00	5.5
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	TOTAL SUSPENDED SOLIDS	MG/L	24	20.413	46.5	18.25	5.0
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	TOTAL SUSPENDED SOLIDS	MG/L	24	17.975	57.0	13.75	5.0
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	TOTAL SUSPENDED SOLIDS	MG/L	23	29.678	89.0	31.50	5.0
LDEQ	Bayou Pirogue near New Canal	1066	TOTAL SUSPENDED SOLIDS	MG/L	24	24.550	45.8	19.90	7.0
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	TOTAL SUSPENDED SOLIDS	MG/L	24	25.463	117.0	20.65	4.5
LDEQ	Drum Bay, Louisiana	1091	TOTAL SUSPENDED SOLIDS	MG/L	23	29.787	110.0	24.00	6.0
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	TOTAL SUSPENDED SOLIDS	MG/L	23	34.148	81.0	28.00	7.0
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	TOTAL SUSPENDED SOLIDS	MG/L	36	12.711	65.0	9.75	4.0
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	TOTAL SUSPENDED SOLIDS	MG/L	23	18.061	72.0	14.00	4.5
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	TOTAL SUSPENDED SOLIDS	MG/L	23	19.235	40.5	19.30	4.0
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	TOTAL SUSPENDED SOLIDS	MG/L	59	74.388	300.0	58.00	4.5
USGS	Mississippi River at Luling, LA	7374400	TOTAL SUSPENDED SOLIDS	MG/L	65	125.477	460.0	103.00	2.0
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	TOTAL SUSPENDED SOLIDS	MG/L	12	129.250	520.0	91.00	8.0
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	TOTAL SUSPENDED SOLIDS	MG/L	176	74.621	296.0	66.35	3.0
LDEQ	Mississippi River near Belle Chase, Louisiana	52	TOTAL SUSPENDED SOLIDS	MG/L	22	91.409	492.0	66.00	8.0
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	TOTAL SUSPENDED SOLIDS	MG/L	11	113.727	484.0	53.00	7.0
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	TOTAL SUSPENDED SOLIDS	MG/L	89	86.824	800.0	76.00	4.0

Summary statistics of sampled water quality

Parameter=TOTAL SUSPENDED SOLIDS

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Morgan Harbor, Louisiana	1088	TOTAL SUSPENDED SOLIDS	MG/L	23	25.313	133.0	17.00	4.5
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	TOTAL SUSPENDED SOLIDS	MG/L	24	18.821	45.0	16.15	5.5
LDEQ	Point Lydia, Louisiana	1090	TOTAL SUSPENDED SOLIDS	MG/L	23	31.874	90.0	28.00	4.0
LDEQ	Violet Canal near New Canal	1068	TOTAL SUSPENDED SOLIDS	MG/L	24	27.396	106.0	23.75	6.5

Summary statistics of sampled water quality

Parameter=TOXAPHENE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	TOXAPHENE	UG/L	23	1.827	2.0	2.00	0.1
USGS	Mississippi River at Luling, LA	7374400	TOXAPHENE	UG/L	6	0.750	1.0	0.75	0.5
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	TOXAPHENE	UG/L	29	0.624	5.5	0.10	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	TOXAPHENE	UG/L	78	0.100	0.1	0.10	0.1

Summary statistics of sampled water quality

Parameter=TRICHLOROETHYLENE (PCE)

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	TRICHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	TRICHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	TRICHLOROETHYLENE (PCE)	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	TRICHLOROETHYLENE (PCE)	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	TRICHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	TRICHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	TRICHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	TRICHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	TRICHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	TRICHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	TRICHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	TRICHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	TRICHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	TRICHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	TRICHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	TRICHLOROETHYLENE (PCE)	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	TRICHLOROETHYLENE (PCE)	UG/L	112	0.108	1.0	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	TRICHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	TRICHLOROETHYLENE (PCE)	UG/L	81	0.100	0.1	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	TRICHLOROETHYLENE (PCE)	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	TRICHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=TRICHLOROETHYLENE (PCE)

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	TRICHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	TRICHLOROETHYLENE (PCE)	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=TURBIDITY

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	TURBIDITY	NTU	23	13.539	56.0	10.00	1.8
LDEQ	Bayou Bashman near Bayou Dupre	1070	TURBIDITY	NTU	24	11.538	42.2	10.30	3.6
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	TURBIDITY	NTU	80	12.274	140.0	10.00	1.0
LDEQ	Bayou Bienvenue, Louisiana	1062	TURBIDITY	NTU	36	13.436	36.5	12.00	3.2
LDEQ	Bayou Bienvenue, Louisiana	1063	TURBIDITY	NTU	36	11.931	32.0	9.95	3.7
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	TURBIDITY	NTU	24	12.521	26.0	12.25	3.9
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	TURBIDITY	NTU	24	12.071	60.0	9.60	5.0
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	TURBIDITY	NTU	23	13.583	28.0	13.00	3.1
LDEQ	Bayou Pirogue near New Canal	1066	TURBIDITY	NTU	24	13.938	24.4	12.95	5.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	TURBIDITY	NTU	24	13.996	41.3	13.00	3.2
LDEQ	Drum Bay, Louisiana	1091	TURBIDITY	NTU	23	15.722	60.0	12.50	2.0
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	TURBIDITY	NTU	23	15.204	45.0	14.00	2.6
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	TURBIDITY	NTU	36	7.079	19.0	6.70	3.2
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	TURBIDITY	NTU	24	11.758	50.0	8.80	2.8
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	TURBIDITY	NTU	23	9.496	19.0	8.20	2.6
USGS	Mississippi River at Belle Chasse, LA	7374525	TURBIDITY	NTU	59	52.466	120.0	46.00	2.0
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	TURBIDITY	NTU	60	54.267	240.0	45.05	2.1
USGS	Mississippi River at Luling, LA	7374400	TURBIDITY	NTU	67	50.272	180.0	40.00	3.9
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	TURBIDITY	NTU	12	66.983	252.0	51.00	4.8
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	TURBIDITY	NTU	175	45.380	165.0	37.00	2.5
LDEQ	Mississippi River near Belle Chase, Louisiana	52	TURBIDITY	NTU	22	52.164	240.0	37.50	1.6
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	TURBIDITY	NTU	12	59.867	234.0	46.00	4.7

Summary statistics of sampled water quality

Parameter=TURBIDITY

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	TURBIDITY	NTU	88	40.992	118.0	38.50	2.5
LDEQ	Morgan Harbor, Louisiana	1088	TURBIDITY	NTU	23	13.283	58.9	9.70	1.8
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	TURBIDITY	NTU	24	11.542	20.5	10.70	3.3
LDEQ	Point Lydia, Louisiana	1090	TURBIDITY	NTU	23	17.583	60.0	16.60	1.5
LDEQ	Violet Canal near New Canal	1068	TURBIDITY	NTU	24	20.783	100.0	15.65	3.8

Summary statistics of sampled water quality

Parameter=VINYL CHLORIDE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	VINYL CHLORIDE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Bashman near Bayou Dupre	1070	VINYL CHLORIDE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	VINYL CHLORIDE	UG/L	9	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1062	VINYL CHLORIDE	UG/L	2	0.100	0.1	0.1	0.1
LDEQ	Bayou Bienvenue, Louisiana	1063	VINYL CHLORIDE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	VINYL CHLORIDE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	VINYL CHLORIDE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	VINYL CHLORIDE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Pirogue near New Canal	1066	VINYL CHLORIDE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	VINYL CHLORIDE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Drum Bay, Louisiana	1091	VINYL CHLORIDE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	VINYL CHLORIDE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	VINYL CHLORIDE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	VINYL CHLORIDE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	VINYL CHLORIDE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	VINYL CHLORIDE	UG/L	1	0.100	0.1	0.1	0.1
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	VINYL CHLORIDE	UG/L	112	0.112	1.0	0.1	0.1
LDEQ	Mississippi River near Belle Chase, Louisiana	52	VINYL CHLORIDE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	VINYL CHLORIDE	UG/L	81	0.100	0.1	0.1	0.1
LDEQ	Morgan Harbor, Louisiana	1088	VINYL CHLORIDE	UG/L	3	0.100	0.1	0.1	0.1
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	VINYL CHLORIDE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=VINYL CHLORIDE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Point Lydia, Louisiana	1090	VINYL CHLORIDE	UG/L	4	0.100	0.1	0.1	0.1
LDEQ	Violet Canal near New Canal	1068	VINYL CHLORIDE	UG/L	4	0.100	0.1	0.1	0.1

Summary statistics of sampled water quality

Parameter=WATER TEMPERATURE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	WATER TEMPERATURE	C	23	22.642	31.46	25.000	3.43
LDEQ	Bayou Bashman near Bayou Dupre	1070	WATER TEMPERATURE	C	24	22.946	31.82	24.505	9.51
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	WATER TEMPERATURE	C	80	21.440	31.91	22.055	9.73
LDEQ	Bayou Bienvenue, Louisiana	1062	WATER TEMPERATURE	C	36	21.225	31.95	21.390	8.58
LDEQ	Bayou Bienvenue, Louisiana	1063	WATER TEMPERATURE	C	36	21.629	31.47	23.110	7.88
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	WATER TEMPERATURE	C	24	23.028	31.96	24.960	8.85
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	WATER TEMPERATURE	C	24	22.713	31.82	24.775	7.59
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	WATER TEMPERATURE	C	23	23.178	31.86	24.110	3.82
LDEQ	Bayou Pirogue near New Canal	1066	WATER TEMPERATURE	C	24	22.637	31.77	24.160	8.19
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	WATER TEMPERATURE	C	24	22.347	31.13	24.570	8.06
LDEQ	Drum Bay, Louisiana	1091	WATER TEMPERATURE	C	23	22.563	31.05	24.660	3.50
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	WATER TEMPERATURE	C	23	23.007	31.75	23.670	4.35
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	WATER TEMPERATURE	C	36	22.259	31.61	23.200	10.12
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	WATER TEMPERATURE	C	23	22.017	30.80	23.420	8.10
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	WATER TEMPERATURE	C	23	23.068	32.08	22.760	4.96
USGS	Mississippi River at Belle Chasse, LA	7374525	WATER TEMPERATURE	C	111	18.233	32.70	17.500	3.50
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	WATER TEMPERATURE	C	61	18.751	32.15	18.040	4.60
USGS	Mississippi River at Luling, LA	7374400	WATER TEMPERATURE	C	71	18.893	32.00	18.500	4.00
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	WATER TEMPERATURE	C	12	18.708	29.80	17.900	4.60
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	WATER TEMPERATURE	C	169	18.677	32.47	18.510	3.07
LDEQ	Mississippi River near Belle Chase, Louisiana	52	WATER TEMPERATURE	C	23	18.035	30.60	15.900	4.70
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	WATER TEMPERATURE	C	12	18.725	29.80	17.950	4.60

Summary statistics of sampled water quality

Parameter=WATER TEMPERATURE

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	WATER TEMPERATURE	C	90	17.590	30.81	16.650	0.10
LDEQ	Morgan Harbor, Louisiana	1088	WATER TEMPERATURE	C	23	22.699	30.91	24.790	3.15
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	WATER TEMPERATURE	C	24	22.537	31.88	24.525	9.31
LDEQ	Point Lydia, Louisiana	1090	WATER TEMPERATURE	C	23	22.564	30.60	24.450	3.92
LDEQ	Violet Canal near New Canal	1068	WATER TEMPERATURE	C	24	22.120	32.16	23.600	6.71

Summary statistics of sampled water quality

Parameter=ZINC

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	ZINC	UG/L	6	3.110	14.25	0.910	0.20
LDEQ	Bayou Bashman near Bayou Dupre	1070	ZINC	UG/L	6	3.828	14.90	1.805	0.74
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	ZINC	UG/L	9	3.117	4.79	2.850	2.01
LDEQ	Bayou Bienvenue, Louisiana	1062	ZINC	UG/L	9	1.637	3.59	1.470	0.63
LDEQ	Bayou Bienvenue, Louisiana	1063	ZINC	UG/L	9	1.582	2.89	1.650	0.66
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	ZINC	UG/L	6	2.065	5.31	1.545	0.73
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	ZINC	UG/L	6	3.903	16.50	1.590	0.75
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	ZINC	UG/L	6	1.530	3.70	0.915	0.73
LDEQ	Bayou Pirogue near New Canal	1066	ZINC	UG/L	6	1.607	2.37	1.650	0.86
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	ZINC	UG/L	6	1.617	2.08	1.730	0.99
LDEQ	Drum Bay, Louisiana	1091	ZINC	UG/L	6	2.323	9.30	1.125	0.20
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	ZINC	UG/L	6	2.193	3.70	1.805	0.73
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	ZINC	UG/L	9	3.381	15.20	2.070	0.63
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	ZINC	UG/L	6	1.767	3.50	1.620	0.53
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	ZINC	UG/L	6	1.932	3.70	1.780	0.73
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	ZINC	UG/L	16	1.968	5.51	1.585	0.77
USGS	Mississippi River at Luling, LA	7374400	ZINC	UG/L	58	23.310	70.00	20.000	4.00
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	ZINC	UG/L	17	2.094	11.70	1.100	0.48
LDEQ	Morgan Harbor, Louisiana	1088	ZINC	UG/L	6	1.633	3.70	1.100	0.37
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	ZINC	UG/L	6	1.673	2.04	1.830	0.84
LDEQ	Point Lydia, Louisiana	1090	ZINC	UG/L	6	1.338	3.70	0.865	0.16
LDEQ	Violet Canal near New Canal	1068	ZINC	UG/L	6	1.625	2.53	1.570	0.82

Summary statistics of sampled water quality

Parameter=pH

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	pH	SU	23	7.771	8.06	7.860	6.25
LDEQ	Bayou Bashman near Bayou Dupre	1070	pH	SU	24	7.292	7.80	7.345	6.47
LDEQ	Bayou Bienvenue north of Chalmette, Louisiana	307	pH	SU	80	7.487	8.24	7.450	6.84
LDEQ	Bayou Bienvenue, Louisiana	1062	pH	SU	36	7.544	8.01	7.525	6.73
LDEQ	Bayou Bienvenue, Louisiana	1063	pH	SU	36	7.493	8.04	7.535	6.62
LDEQ	Bayou Chaperon near Bayou Bienvenue	1071	pH	SU	24	7.391	7.97	7.315	6.93
LDEQ	Bayou Dupre adjacent to Toca loading dock	1069	pH	SU	24	7.409	7.84	7.420	6.45
LDEQ	Bayou La Loutre near Mississippi River Gulf Outlet	1086	pH	SU	23	7.546	7.99	7.510	7.09
LDEQ	Bayou Pirogue near New Canal	1066	pH	SU	24	7.142	7.64	7.175	6.28
LDEQ	Bayou Terre Beau near New Canal, Louisiana	1067	pH	SU	24	7.180	7.58	7.210	6.32
LDEQ	Drum Bay, Louisiana	1091	pH	SU	23	7.902	8.58	7.890	7.53
LDEQ	Eloi Bay near Mississippi River Gulf Outlet marker	1087	pH	SU	23	7.737	8.18	7.670	7.34
LDEQ	Intracoastal Waterway at New Orleans Public Servic	1064	pH	SU	36	7.520	7.96	7.515	6.39
LDEQ	Lake Borgne near mouth of Blind Rigolets	1074	pH	SU	23	7.362	7.83	7.380	6.91
LDEQ	Mississippi River Gulf Outlet at marker #94	1085	pH	SU	23	7.720	8.36	7.680	7.33
USGS	Mississippi River at Belle Chasse, LA	7374525	pH	SU	110	7.765	8.50	7.800	7.30
LDEQ	Mississippi River at Belle Chasse, Louisiana	51	pH	SU	61	7.588	7.95	7.600	7.20
USGS	Mississippi River at Luling, LA	7374400	pH	SU	72	7.728	8.40	7.700	7.10
LDEQ	Mississippi River at Pointe a la Hache, Louisiana	50	pH	SU	12	7.600	7.90	7.600	7.30
LDEQ	Mississippi River east of Belle Chasse, Louisiana	320	pH	SU	169	7.705	8.40	7.700	7.02
LDEQ	Mississippi River near Belle Chase, Louisiana	52	pH	SU	23	7.737	8.40	7.640	7.10
LDEQ	Mississippi River near Pointe a la Hache, Louisian	49	pH	SU	12	7.600	7.90	7.600	7.30

Summary statistics of sampled water quality

Parameter=pH

Agency	Site Description	Site	Parameter	Units	N	Mean	Maximum	Median	Minimum
LDEQ	Mississippi River west of Point a la Hache, Louisi	322	pH	SU	90	7.663	8.60	7.795	0.10
LDEQ	Morgan Harbor, Louisiana	1088	pH	SU	23	7.735	8.12	7.790	6.94
LDEQ	New Canal near Bayou Pirogue, Louisiana	1065	pH	SU	24	7.124	7.72	7.125	6.30
LDEQ	Point Lydia, Louisiana	1090	pH	SU	23	7.930	8.39	7.910	7.62
LDEQ	Violet Canal near New Canal	1068	pH	SU	24	7.382	7.91	7.425	6.43

APPENDIX C

Percent of each parameter which exceeds various threshold levels

Comparison of sampled values to LDEQ Thresholds

PARAMETER=1,1,1-TRICHLOROETHANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	9	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	111	.	.	.	.	.	.	.	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1062	5	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	5	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=1,1,1-TRICHLOROETHANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	4	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=1,1,2,2-TETRACHLOROETHANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	9	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	111	.	.	.	.	.	.	2.70	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	2.50	.
Bayou Bienvenue, Louisiana	1062	5	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	5	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=1,1,2,2-TETRACHLOROETHANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	4	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=1,1,2-TRICHLOROETHANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	9	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	111	.	.	.	.	.	.	0.90	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1062	5	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	5	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=1,1,2-TRICHLOROETHANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	4	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=1,2-DICHLOROETHANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	2	.	.	.	.	.	.	50.00	50.00
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	10	.	.	.	.	.	.	10.00	.
Mississippi River east of Belle Chasse, Louisiana	320	111	.	.	.	.	.	.	4.50	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	2.50	.
Bayou Bienvenue, Louisiana	1062	6	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	6	.	.	.	.	.	.	25.00	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=1,2-DICHLOROETHANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	4	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=2,4-DICHLOROPHENOL

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	29	.	.	.	.	.	.	.	.
Mississippi River west of Point a la Hache, Louisi	322	77	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=2-CHLOROPHENOL

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	28	.	.	.	.	.	.	.	.
Mississippi River west of Point a la Hache, Louisi	322	51	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=4,4 -DDT

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	14	100.00	21.43	100.00	21.43	100.00	21.43	100.00	100.00
Mississippi River east of Belle Chasse, Louisiana	320	30	100.00	.	100.00	3.33	100.00	3.33	100.00	100.00
Mississippi River west of Point a la Hache, Louisi	322	78	100.00	.	100.00	.	100.00	.	100.00	100.00
Mississippi River at Luling, LA	7374400	6	100.00	.	100.00	.	100.00	.	100.00	100.00

Comparison of sampled values to LDEQ Thresholds

PARAMETER=4,4'-DDD

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	12	100.00	100.00	100.00	100.00	8.33	8.33	.	.
Mississippi River east of Belle Chasse, Louisiana	320	29	100.00	100.00	100.00	100.00	.	.	.	.
Mississippi River west of Point a la Hache, Louisi	322	78	100.00	100.00	100.00	100.00	.	.	.	.
Mississippi River at Luling, LA	7374400	6	100.00	.	100.00	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=4,4'-DDE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	17	.	.	35.29	35.29	35.29	35.29	100.00	100.00
Mississippi River east of Belle Chasse, Louisiana	320	29	.	.	.	.	.	.	100.00	100.00
Mississippi River west of Point a la Hache, Louisi	322	78	.	.	.	.	.	.	100.00	100.00
Mississippi River at Luling, LA	7374400	6	.	.	.	.	.	.	100.00	100.00

Comparison of sampled values to LDEQ Thresholds

PARAMETER=ALDRIN

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	20	.	45.00	.	45.00	.	45.00	100.00	100.00
Mississippi River east of Belle Chasse, Louisiana	320	29	.	.	.	.	.	.	100.00	100.00
Mississippi River west of Point a la Hache, Louisi	322	78	.	.	.	.	.	.	100.00	100.00
Mississippi River at Luling, LA	7374400	6	.	.	.	.	.	.	100.00	100.00

Comparison of sampled values to LDEQ Thresholds

PARAMETER=ARSENIC

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River near Pointe a la Hache, Louisian	49	11	.	.	.	.	.	.	9.09	.
Mississippi River at Pointe a la Hache, Louisiana	50	12	.	.	.	.	.	.	8.33	.
Mississippi River at Belle Chasse, Louisiana	51	29	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	22	.	.	.	.	.	.	4.55	.
Bayou Bienvenue north of Chalmette, Louisiana	307	53	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	116	.	.	.	.	.	.	.	.
Mississippi River west of Point a la Hache, Louisi	322	88	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1062	18	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	18	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	9	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	6	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	6	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=ARSENIC

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Terre Beau near New Canal, Louisiana	1067	6	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	6	.	.	.	.	.	.	.	.
Bayou Dupre adjacent to Toca loading dock	1069	6	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	6	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	6	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	6	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	6	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	6	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	6	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	6	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	6	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	6	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=ARSENIC

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Drum Bay, Louisiana	1091	5	.	.	.	.	.	.	.	.
Mississippi River at Luling, LA	7374400	59	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=BENZIDINE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	100.00	100.00
Mississippi River east of Belle Chasse, Louisiana	320	29	.	.	.	.	.	.	100.00	100.00
Mississippi River west of Point a la Hache, Louisi	322	78	.	.	.	.	.	.	100.00	100.00

Comparison of sampled values to LDEQ Thresholds

PARAMETER=BROMODICHLOROMETHANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	9	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	111	.	.	.	.	.	.	0.90	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1062	5	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	5	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=BROMODICHLOROMETHANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	4	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=BROMOFORM

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	9	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	113	.	.	.	.	.	.	.	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1062	5	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	5	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=BROMOFORM

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	4	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=CARBON TETRACHLORIDE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	9	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	110	.	.	.	.	.	.	.	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1062	6	.	.	.	.	.	.	33.33	33.33
Bayou Bienvenue, Louisiana	1063	6	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=CARBON TETRACHLORIDE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	4	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=CHLORDANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	7	100.00	.	100.00	100.00	100.00	100.00	100.00	100.00
Mississippi River east of Belle Chasse, Louisiana	320	29	100.00	.	100.00	100.00	100.00	100.00	100.00	100.00
Mississippi River west of Point a la Hache, Louisi	322	78	100.00	.	100.00	100.00	100.00	100.00	100.00	100.00
Mississippi River at Luling, LA	7374400	6	100.00	.	100.00	50.00	100.00	50.00	100.00	100.00

Comparison of sampled values to LDEQ Thresholds

PARAMETER=CHLOROFORM

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	9	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	111	.	.	.	.	.	.	.	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1062	5	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	5	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=CHLOROFORM

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	4	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=CIS-1,3-DICHLOROPROPENE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	9	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	112	.	.	.	.	.	.	1.79	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1062	5	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	5	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=CIS-1,3-DICHLOROPROPENE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	4	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=DIBROMOCHLOROMETHANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	9	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	113	.	.	.	.	.	.	4.42	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1062	5	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	5	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=DIBROMOCHLOROMETHANE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	4	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=DIELDRIN

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	15	60.00	26.67	100.00	26.67	100.00	26.67	100.00	100.00
Mississippi River east of Belle Chasse, Louisiana	320	29	100.00	.	100.00	.	100.00	.	100.00	100.00
Mississippi River west of Point a la Hache, Louisi	322	78	100.00	.	100.00	.	100.00	.	100.00	100.00
Mississippi River at Luling, LA	7374400	6	.	.	100.00	.	100.00	.	100.00	100.00

Comparison of sampled values to LDEQ Thresholds

PARAMETER=DISSOLVED OXYGEN

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River near Pointe a la Hache, Louisian	49	12	100.00	100.00	100.00	100.00	100.00	100.00	100.00	.
Mississippi River at Pointe a la Hache, Louisiana	50	12	100.00	100.00	100.00	100.00	100.00	100.00	100.00	.
Mississippi River at Belle Chasse, Louisiana	51	61	98.36	98.36	100.00	100.00	98.36	98.36	100.00	.
Mississippi River near Belle Chase, Louisiana	52	23	100.00	100.00	100.00	100.00	100.00	100.00	100.00	.
Bayou Bienvenue north of Chalmette, Louisiana	307	79	77.22	77.22	87.34	87.34	77.22	77.22	100.00	.
Mississippi River east of Belle Chasse, Louisiana	320	169	98.82	98.82	100.00	100.00	98.82	98.82	100.00	.
Mississippi River west of Point a la Hache, Louisi	322	90	97.78	97.78	98.89	98.89	97.78	97.78	100.00	.
Bayou Bienvenue, Louisiana	1062	72	97.22	97.22	100.00	100.00	97.22	97.22	100.00	.
Bayou Bienvenue, Louisiana	1063	72	91.67	91.67	100.00	100.00	91.67	91.67	100.00	.
Intracoastal Waterway at New Orleans Public Servic	1064	36	94.44	94.44	100.00	100.00	94.44	94.44	100.00	.
New Canal near Bayou Pirogue, Louisiana	1065	23	56.52	56.52	60.87	60.87	56.52	56.52	100.00	.
Bayou Pirogue near New Canal	1066	23	56.52	56.52	65.22	65.22	56.52	56.52	100.00	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=DISSOLVED OXYGEN

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Terre Beau near New Canal, Louisiana	1067	23	56.52	56.52	65.22	65.22	56.52	56.52	100.00	.
Violet Canal near New Canal	1068	23	60.87	60.87	65.22	65.22	60.87	60.87	100.00	.
Bayou Dupre adjacent to Toca loading dock	1069	23	73.91	73.91	78.26	78.26	73.91	73.91	100.00	.
Bayou Bashman near Bayou Dupre	1070	23	60.87	60.87	82.61	82.61	60.87	60.87	100.00	.
Bayou Chaperon near Bayou Bienvenue	1071	23	65.22	65.22	78.26	78.26	65.22	65.22	100.00	.
Lake Borgne near mouth of Blind Rigolets	1074	23	100.00	100.00	100.00	100.00	100.00	100.00	100.00	.
Mississippi River Gulf Outlet at marker #94	1085	23	91.30	91.30	100.00	100.00	91.30	91.30	100.00	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	23	95.65	95.65	100.00	100.00	95.65	95.65	100.00	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	23	91.30	91.30	100.00	100.00	91.30	91.30	100.00	.
Morgan Harbor, Louisiana	1088	23	95.65	95.65	100.00	100.00	95.65	95.65	100.00	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	23	100.00	100.00	100.00	100.00	100.00	100.00	100.00	.
Point Lydia, Louisiana	1090	23	91.30	91.30	100.00	100.00	91.30	91.30	100.00	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=DISSOLVED OXYGEN

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Drum Bay, Louisiana	1091	23	95.65	95.65	100.00	100.00	95.65	95.65	100.00	.
Mississippi River at Luling, LA	7374400	72	98.61	98.61	100.00	100.00	98.61	98.61	100.00	.
Mississippi River at Belle Chasse, LA	7374525	90	98.89	98.89	100.00	100.00	98.89	98.89	100.00	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=ENDOSULFAN I

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	100.00	.	100.00	100.00	100.00	100.00	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=ENDOSULFAN II

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	18	.	.	.	.	.	.	100.00	.
Mississippi River east of Belle Chasse, Louisiana	320	29	.	.	.	.	.	.	100.00	.
Mississippi River west of Point a la Hache, Louisi	322	78	.	.	.	.	.	.	100.00	.
Mississippi River at Luling, LA	7374400	6	.	.	.	.	.	.	100.00	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=ENDRIN

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	13	100.00	53.85	100.00	100.00	100.00	100.00	15.38	15.38
Mississippi River east of Belle Chasse, Louisiana	320	26	100.00	100.00	100.00	100.00	100.00	100.00	.	.
Mississippi River west of Point a la Hache, Louisi	322	78	100.00	100.00	100.00	100.00	100.00	100.00	.	.
Mississippi River at Luling, LA	7374400	5	.	.	100.00	.	100.00	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=ETHYLBENZENE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	9	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	111	.	.	.	.	.	.	.	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1062	5	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	5	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	5	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=ETHYLBENZENE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	5	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=FECAL COLIFORM

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River near Pointe a la Hache, Louisian	49	10	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
Mississippi River at Pointe a la Hache, Louisiana	50	10	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mississippi River at Belle Chasse, Louisiana	51	55	78.18	78.18	78.18	78.18	78.18	78.18	78.18	78.18
Mississippi River near Belle Chase, Louisiana	52	10	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Bayou Bienvenue north of Chalmette, Louisiana	307	75	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Mississippi River east of Belle Chasse, Louisiana	320	174	81.03	81.03	81.03	81.03	81.03	81.03	81.03	81.03
Mississippi River west of Point a la Hache, Louisi	322	85	91.76	91.76	91.76	91.76	91.76	91.76	91.76	91.76
Bayou Bienvenue, Louisiana	1062	68	20.59	20.59	20.59	20.59	20.59	20.59	20.59	20.59
Bayou Bienvenue, Louisiana	1063	68	26.47	26.47	26.47	26.47	26.47	26.47	26.47	26.47
Intracoastal Waterway at New Orleans Public Servic	1064	32	15.63	15.63	15.63	15.63	15.63	15.63	15.63	15.63
New Canal near Bayou Pirogue, Louisiana	1065	24	66.67	66.67	66.67	66.67	66.67	66.67	66.67	66.67
Bayou Pirogue near New Canal	1066	24	70.83	70.83	70.83	70.83	70.83	70.83	70.83	70.83

Comparison of sampled values to LDEQ Thresholds

PARAMETER=FECAL COLIFORM

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Terre Beau near New Canal, Louisiana	1067	24	58.33	58.33	58.33	58.33	58.33	58.33	58.33	58.33
Violet Canal near New Canal	1068	24	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Bayou Dupre adjacent to Toca loading dock	1069	24	20.83	20.83	20.83	20.83	20.83	20.83	20.83	20.83
Bayou Bashman near Bayou Dupre	1070	24	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Bayou Chaperon near Bayou Bienvenue	1071	24	33.33	33.33	33.33	33.33	33.33	33.33	33.33	33.33
Lake Borgne near mouth of Blind Rigolets	1074	23	8.70	8.70	8.70	8.70	8.70	8.70	8.70	8.70
Mississippi River Gulf Outlet at marker #94	1085	24	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33
Bayou La Loutre near Mississippi River Gulf Outlet	1086	24	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33
Eloi Bay near Mississippi River Gulf Outlet marker	1087	24	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	24	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	24	4.17	4.17	4.17	4.17	4.17	4.17	4.17	4.17
Point Lydia, Louisiana	1090	24	4.17	4.17	4.17	4.17	4.17	4.17	4.17	4.17

Comparison of sampled values to LDEQ Thresholds

PARAMETER=FECAL COLIFORM

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Drum Bay, Louisiana	1091	24	.	.	.	.	.	.	.	.
Mississippi River at Belle Chasse, LA	7374525	36	69.44	69.44	69.44	69.44	69.44	69.44	69.44	69.44

Comparison of sampled values to LDEQ Thresholds

PARAMETER=HEPTACHLOR

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	18	100.00	38.89	100.00	44.44	100.00	44.44	100.00	100.00
Mississippi River east of Belle Chasse, Louisiana	320	29	100.00	.	100.00	89.66	100.00	89.66	100.00	100.00
Mississippi River west of Point a la Hache, Louisi	322	78	100.00	.	100.00	100.00	100.00	100.00	100.00	100.00
Mississippi River at Luling, LA	7374400	6	100.00	.	100.00	.	100.00	.	100.00	100.00

Comparison of sampled values to LDEQ Thresholds

PARAMETER=HEXACHLOROBENZENE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	100.00	100.00
Mississippi River east of Belle Chasse, Louisiana	320	29	.	.	.	.	.	.	100.00	100.00
Mississippi River west of Point a la Hache, Louisi	322	78	.	.	.	.	.	.	100.00	100.00

Comparison of sampled values to LDEQ Thresholds

PARAMETER=HEXACHLOROBUTADIENE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	100.00	.
Mississippi River east of Belle Chasse, Louisiana	320	29	.	.	.	.	.	.	100.00	.
Mississippi River west of Point a la Hache, Louisi	322	78	.	.	.	.	.	.	100.00	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=METHYLENE CHLORIDE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	10	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	111	.	.	.	.	.	.	.	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1062	7	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	7	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	5	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=METHYLENE CHLORIDE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	4	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=PCB (multiple forms)

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	11	100.00	90.91	100.00	90.91	100.00	.	100.00	100.00
Mississippi River east of Belle Chasse, Louisiana	320	29	100.00	10.34	100.00	10.34	100.00	.	100.00	100.00
Mississippi River west of Point a la Hache, Louisi	322	78	100.00	.	100.00	.	100.00	.	100.00	100.00
Mississippi River at Luling, LA	7374400	6	100.00	.	100.00	.	100.00	.	100.00	100.00

Comparison of sampled values to LDEQ Thresholds

PARAMETER=PHENOL

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	2	.	.	.	.	.	.	50.00	50.00
Mississippi River east of Belle Chasse, Louisiana	320	29	.	.	.	.	.	.	.	.
Mississippi River west of Point a la Hache, Louisi	322	77	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=TOLUENE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	.	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	.	.
Bayou Bienvenue north of Chalmette, Louisiana	307	9	.	.	.	.	.	.	.	.
Mississippi River east of Belle Chasse, Louisiana	320	111	.	.	.	.	.	.	.	.
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1062	5	.	.	.	.	.	.	.	.
Bayou Bienvenue, Louisiana	1063	5	.	.	.	.	.	.	.	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	.	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	.	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	.	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	.	.
Violet Canal near New Canal	1068	5	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=TOLUENE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	5	.	.	.	.	.	.	.	.
Bayou Bashman near Bayou Dupre	1070	5	.	.	.	.	.	.	.	.
Bayou Chaperon near Bayou Bienvenue	1071	7	.	.	.	.	.	.	.	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	.	.
Mississippi River Gulf Outlet at marker #94	1085	4	.	.	.	.	.	.	.	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	.	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	.	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	.	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	.	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	.	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	.	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=TOXAPHENE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	11	100.00	90.91	100.00	90.91	100.00	90.91	100.00	100.00
Mississippi River east of Belle Chasse, Louisiana	320	29	100.00	10.34	100.00	10.34	100.00	10.34	100.00	100.00
Mississippi River west of Point a la Hache, Louisi	322	78	100.00	.	100.00	.	100.00	.	100.00	100.00
Mississippi River at Luling, LA	7374400	6	100.00	50.00	100.00	100.00	100.00	100.00	100.00	100.00

Comparison of sampled values to LDEQ Thresholds

PARAMETER=VINYL CHLORIDE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River at Belle Chasse, Louisiana	51	1	.	.	.	.	.	.	100.00	.
Mississippi River near Belle Chase, Louisiana	52	3	.	.	.	.	.	.	100.00	.
Bayou Bienvenue north of Chalmette, Louisiana	307	9	.	.	.	.	.	.	100.00	.
Mississippi River east of Belle Chasse, Louisiana	320	111	.	.	.	.	.	.	100.00	1.80
Mississippi River west of Point a la Hache, Louisi	322	80	.	.	.	.	.	.	100.00	.
Bayou Bienvenue, Louisiana	1062	5	.	.	.	.	.	.	100.00	.
Bayou Bienvenue, Louisiana	1063	5	.	.	.	.	.	.	100.00	.
Intracoastal Waterway at New Orleans Public Servic	1064	4	.	.	.	.	.	.	100.00	.
New Canal near Bayou Pirogue, Louisiana	1065	4	.	.	.	.	.	.	100.00	.
Bayou Pirogue near New Canal	1066	3	.	.	.	.	.	.	100.00	.
Bayou Terre Beau near New Canal, Louisiana	1067	4	.	.	.	.	.	.	100.00	.
Violet Canal near New Canal	1068	4	.	.	.	.	.	.	100.00	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=VINYL CHLORIDE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Dupre adjacent to Toca loading dock	1069	4	.	.	.	.	.	.	100.00	.
Bayou Bashman near Bayou Dupre	1070	4	.	.	.	.	.	.	100.00	.
Bayou Chaperon near Bayou Bienvenue	1071	4	.	.	.	.	.	.	100.00	.
Lake Borgne near mouth of Blind Rigolets	1074	4	.	.	.	.	.	.	100.00	.
Mississippi River Gulf Outlet at marker #94	1085	3	.	.	.	.	.	.	100.00	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	3	.	.	.	.	.	.	100.00	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	4	.	.	.	.	.	.	100.00	.
Morgan Harbor, Louisiana	1088	3	.	.	.	.	.	.	100.00	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	3	.	.	.	.	.	.	100.00	.
Point Lydia, Louisiana	1090	4	.	.	.	.	.	.	100.00	.
Drum Bay, Louisiana	1091	4	.	.	.	.	.	.	100.00	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=WATER TEMPERATURE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Mississippi River near Pointe a la Hache, Louisian	49	12	.	.	.	.	.	.	100.00	.
Mississippi River at Pointe a la Hache, Louisiana	50	12	.	.	.	.	.	.	100.00	.
Mississippi River at Belle Chasse, Louisiana	51	61	.	.	.	.	.	.	100.00	.
Mississippi River near Belle Chase, Louisiana	52	23	.	.	.	.	.	.	100.00	.
Bayou Bienvenue north of Chalmette, Louisiana	307	80	.	.	.	.	.	.	100.00	.
Mississippi River east of Belle Chasse, Louisiana	320	169	.	.	.	.	.	.	100.00	.
Mississippi River west of Point a la Hache, Louisi	322	90	.	.	.	.	.	.	100.00	.
Bayou Bienvenue, Louisiana	1062	72	.	.	.	.	.	.	100.00	.
Bayou Bienvenue, Louisiana	1063	72	.	.	.	.	.	.	100.00	.
Intracoastal Waterway at New Orleans Public Servic	1064	36	.	.	.	.	.	.	100.00	.
New Canal near Bayou Pirogue, Louisiana	1065	24	.	.	.	.	.	.	100.00	.
Bayou Pirogue near New Canal	1066	24	.	.	.	.	.	.	100.00	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=WATER TEMPERATURE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Bayou Terre Beau near New Canal, Louisiana	1067	24	.	.	.	.	.	.	100.00	.
Violet Canal near New Canal	1068	24	.	.	.	.	.	.	100.00	.
Bayou Dupre adjacent to Toca loading dock	1069	24	.	.	.	.	.	.	100.00	.
Bayou Bashman near Bayou Dupre	1070	24	.	.	.	.	.	.	100.00	.
Bayou Chaperon near Bayou Bienvenue	1071	24	.	.	.	.	.	.	100.00	.
Lake Borgne near mouth of Blind Rigolets	1074	23	.	.	.	.	.	.	100.00	.
Mississippi River Gulf Outlet at marker #94	1085	23	.	.	.	.	.	.	100.00	.
Bayou La Loutre near Mississippi River Gulf Outlet	1086	23	.	.	.	.	.	.	100.00	.
Eloi Bay near Mississippi River Gulf Outlet marker	1087	23	.	.	.	.	.	.	100.00	.
Morgan Harbor, Louisiana	1088	23	.	.	.	.	.	.	100.00	.
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	23	.	.	.	.	.	.	100.00	.
Point Lydia, Louisiana	1090	23	.	.	.	.	.	.	100.00	.

Comparison of sampled values to LDEQ Thresholds

PARAMETER=WATER TEMPERATURE

Site Description	Site	Number of Samples	Percent Over Freshwater Chronic Threshold	Percent Over Freshwater Acute Threshold	Percent Over Brackish Chronic Threshold	Percent Over Brackish Acute Threshold	Percent Over Marine Chronic Threshold	Percent Over Marine Acute Threshold	Percent Over Drinking Water Supply Threshold	Percent Over Non-Drinking Water Supply Threshold
Drum Bay, Louisiana	1091	23	.	.	.	.	.	.	100.00	.
Mississippi River at Luling, LA	7374400	71	.	.	.	.	.	.	100.00	.
Mississippi River at Belle Chasse, LA	7374525	93	.	.	.	.	.	.	100.00	.

Percent of measured sulfate values in the Mississippi River which exceed the applicable threshold

Site Description	Mississippi River Standard
Mississippi River at Belle Chasse, LA	0.00
Mississippi River at Belle Chasse, Louisiana	0.00
Mississippi River at Luling, LA	0.00
Mississippi River at Pointe a la Hache, Louisiana	0.00
Mississippi River east of Belle Chasse, Louisiana	0.57
Mississippi River near Belle Chase, Louisiana	0.00
Mississippi River near Pointe a la Hache, Louisian	0.00
Mississippi River west of Point a la Hache, Louisi	0.00

Percent of measured turbidity values which exceed various threshold levels

Site Description	Mississippi River Standard	Standard for Estuaries, Lakes, Bays, Bayous, Canals
Bay Boudreau 5.18 nautical miles from Morgan Harbo	.	4.35
Bayou La Loutre near Mississippi River Gulf Outlet	.	0.00
Drum Bay, Louisiana	.	4.35
Eloi Bay near Mississippi River Gulf Outlet marker	.	0.00
Morgan Harbor, Louisiana	.	4.35
Point Lydia, Louisiana	.	4.35
Bayou Bashman near Bayou Dupre	.	0.00
Bayou Bienvenue north of Chalmette, Louisiana	.	1.25
Bayou Chaperon near Bayou Bienvenue	.	0.00
Bayou Dupre adjacent to Toca loading dock	.	4.17
Bayou Pirogue near New Canal	.	0.00
Bayou Terre Beau near New Canal, Louisiana	.	0.00
New Canal near Bayou Pirogue, Louisiana	.	0.00
Violet Canal near New Canal	.	8.33
Lake Borgne near mouth of Blind Rigolets	.	0.00
Bayou Bienvenue, Louisiana	.	0.00
Intracoastal Waterway at New Orleans Public Servic	.	0.00
Mississippi River Gulf Outlet at marker #94	.	0.00
Mississippi River at Belle Chasse, LA	0.00	.
Mississippi River at Belle Chasse, Louisiana	1.67	.
Mississippi River at Luling, LA	1.49	.
Mississippi River at Pointe a la Hache, Louisiana	8.33	.
Mississippi River east of Belle Chasse, Louisiana	1.71	.
Mississippi River near Belle Chase, Louisiana	4.55	.
Mississippi River near Pointe a la Hache, Louisian	8.33	.
Mississippi River west of Point a la Hache, Louisi	0.00	.

Percent of measured total dissolved solids values in the Mississippi River which exceed the applicable threshold

Site Description	Mississippi River Standard
Mississippi River at Belle Chasse, Louisiana	1.67
Mississippi River at Pointe a la Hache, Louisiana	0.00
Mississippi River east of Belle Chasse, Louisiana	2.86
Mississippi River near Belle Chase, Louisiana	0.00
Mississippi River near Pointe a la Hache, Louisian	0.00
Mississippi River west of Point a la Hache, Louisi	1.12

Percent of measured fecal coliform values which exceed various threshold levels

Site Description	Primary Contact	Secondary Contact	Drinking Water Supply	Oyster Propagation
Bay Boudreau 5.18 nautical miles from Morgan Harbo	0.00	0.00	0.00	4.17
Bayou Bashman near Bayou Dupre	0.00	0.00	0.00	25.00
Bayou Bienvenue north of Chalmette, Louisiana	7.89	0.00	0.00	39.47
Bayou Bienvenue, Louisiana	0.00	0.00	0.00	23.19
Bayou Chaperon near Bayou Bienvenue	4.17	0.00	0.00	33.33
Bayou Dupre adjacent to Toca loading dock	0.00	0.00	0.00	20.83
Bayou La Loutre near Mississippi River Gulf Outlet	0.00	0.00	0.00	8.70
Bayou Loutre near Mississippi River Gulf Outlet	0.00	0.00	0.00	0.00
Bayou Pirogue near New Canal	4.17	0.00	0.00	70.83
Bayou Terre Beau near New Canal, Louisiana	4.17	0.00	0.00	58.33
Drum Bay, Louisiana	0.00	0.00	0.00	0.00
Eloi Bay near Mississippi River Gulf Outlet marker	0.00	0.00	0.00	0.00
Intracoastal Waterway at New Orleans Public Servic	0.00	0.00	0.00	15.15
Lake Borgne near mouth of Blind Rigolets	0.00	0.00	0.00	8.70
Mississippi River Gulf Outlet at marker #94	0.00	0.00	0.00	8.33
Mississippi River at Belle Chasse, Louisiana	9.09	1.82	1.82	78.18
Mississippi River at Pointe a la Hache, Louisiana	30.00	0.00	0.00	100.00
Mississippi River east of Belle Chasse, Louisiana	18.39	1.15	1.15	81.03
Mississippi River near Belle Chase, Louisiana	30.00	20.00	20.00	100.00
Mississippi River near Pointe a la Hache, Louisian	40.00	10.00	10.00	80.00
Mississippi River west of Point a la Hache, Louisi	20.00	0.00	0.00	91.76
Morgan Harbor, Louisiana	0.00	0.00	0.00	8.33
New Canal near Bayou Pirogue, Louisiana	8.33	0.00	0.00	66.67
Point Lydia, Louisiana	0.00	0.00	0.00	4.17
Violet Canal near New Canal	4.17	0.00	0.00	50.00
Mississippi River at Belle Chasse, LA	8.33	0.00	0.00	69.44

Percent of sampled arsenic values above the LDEQ criteria

Site Description	Site	Number of Samples	Freshwater Acute	Freshwater Chronic	Marine Water Acute	Marine Water Chronic	Brackish Water Acute	Brackish Water Chronic	Drinking Water Supply
Mississippi River near Pointe a la Hache, Louisian	49	11	0.00	0.00	0.00	0.00	0.00	0.00	9.09
Mississippi River at Pointe a la Hache, Louisiana	50	12	0.00	0.00	0.00	0.00	0.00	0.00	8.33
Mississippi River at Belle Chasse, Louisiana	51	29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi River near Belle Chase, Louisiana	52	22	0.00	0.00	0.00	0.00	0.00	0.00	4.55
Bayou Bienvenue north of Chalmette, Louisiana	307	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi River east of Belle Chasse, Louisiana	320	116	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi River west of Point a la Hache, Louisi	322	88	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Bienvenue, Louisiana	1062	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Bienvenue, Louisiana	1063	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Intracoastal Waterway at New Orleans Public Servic	1064	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
New Canal near Bayou Pirogue, Louisiana	1065	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Pirogue near New Canal	1066	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Terre Beau near New Canal, Louisiana	1067	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Violet Canal near New Canal	1068	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Dupre adjacent to Toca loading dock	1069	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Bashman near Bayou Dupre	1070	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Chaperon near Bayou Bienvenue	1071	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lake Borgne near mouth of Blind Rigolets	1074	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi River Gulf Outlet at marker #94	1085	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou La Loutre near Mississippi River Gulf Outlet	1086	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Loutre near Mississippi River Gulf Outlet	1086	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eloi Bay near Mississippi River Gulf Outlet marker	1087	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Percent of sampled arsenic values above the LDEQ criteria

Site Description	Site	Number of Samples	Freshwater Acute	Freshwater Chronic	Marine Water Acute	Marine Water Chronic	Brackish Water Acute	Brackish Water Chronic	Drinking Water Supply
Morgan Harbor, Louisiana	1088	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Point Lydia, Louisiana	1090	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Drum Bay, Louisiana	1091	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi River at Luling, LA	7374400	59	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Percent of sampled chromium values above the chromium (VI) LDEQ criteria

Site Description	Site	Number of Samples	Freshwater Acute	Freshwater Chronic	Marine Water Acute	Marine Water Chronic	Brackish Water Acute	Brackish Water Chronic	Drinking Water Supply
Mississippi River near Pointe a la Hache, Louisian	49	12	33.33	41.67	0.00	0.00	33.33	41.67	0.00
Mississippi River at Pointe a la Hache, Louisiana	50	12	33.33	50.00	0.00	0.00	33.33	50.00	0.00
Mississippi River at Belle Chasse, Louisiana	51	24	16.67	20.83	0.00	0.00	16.67	20.83	0.00
Mississippi River near Belle Chase, Louisiana	52	22	13.64	22.73	0.00	0.00	13.64	22.73	0.00
Bayou Bienvenue north of Chalmette, Louisiana	307	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi River east of Belle Chasse, Louisiana	320	116	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi River west of Point a la Hache, Louisi	322	88	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Bienvenue, Louisiana	1062	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Bienvenue, Louisiana	1063	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Intracoastal Waterway at New Orleans Public Servic	1064	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
New Canal near Bayou Pirogue, Louisiana	1065	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Pirogue near New Canal	1066	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Terre Beau near New Canal, Louisiana	1067	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Violet Canal near New Canal	1068	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Dupre adjacent to Toca loading dock	1069	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Bashman near Bayou Dupre	1070	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou Chaperon near Bayou Bienvenue	1071	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lake Borgne near mouth of Blind Rigolets	1074	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi River Gulf Outlet at marker #94	1085	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayou La Loutre near Mississippi River Gulf Outlet	1086	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eloi Bay near Mississippi River Gulf Outlet marker	1087	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Morgan Harbor, Louisiana	1088	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Percent of sampled chromium values above the chromium (VI) LDEQ criteria

Site Description	Site	Number of Samples	Freshwater Acute	Freshwater Chronic	Marine Water Acute	Marine Water Chronic	Brackish Water Acute	Brackish Water Chronic	Drinking Water Supply
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Point Lydia, Louisiana	1090	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Drum Bay, Louisiana	1091	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi River at Luling, LA	7374400	59	0.00	5.08	0.00	0.00	0.00	5.08	0.00

Percent of sampled mercury values above the LDEQ criteria

Site Description	Site	Number of Samples	Freshwater Acute	Freshwater Chronic	Marine Water Acute	Marine Water Chronic	Brackish Water Acute	Brackish Water Chronic	Drinking Water Supply
Mississippi River near Pointe a la Hache, Louisian	49	12	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Mississippi River at Pointe a la Hache, Louisiana	50	12	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Mississippi River at Belle Chasse, Louisiana	51	13	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Mississippi River near Belle Chase, Louisiana	52	22	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Bayou Bienvenue north of Chalmette, Louisiana	307	43	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Mississippi River east of Belle Chasse, Louisiana	320	99	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Mississippi River west of Point a la Hache, Louisi	322	87	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Mississippi River Gulf Outlet at marker #94	1085	1	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Bayou La Loutre near Mississippi River Gulf Outlet	1086	1	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Eloi Bay near Mississippi River Gulf Outlet marker	1087	1	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Morgan Harbor, Louisiana	1088	1	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Bay Boudreau 5.18 nautical miles from Morgan Harbo	1089	1	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Point Lydia, Louisiana	1090	1	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Drum Bay, Louisiana	1091	1	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Mississippi River at Luling, LA	7374400	59	0.00	100.00	0.00	100.00	0.00	100.00	0.00

APPENDIX D

Estimated TN, NOx, TP and TSS load to the CWA, LBWA and Lake Borgne under proposed diversion scenarios

Table D1. Estimated TN Loads to CWA, LBWA, and Lake Borgne under proposed diversion scenarios

Month	TN Concentration (mg/L)			TN loading (kg/month)			% Reduction in CWA	% Reduction in LBWA	Total % Reduction
	Input to CWA	Input to LBWA	Input to Lake Borgne	Input to CWA	Input to LBWA	Input to Lake Borgne			
January	2.1	1.4	0.6	158,304	102,897	46,304	35	55	71
February	2.1	1.4	0.6	146,547	95,255	42,865	35	55	71
March	2.1	1.4	0.6	158,759	103,193	46,437	35	55	71
April	2.3	2.2	1.9	166,190	1,106,326	995,694	5	10	10
May	2.5	2.4	2.1	186,217	1,248,774	1,123,896	4	10	10
June	2.6	1.9	0.9	194,011	135,807	67,904	30	50	65
July	2.7	1.9	1.0	206,849	144,794	72,397	30	50	65
August	1.9	1.1	0.5	141,313	84,788	40,698	40	52	71
September	1.4	0.8	0.3	104,676	57,572	23,029	45	60	78
October	1.4	0.8	0.3	103,463	56,904	22,762	45	60	78
November	1.8	1.1	0.5	130,955	78,573	37,715	40	52	71
December	2.0	1.2	0.6	151,325	90,795	43,582	40	52	71

Table D2. Estimated NOx Loads to CWA, LBWA, and Lake Borgne under proposed diversion scenarios

Month	NOx Concentration (mg/L)			NOx loading (kg/month)			% Reduction in CWA	% Reduction in LBWA	Total % Reduction
	Input to CWA	Input to LBWA	Input to Lake Borgne	Input to CWA	Input to LBWA	Input to Lake Borgne			
January	1.2	0.5	0.1	89,506	35,780	7,354	60	79	92
February	1.5	0.7	0.2	103,110	46,121	12,686	55	72	88
March	1.4	0.6	0.2	107,483	46,811	12,080	56	74	89
April	1.6	1.5	1.2	116,861	755,990	610,949	8	19	19
May	2.0	1.9	1.6	155,270	1,011,933	868,969	7	14	14
June	1.7	0.8	0.3	127,579	60,655	19,112	52	68	85
July	2.3	1.2	0.5	176,963	94,316	37,252	47	61	79
August	1.6	0.7	0.2	122,274	56,334	16,576	54	71	86
September	1.3	0.5	0.1	91,757	37,713	8,381	59	78	91
October	0.9	0.3	0.0	67,053	23,020	2,747	66	88	96
November	1.1	0.4	0.1	83,902	33,018	6,480	61	80	92
December	1.4	0.6	0.2	105,511	45,570	11,521	57	75	89

Table D3. Estimated TP Loads to CWA, LBWA, and Lake Borgne under proposed diversion scenarios

Month	TP Concentration (mg/L)			TP loading (kg/month)			% Reduction in CWA	% Reduction in LBWA	Total % Reduction
	Input to CWA	Input to LBWA	Input to Lake Borgne	Input to CWA	Input to LBWA	Input to Lake Borgne			
January	0.23	0.12	0.040	17,522	8,761	3,066	50	65	83
February	0.25	0.13	0.044	17,128	8,564	2,997	50	65	83
March	0.24	0.12	0.041	17,825	8,913	3,119	50	65	83
April	0.22	0.20	0.142	16,002	104,176	72,923	7	30	30
May	0.21	0.20	0.137	15,929	103,698	72,588	7	30	30
June	0.22	0.11	0.039	16,443	8,221	2,877	50	65	83
July	0.24	0.12	0.041	17,901	8,951	3,133	50	65	83
August	0.20	0.10	0.035	15,322	7,661	2,681	50	65	83
September	0.18	0.09	0.031	13,140	6,570	2,299	50	65	83
October	0.19	0.09	0.033	14,109	7,054	2,469	50	65	83
November	0.20	0.10	0.035	14,534	7,267	2,543	50	65	83
December	0.21	0.10	0.036	15,626	7,813	2,734	50	65	83

Table D4. Estimated TSS Loads to CWA, LBWA, and Lake Borgne under proposed diversion scenarios

Month	TSS Concentration (mg/L)			TSS loading (kg/month)			% Reduction in CWA	% Reduction in LBWA	Total % Reduction
	Input to CWA	Input to LBWA	Input to Lake Borgne	Input to CWA	Input to LBWA	Input to Lake Borgne			
January	151	97	39.9	11,426,085	7,389,130	3,029,763	35	59	73
February	148	95	37.4	10,145,973	6,499,690	2,562,197	36	61	75
March	145	92	34.6	11,019,289	6,982,334	2,622,967	37	62	76
April	194	187	174.3	14,252,914	95,941,802	89,545,644	4	7	7
May	111	103	90.8	8,398,896	54,836,058	48,226,695	7	12	12
June	155	102	44.7	11,407,205	7,500,474	3,281,732	34	56	71
July	149	96	38.3	11,301,991	7,265,036	2,905,668	36	60	74
August	129	76	18.6	9,810,204	5,773,249	1,413,881	41	76	86
September	69	15	0.0	5,034,365	1,127,634	-	78	100	100
October	159	105	47.9	12,027,973	7,991,018	3,631,651	34	55	70
November	88	34.5	0.0	6,441,327	2,534,596	3,351	61	100	100
December	160	107	49.7	12,168,907	8,131,951	3,772,584	33	54	69

APPENDIX E

Estimated TN, NOx, TP and TSS load to the CWA, LBWA and Lake Borgne under the proposed diversion scenarios

Table E1. Estimated change in salinity, TN, chlorophyll-a, TP and TSS under FWOP and FWP scenarios in Lake Borgne

Location	Month	Salinity (FWOP)	Salinity (FWP)	% H20 LB	% H20 MR	Temp Avg. LB	Temp MR via CW & LBWA	Temp (FWOP)	Temp (FWP)	TN Avg. LB	TN MR via CW & LBWA	TN (FWOP)	TN (FWP)	Chl-a (FWOP)	Chl-a (FWP)	TP Avg. LB	TP MR via CW & LBWA	TP (FWOP)	TP (FWP)	TSS Avg. LB	TSS MR via CW & LBWA	TSS (FWOP)	TSS (FWP)
Zone 2	**Jan**	6.22	4.70	0.76	0.24	12.65	6.73	12.65	12.65	0.405	0.60	0.41	0.45	4.11	4.88	0.060	0.040	0.060	0.055	10.3	39.9	10.3	17.5
Zone 2	**Feb**	5.08	3.76	0.74	0.26	14.27	7.98	14.27	14.27	0.605	0.60	0.61	0.60	5.61	6.20	0.060	0.044	0.060	0.056	17.9	37.4	17.9	22.9
Zone 2	**Mar**	4.15	3.05	0.74	0.26	17.42	10.71	17.42	17.42	0.397	0.60	0.40	0.45	6.79	7.39	0.070	0.041	0.070	0.062	35.0	34.6	35.0	34.9
Zone 2	**Apr**	3.64	2.28	0.63	0.37	20.92	15.74	20.92	20.92	0.415	1.94	0.42	0.98	8.35	10.07	0.090	0.140	0.090	0.109	27.3	174.3	27.3	82.2
Zone 2	**May**	3.63	1.64	0.45	0.55	25.76	21.26	25.76	25.76	0.385	2.12	0.39	1.34	10.09	12.83	0.080	0.140	0.080	0.113	13.3	90.8	13.3	55.9
Zone 2	**Jun**	4.00	1.90	0.48	0.52	28.36	26.14	28.36	28.36	0.575	0.90	0.58	0.75	11.26	12.53	0.100	0.039	0.100	0.068	14.0	44.7	14.0	30.1
Zone 2	**Jul**	4.38	2.57	0.59	0.41	29.09	28.64	29.09	29.09	0.510	1.00	0.51	0.71	11.23	12.43	0.080	0.041	0.080	0.064	8.3	38.3	8.3	20.6
Zone 2	**Aug**	5.04	3.33	0.66	0.34	29.27	29.49	29.27	29.27	0.540	0.50	0.54	0.53	11.06	11.80	0.075	0.035	0.075	0.061	10.8	18.6	10.8	13.4
Zone 2	**Sep**	5.70	4.01	0.70	0.30	27.26	27.58	27.26	27.26	0.660	0.30	0.66	0.55	10.25	10.80	0.070	0.031	0.070	0.058	20.0	0.0	20.0	14.1
Zone 2	**Oct**	6.38	4.66	0.73	0.27	22.68	21.60	22.68	22.68	0.770	0.30	0.77	0.64	8.46	8.99	0.130	0.033	0.130	0.104	17.5	47.9	17.5	25.7
Zone 2	**Nov**	6.82	5.07	0.74	0.26	17.66	15.54	17.66	17.66	0.360	0.50	0.36	0.40	5.61	6.46	0.120	0.035	0.120	0.098	20.5	0.0	20.5	15.2
Zone 2	**Dec**	6.71	4.99	0.74	0.26	13.19	10.62	13.19	13.19	0.445	0.60	0.45	0.48	4.17	5.02	0.060	0.036	0.060	0.054	4.3	49.7	4.3	15.9

Results for Zone 2 (SW Lake Borgne)

Salinity data from UNO model runs for Future w/out Project (FWOP) and Future w/ project (FWP)

FWOP replicates current condition with closure of MRGO. FWP replicates 7,000 cfs diversion of MR through Central Wetlands in April and May; 1,000 cfs in other months

Additional treatment via 11,209 acres between MRGO and Lake Borgne

LB = Lake Borgne. Avg. LB = average data from all sources (LADEQ, LDWF) for each month

MR = Mississippi River, average of data from USGS for stations close to Violet from 1990 to present. MR through CW = MR water quality after processing through the Central Wetlands

Nutrient and TSS removal rates calculated as in spreasheet for potential wetland configuration of Central Wetlands, and using algorithms derived from Mitsch et al. (2001), Richardson and Nichols (1985), Cable et al. (2007), and Wheelock (2003)

Chl-a = chlorophyll-a (ug/liter). Predicted Chl-a from empirically-derived equation from Breton Sound Station 18.

Chl-a = 1.42519 + (1.9377*TN) + (0.370629*Temp) - (0.448084*salinity)

Table E2. Estimated change in salinity, TN, chlorophyll-a, TP and TSS under FWOP and FWP scenarios in the Biloxi Marsh

Location	Month	Salinity (FWOP)	Salinity (FWP)	% H20 LB	% H20 MR	Temp Avg. LB	Temp MR via CW & LBWA	Temp (FWOP)	Temp (FWP)	TN Avg. LB	TN MR via CW & LBWA	TN (FWOP)	TN (FWP)	Chl-a (FWOP)	Chl-a (FWP)	TP Avg. LB	TP MR via CW & LBWA	TP (FWOP)	TP (FWP)	TSS Avg. LB	TSS MR via CW & LBWA	TSS (FWOP)	TSS (FWP)
Zone 998	Jan	10.76	10.42	0.97	0.03	12.65	6.73	12.65	12.65	0.405	0.60	0.41	0.41	2.07	2.24	0.060	0.040	0.060	0.059	10.3	39.9	10.3	11.2
Zone 998	Feb	7.84	7.61	0.97	0.03	14.27	7.98	14.27	14.27	0.605	0.60	0.61	0.60	4.37	4.48	0.060	0.044	0.060	0.060	17.9	37.4	17.9	18.5
Zone 998	Mar	7.04	6.86	0.98	0.02	17.42	10.71	17.42	17.42	0.397	0.60	0.40	0.40	5.50	5.59	0.070	0.041	0.070	0.069	35.0	34.6	35.0	35.0
Zone 998	Apr	7.44	7.12	0.96	0.04	20.92	15.74	20.92	20.92	0.415	1.94	0.42	0.48	6.65	6.92	0.090	0.140	0.090	0.092	27.3	174.3	27.3	33.6
Zone 998	May	8.97	8.31	0.93	0.07	25.76	21.26	25.76	25.76	0.385	2.12	0.39	0.51	7.70	8.24	0.080	0.140	0.080	0.084	13.3	90.8	13.3	18.9
Zone 998	Jun	10.05	9.41	0.94	0.06	28.36	26.14	28.36	28.36	0.575	0.90	0.58	0.60	8.35	8.87	0.100	0.039	0.100	0.096	14.0	44.7	14.0	15.9
Zone 998	Jul	11.08	10.58	0.96	0.04	29.09	28.64	29.09	29.09	0.510	1.00	0.51	0.53	8.23	8.50	0.080	0.041	0.080	0.078	8.3	38.3	8.3	9.6
Zone 998	Aug	13.18	12.68	0.96	0.04	29.27	29.49	29.27	29.27	0.540	0.50	0.54	0.54	7.41	7.64	0.075	0.035	0.075	0.073	10.8	18.6	10.8	11.1
Zone 998	Sep	14.37	13.85	0.96	0.04	27.26	27.58	27.26	27.26	0.660	0.30	0.66	0.65	6.37	6.58	0.070	0.031	0.070	0.069	20.0	0.0	20.0	19.3
Zone 998	Oct	15.72	15.17	0.96	0.04	22.68	21.60	22.68	22.68	0.770	0.30	0.77	0.75	4.28	4.49	0.130	0.033	0.130	0.127	17.5	47.9	17.5	18.6
Zone 998	Nov	15.62	15.07	0.96	0.04	17.66	15.54	17.66	17.66	0.360	0.50	0.36	0.36	1.67	1.93	0.120	0.035	0.120	0.117	20.5	0.0	20.5	19.8
Zone 998	Dec	13.86	13.38	0.97	0.03	13.19	10.62	13.19	13.19	0.445	0.60	0.45	0.45	0.96	1.19	0.060	0.036	0.060	0.059	4.3	49.7	4.3	5.8

Results for Zone 998 (weighted average for Biloxi Marsh)

Salinity data from UNO model runs for Future w/out Project (FWOP) and Future w/ project (FWP)

FWOP replicates current condition with closure of MRGO. FWP replicates 7,000 cfs diversion of MR through Central Wetlands in April and May, 1,000 cfs in other months

Additional treatment via 11,209 acres between MRGO and Lake Borgne

LB = Lake Borgne. Avg. LB = average data from all sources (LADEQ, LDWF) for each month

MR = Mississippi River, average of data from USGS for stations close to Violet from 1990 to present. MR through CW = MR water quality after processing through the Central Wetlands

Nutrient and TSS removal rates calculated as in spreasheet for potential wetland configuration of Central Wetlands, and using algorithms derived from Mitsch et al. (2001), Richardson and Nichols (1985), Cable et al. (2007), and Wheelock (2003)

Chl-a = chlorophyll-a (ug/liter). Predicted Chl-a from empirically-derived equation from Breton Sound Station 18.

Chl-a = 1.42519 + (1.9377*TN) + (0.370629*Temp) - (0.448084*salinity)

Table E3. Estimated change in salinity, TN, chlorophyll-a, TP and TSS under FWOP and FWP scenarios in Mississippi Sound

Location	Month	Salinity (FWOP)	Salinity (FWP)	% H20 LB	% H20 MR	Temp Avg. LB	Temp MR via CW & LBWA	Temp (FWOP)	Temp (FWP)	TN Avg. LB	TN MR via CW & LBWA	TN (FWOP)	TN (FWP)	Chl-a (FWOP)	Chl-a (FWP)	TP Avg. LB	TP MR via CW & LBWA	TP (FWOP)	TP (FWP)	TSS Avg. LB	TSS MR via CW & LBWA	TSS (FWOP)	TSS (FWP)
Zone 14	Jan	17.00	16.74	0.99	0.01	12.65	6.73	12.65	12.65	0.405	0.60	0.41	0.41	-0.72	-0.60	0.060	0.040	0.060	0.060	10.3	39.9	10.3	10.7
Zone 14	Feb	13.89	13.68	0.98	0.02	14.27	7.98	14.27	14.27	0.605	0.60	0.61	0.60	1.66	1.76	0.060	0.044	0.060	0.060	17.9	37.4	17.9	18.2
Zone 14	Mar	13.47	13.27	0.99	0.01	17.42	10.71	17.42	17.42	0.397	0.60	0.40	0.40	2.62	2.71	0.070	0.041	0.070	0.070	35.0	34.6	35.0	35.0
Zone 14	Apr	15.30	14.63	0.96	0.04	20.92	15.74	20.92	20.92	0.415	1.94	0.42	0.48	3.13	3.55	0.090	0.140	0.090	0.092	27.3	174.3	27.3	33.7
Zone 14	May	17.13	16.31	0.95	0.05	25.76	21.26	25.76	25.76	0.385	2.12	0.39	0.47	4.04	4.57	0.080	0.140	0.080	0.083	13.3	90.8	13.3	17.0
Zone 14	Jun	18.88	18.46	0.98	0.02	28.36	26.14	28.36	28.36	0.575	0.90	0.58	0.58	4.59	4.79	0.100	0.039	0.100	0.099	14.0	44.7	14.0	14.7
Zone 14	Jul	19.63	19.35	0.99	0.01	29.09	28.64	29.09	29.09	0.510	1.00	0.51	0.52	4.40	4.54	0.080	0.041	0.080	0.079	8.3	38.3	8.3	8.7
Zone 14	Aug	20.99	20.73	0.99	0.01	29.27	29.49	29.27	29.27	0.540	0.50	0.54	0.54	3.97	4.03	0.075	0.035	0.075	0.075	10.8	18.6	10.8	10.8
Zone 14	Sep	21.59	21.30	0.99	0.01	27.26	27.58	27.26	27.26	0.660	0.30	0.66	0.66	3.13	3.26	0.070	0.031	0.070	0.069	20.0	0.0	20.0	19.7
Zone 14	Oct	22.44	22.13	0.99	0.01	22.68	21.60	22.68	22.68	0.770	0.30	0.77	0.76	1.27	1.40	0.130	0.033	0.130	0.129	17.5	47.9	17.5	17.8
Zone 14	Nov	22.21	21.88	0.98	0.02	17.66	15.54	17.66	17.66	0.360	0.50	0.36	0.36	-1.28	-1.13	0.120	0.035	0.120	0.119	20.5	0.0	20.5	20.2
Zone 14	Dec	20.57	20.25	0.98	0.02	13.19	10.62	13.19	13.19	0.445	0.60	0.45	0.45	-2.04	-1.89	0.060	0.036	0.060	0.060	4.3	49.7	4.3	5.0

Results for Zone 14 (W. Mississippi Sound, south of St. Louis Bay)
Salinity data from UNO model runs for Future w/out Project (FWOP) and Future w/ project (FWP)
FWOP replicates current condition with closure of MRGO. FWP replicates 7,000 cfs diversion of MR through Central Wetlands in April and May; 1,000 cfs in other months
Additional treatment via 11,209 acres between MRGO and Lake Borgne
LB = Lake Borgne. Avg. LB = average data from all sources (LADEQ, LDWF) for each month
MR = Mississippi River, average of data from USGS for stations close to Violet from 1990 to present. MR through CW = MR water quality after processing through the Central Wetlands
Nutrient and TSS removal rates calculated as in spreasheet for potential wetland configuration of Central Wetlands, and using algorithms derived from Mitsch et al. (2001), Richardson and Nichols (1985), Cable et al. (2007), and Wheelock (2003)
Chl-a = chlorophyll-a (ug/liter). Predicted Chl-a from empirically-derived equation from Breton Sound Station 18.
Chl-a = 1.42519 + (1.9377*TN) + (0.370629*Temp) - (0.448084*salinity)

ANNEX 4

INDIVIDUAL SOIL BORING LOGS

APPENDIX ED-F-1

INDIVIDUAL SOIL BORING LOGS

UNIFIED SOIL CLASSIFICATION

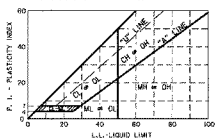
MAJOR DIVISION		TYPE	LETTER SYMBOL	TYPICAL NAMES
COARSE - GRAINED SOILS More than half of material is larger than No. 200 sieve size.	GRAVELS More than half of coarse fraction is larger than No. 4 sieve size.	GRAVELS WITH FINES (Appreciable amount of fines)	GW	GRAVEL, Well Graded, gravel-sand mixtures, little or no fines
			GP	GRAVEL, Poorly Graded, gravel-sand mixtures, little or no fines
			GM	SILTY GRAVEL, gravel-sand-silt mixtures
			GC	CLAYEY GRAVEL, gravel-sand-clay mixtures
	SANDS 50% or more of coarse fraction passes No. 4 sieve	CLEAN SANDS (Little or no fines)	SW	SAND, Well-Graded, gravelly sands
			SP	SAND, Poorly-Graded, gravelly sands
		SANDS WITH FINES (Appreciable amount of fines)	SM	SILTY SAND, sand-silt mixtures
			SC	CLAYEY SAND, sand-clay mixtures
FINE - GRAINED SOILS More than half of material is smaller than No. 200 sieve size.	SILTS AND CLAYS Liquid limit less than 50		ML	SILT & very fine sand, silty or clayey fine sand or clayey silt with slight plasticity
			CL	LEAN CLAY, Sandy Clay, Silty Clay, of low to medium plasticity
			OL	ORGANIC SILTS, and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid limit greater than 50		MH	SILT, fine sandy or silty soil with high plasticity
			CH	FAT CLAY, inorganic clay of high plasticity
			OH	ORGANIC CLAYS of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS			Pt	PEAT, and other highly organic soil
WOOD			Wd	WOOD
SHELLS			Sl	SHELLS
NO SAMPLE			NS	No Sample Retrieved

NOTE: Soils possessing characteristics of two groups are designated by combinations of group symbols.

DESCRIPTIVE SYMBOLS

COLOR	
COLOR	SYMBOL
TAN	T
YELLOW	Y
RED	R
BLACK	Bl
GRAY	Gr
LIGHT GRAY	lGr
DARK GRAY	dGr
BROWN	Br
LIGHT BROWN	lBr
DARK BROWN	dBr
BROWNISH-GRAY	brGr
GRAYISH-BROWN	gyBr
GREENISH-GRAY	grGr
GRAYISH-GREEN	gyGn
GREEN	Gn
BLUE	Bl
BLUE-GREEN	BlGn
WHITE	Wh
MOTTLED	Mo*

CONSISTENCY FOR COHESIVE SOILS		
CONSISTENCY	COHESION IN LBS./SQ.FT. FROM UNCONFINED COMPRESSION TEST	SYMBOL
VERY SOFT	< 250	vSo
SOFT	250-500	So
MEDIUM	500-1000	M
STIFF	1000-2000	St
VERY STIFF	2000-4000	vSt
HARD	> 4000	H



PLASTICITY CHART

For classification of fine-grained soils in accordance with ASTM D 2487

MODIFICATIONS	
MODIFICATION	SYMBOL
Traces	Tr
Fine	f
Medium	M
Coarse	C
Concretions	cc
Rootlets	rt
Lignite fragments	lg
Shale fragments	sh
Sandstone fragments	sds
Shell fragments	slf
Organic matter	O
Clay strata or lenses	CS
Silt strata or lenses	SiS
Sand strata or lenses	SS
Sandy	S
Gravelly	G
Boulders	B
Slickensides	SL
Wood	Wd
Oxidized	Ox

NOTES:

FIGURES TO LEFT OF BORING UNDER COLUMN " W OR D_{10}"

Are natural water contents in percent dry weight

When underlined denotes D_{10} size in mm*

FIGURES TO LEFT OF BORING UNDER COLUMNS " LL" AND " PL"

Are liquid and plastic limits, respectively

SYMBOLS TO LEFT OF BORING

▽	Ground-water surface and date observed
(C)	Denotes location of consolidation test**
(S)	Denotes location of consolidated-drained direct shear test**
(R)	Denotes location of consolidated-undrained triaxial compression test**
(U)	Denotes location of unconsolidated-undrained triaxial compression test**
(T)	Denotes location of sample subjected to consolidation test and each of the above three types of shear test**
FW	Denotes free water encountered in boring or sample

FIGURES TO RIGHT OF BORING

Are values of cohesion in lbs./sq.ft. from unconfined compression tests

In parenthesis are driving resistances in blows per foot determined with a standard split spoon sampler (1 3/8" I.D., 2" O.D.) and a 140 lb. driving hammer with a 30" drop

Where underlined with a solid line denotes laboratory permeability in centimeters per second of undisturbed sample

Where underlined with a dashed line denotes laboratory permeability in centimeters per second of sample remolded to the estimated natural void ratio

*The D_{10} size of a soil is the grain diameter in millimeters of which 10% of the soil is finer, and 90% coarser than D_{10}.
(Where a 0999 is shown, a D_{10} size does not exist.)

**Results of these tests are available for inspection in the U.S. Army Engineer District Office, if these symbols appear beside the boring logs on the drawings.

TYPICAL NOTES:

1. While the borings are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local variations characteristic of the subsurface materials of the region are anticipated and, if encountered, such variations will not be considered as differing materially within the purview of the contract clause entitled "Differing Site Conditions".
2. Ground-water elevations shown on the boring logs represent ground-water surfaces encountered in such borings on the dates shown. Absence of water surface data on certain borings indicates that no ground-water data are available from the boring but does not necessarily mean that ground-water will not be encountered at the locations or within the vertical reaches of such borings.
3. Consistency of cohesive soils shown on the boring logs is based on driller's log and visual examination and is approximate, except within those vertical reaches of the borings where shear strengths from unconfined compression tests are shown.
4. Unless otherwise noted:
   a. Undisturbed borings, indicated by the letter "U", are taken with a 5" I.D. Piston Type Sampler.
   b. General type borings are taken with a 1 7/8" I.D. Tube Sampler and/or a 1 3/8 I.D. Split Spoon Sampler.

Safety is a Part of Your Contract

REVISED 23 JUNE 92

SOIL BORING LEGEND

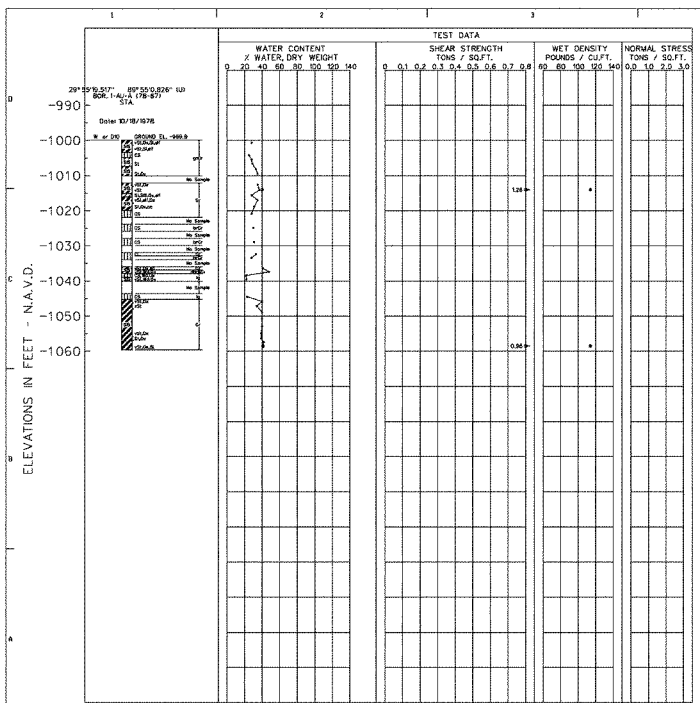
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA

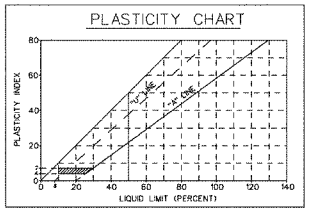
DESIGNED BY: X	PLOT SCALE: X	PLOT DATE: X	CADD FILE: BORLEGN.DGN
DRAWN BY: X			FILE NO. X
CHECKED BY: X	DATE: X		

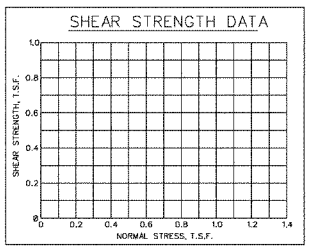
PLATE A

973

Bor Legend.dgn 2/28/2012 10:50:27 AM







TABULAR TEST DATA

ENVELOPE		TYPE	STRENGTH		CLASS
NO.	EL.		ϕ	c - 15F	

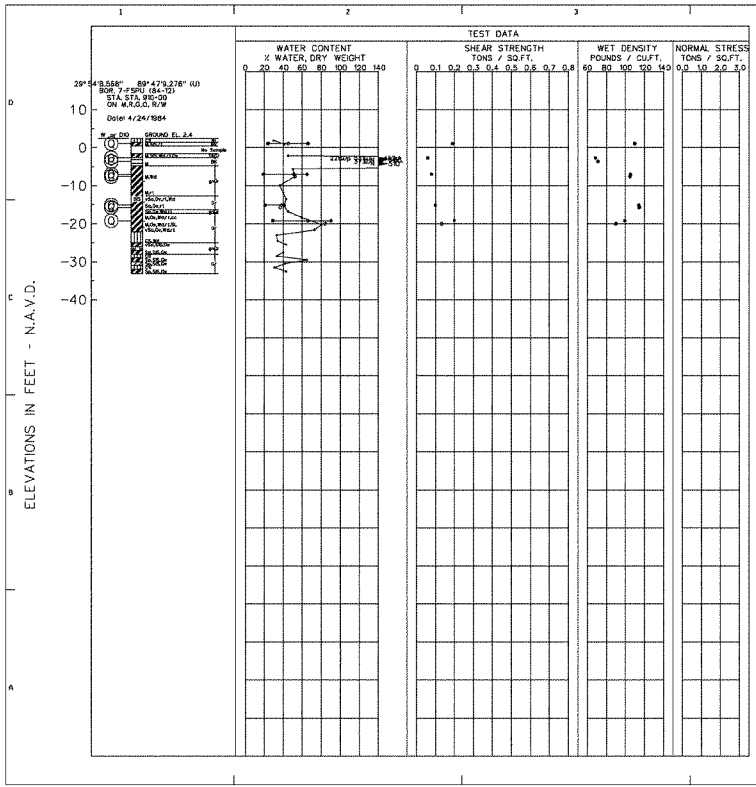
NOTES

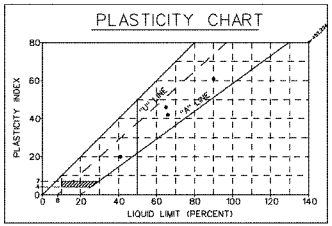
- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (O) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ω_P —— ω_N —— ω_L ATTERBERG LIMITS

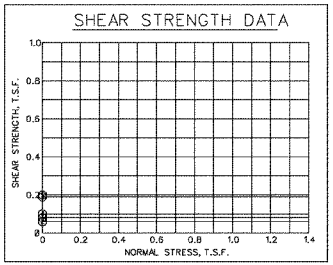
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH c - TSF	CLASS
1	-1.1	Q	0.0	0.190	CH
2	-2.7	Q	0.0	0.080	CH
3	-7.0	Q	0.0	0.080	CH
4	-13.1	Q	0.0	0.100	CL
5	-19.2	Q	0.0	0.200	CH
6	-3.6	C	0.0	0.000	PT
7	-7.6	C	0.0	0.000	CH
8	-15.7	C	0.0	0.000	ML

NOTES

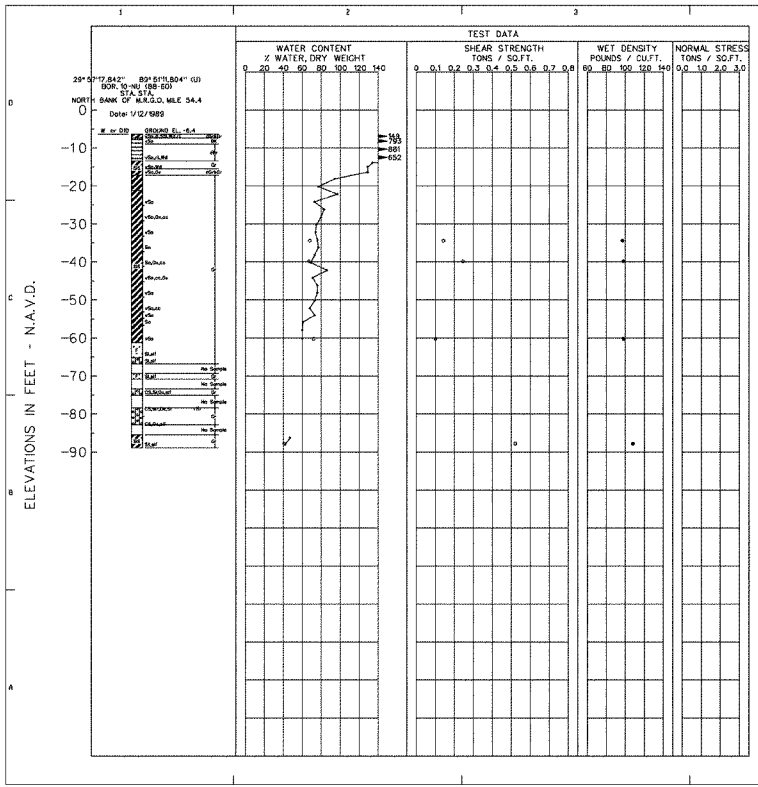
- o - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- □ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ω_P ω_N ω_L ATTERBERG LIMITS

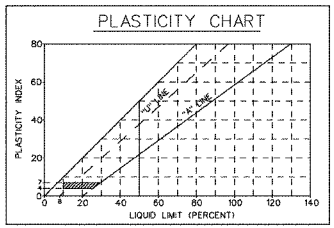
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

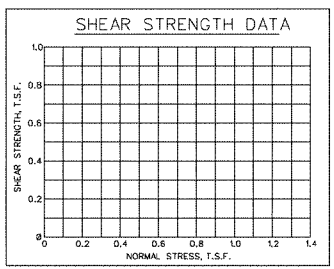
US ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH Φ	STRENGTH C - TSF	CLASS

NOTES

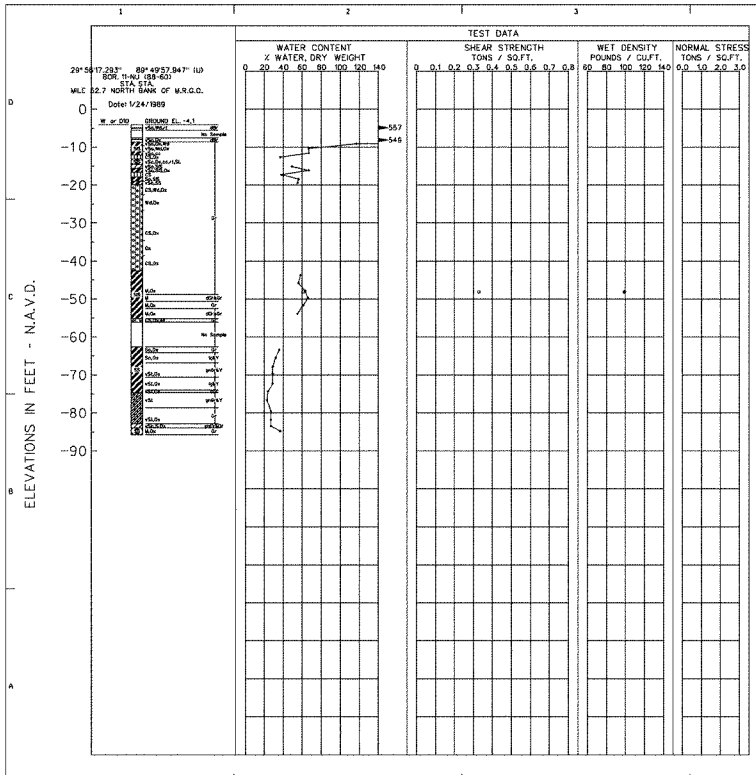
- o - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ◻ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ω_P ω_N ω_L - ATTERBERG LIMITS

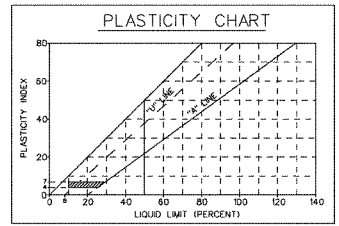
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

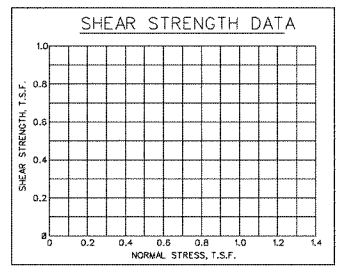
US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH Φ	STRENGTH c - TSF	CLASS

NOTES

- o - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- □ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- (L)P ●——○ (L)N ○——● (L)L ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

US ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT

DATE | REVISION | DRAWN | CHKD | APPD | REVISION

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER

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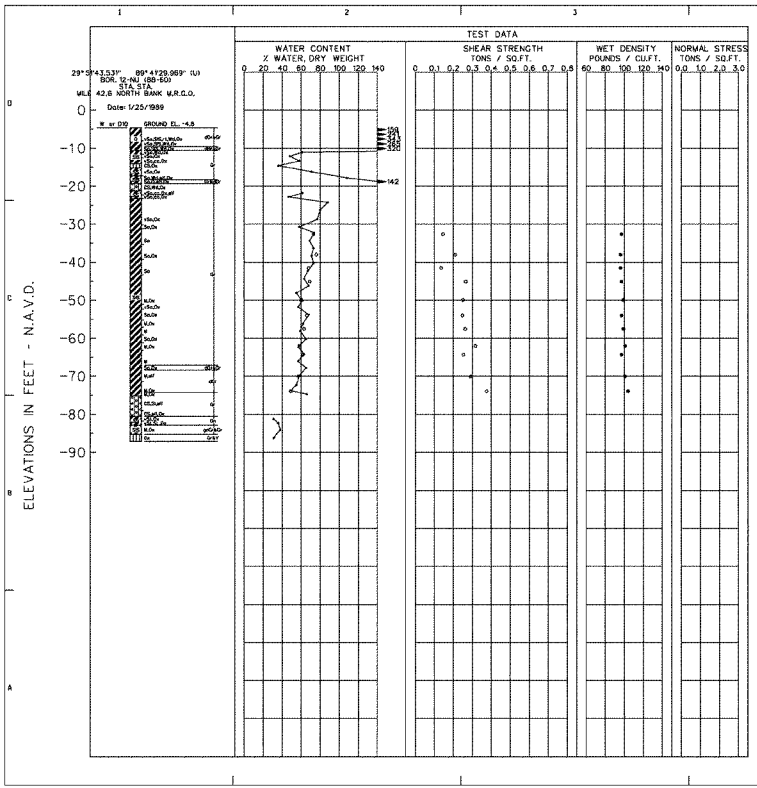

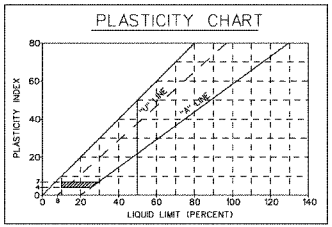

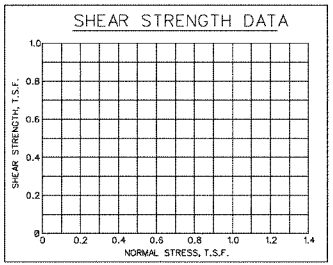

TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH Φ	STRENGTH c - PSF	CLASS

NOTES

- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ω_P ω_N ω_L - ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS MISSISSIPPI VALLEY DIVISION

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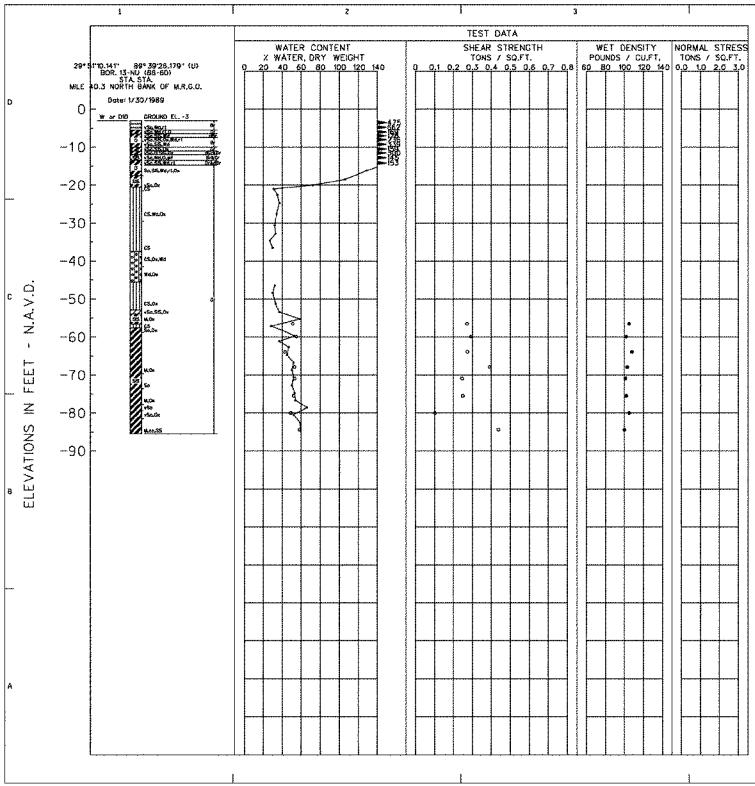
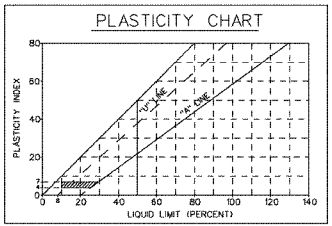
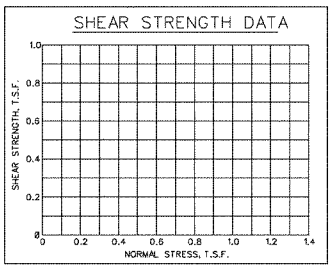






TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH Φ	STRENGTH c - TSF	CLASS

NOTES

- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- □ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

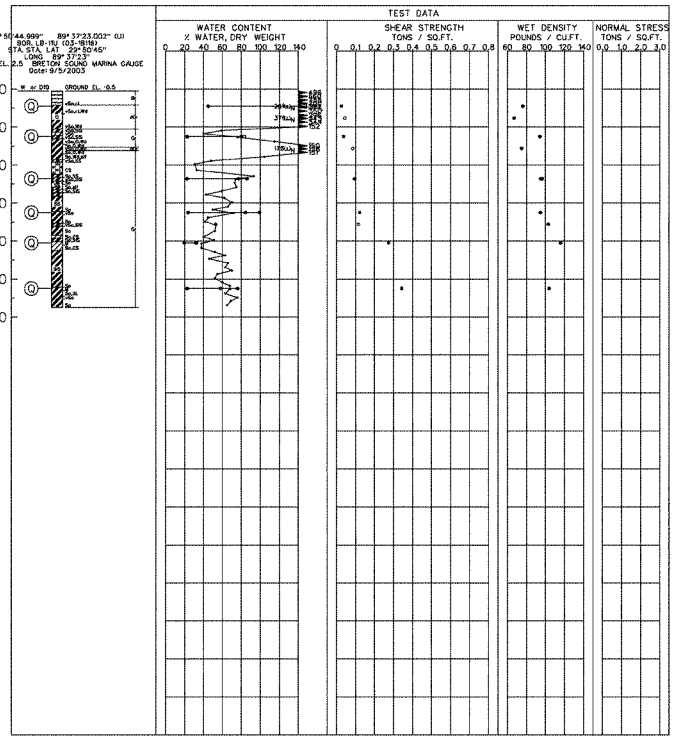
(L)P (L)N (L)L ATTERBERG LIMITS

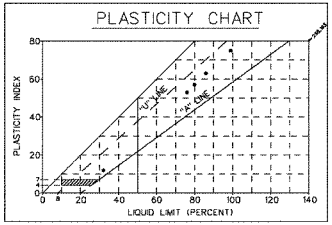
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

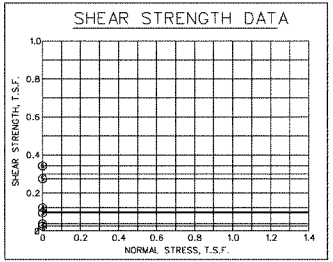
US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH c - TSF	CLASS
1	-4.5	Q	0.0	0.026	CH
2	-12.5	Q	0.0	0.038	CH
3	-23.6	Q	0.0	0.036	CH
4	-32.5	Q	0.0	0.122	CH
5	-40.5	Q	0.0	0.275	CL
6	-52.5	Q	0.0	0.343	CH

NOTES

- o - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ωP ωN ωL - ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER

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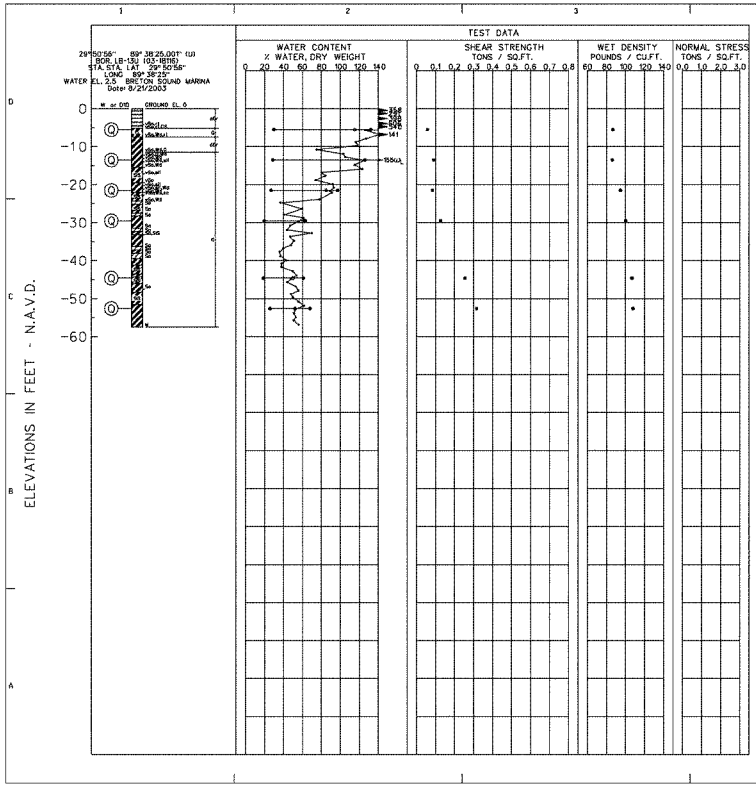
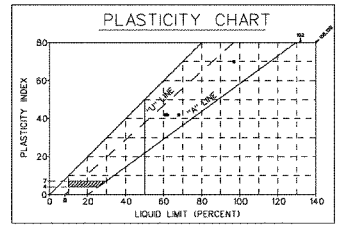
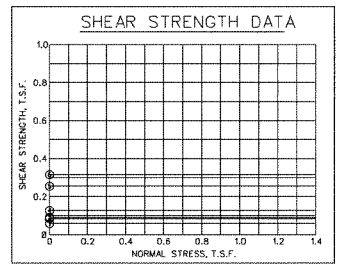






TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH C - TSF	CLASS
1	-5.5	Q	0.0	0.058	CH
2	-13.5	Q	0.0	0.091	CH
3	-21.5	Q	0.0	0.084	CH
4	-29.5	Q	0.0	0.127	CH
5	-44.6	Q	0.0	0.255	CH
6	-52.6	Q	0.0	0.316	CH

NOTES

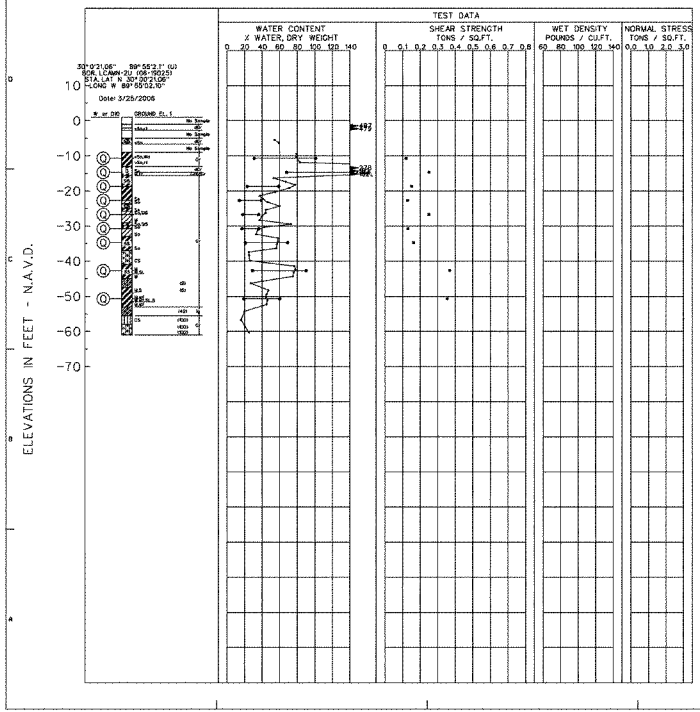
- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ω_P ω_N ω_L ATTERBERG LIMITS

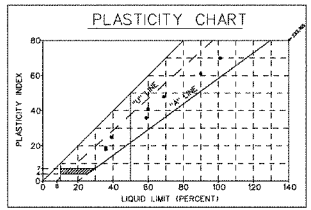
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

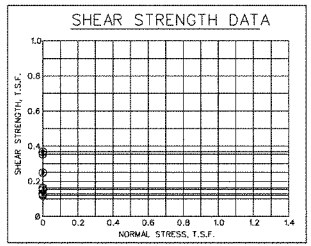
US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS VICKSBURG, MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH c - TSF	CLASS
1	-10.7	Q	0.0	0.122	CH
2	-14.7	Q	0.0	0.250	CH
3	-18.7	Q	0.0	0.152	CH
4	-22.7	Q	0.0	0.128	CL
5	-26.7	Q	0.0	0.250	CL
6	-30.7	Q	0.0	0.129	CL
7	-34.7	Q	0.0	0.162	CH
8	-42.7	Q	0.0	0.368	CH
9	-50.7	Q	0.0	0.354	CH

NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
LL PL ■ — WN ○ — LL ■ ATTERBERG LIMITS

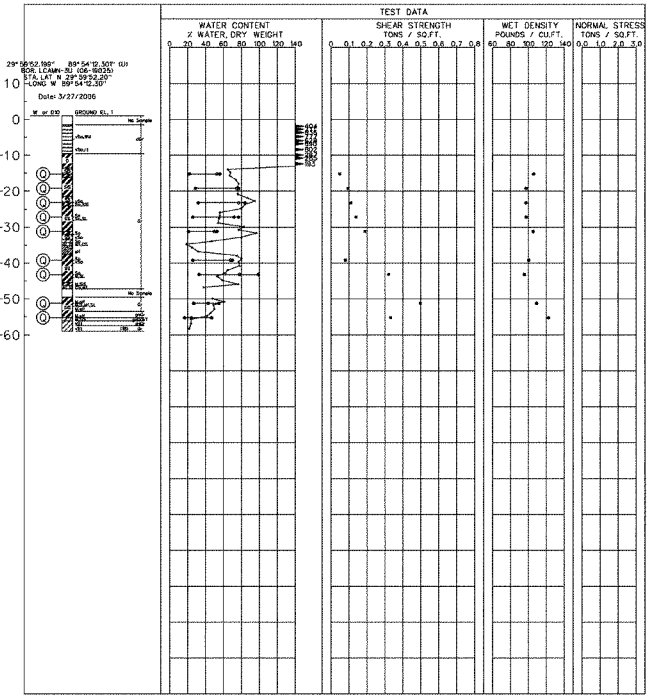
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

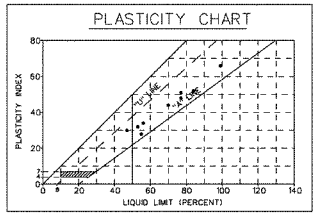
US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

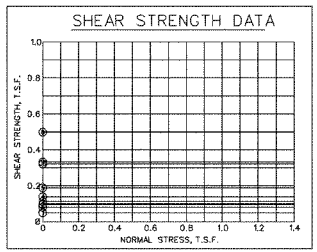
U.S. ARMY CORPS OF ENGINEERS
COMPOSITE SOIL BORING REPORT
MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER

982







TABULAR TEST DATA

ENVELOPE NO.	ENVELOPE EL.	TYPE	STRENGTH φ	STRENGTH c - TSF	CLASS
1	-13.2	Q	0.0	0.049	CH
2	-13.2	Q	0.0	0.095	CH
3	-23.2	Q	0.0	0.112	CH
4	-27.2	Q	0.0	0.138	CH
5	-31.2	Q	0.0	0.188	CH
6	-33.2	Q	0.0	0.080	CH
7	-43.2	Q	0.0	0.321	CH
8	-51.2	Q	0.0	0.458	CH
9	-55.2	Q	0.0	0.332	CL

NOTES

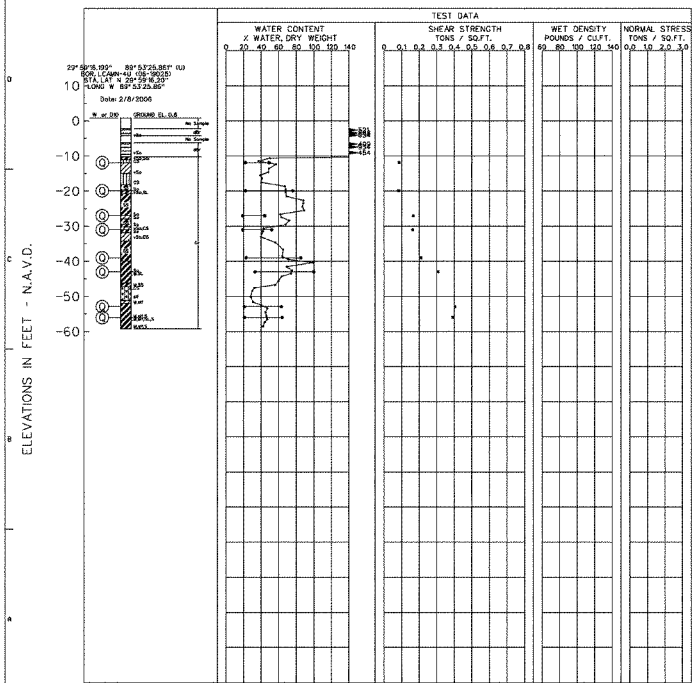
- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- LL ●——○ PL ●— LN - ATTERBERG LIMITS

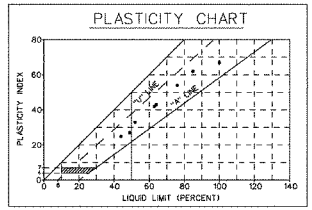
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

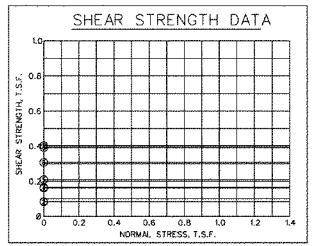
U.S. ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT

U.S. ARMY ENGINEER RESEARCH AND DEVELOPMENT CENTER
MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH c - TSF	CLASS
1	-11.9	Q	0.0	0.085	CL
2	-19.5	Q	0.0	0.083	CH
3	-27.0	Q	0.0	0.166	CL
4	-31.0	Q	0.0	0.152	CH
5	-39.0	Q	0.0	0.210	CL
6	-43.0	Q	0.0	0.308	CH
7	-52.9	Q	0.0	0.404	CH
8	-55.0	Q	0.0	0.392	CH

NOTES

- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

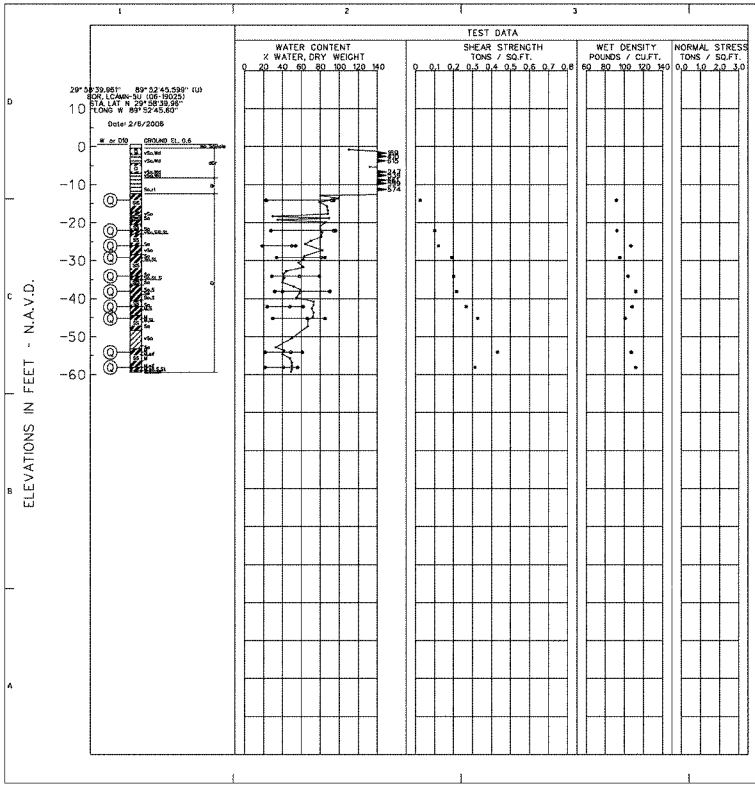
LL(●) PL(○) LL(●) ATTERBERG LIMITS

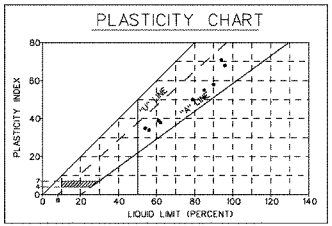
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

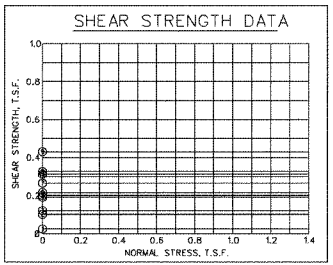
U.S. ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

U.S. ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH c - TSF	CLASS
1	-14.1	Q	0.0	0.025	CH
2	-22.1	Q	0.0	0.102	CH
3	-26.1	Q	0.0	0.121	CH
4	-29.2	Q	0.0	0.192	CH
5	-34.1	Q	0.0	0.201	CH
6	-38.1	Q	0.0	0.216	CH
7	-42.1	Q	0.0	0.266	CH
8	-45.2	Q	0.0	0.327	CH
9	-54.1	Q	0.0	0.431	CH
10	-58.1	Q	0.0	0.313	CH

NOTES

- o - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- □ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ωP ωN ωL ATTERBERG LIMITS

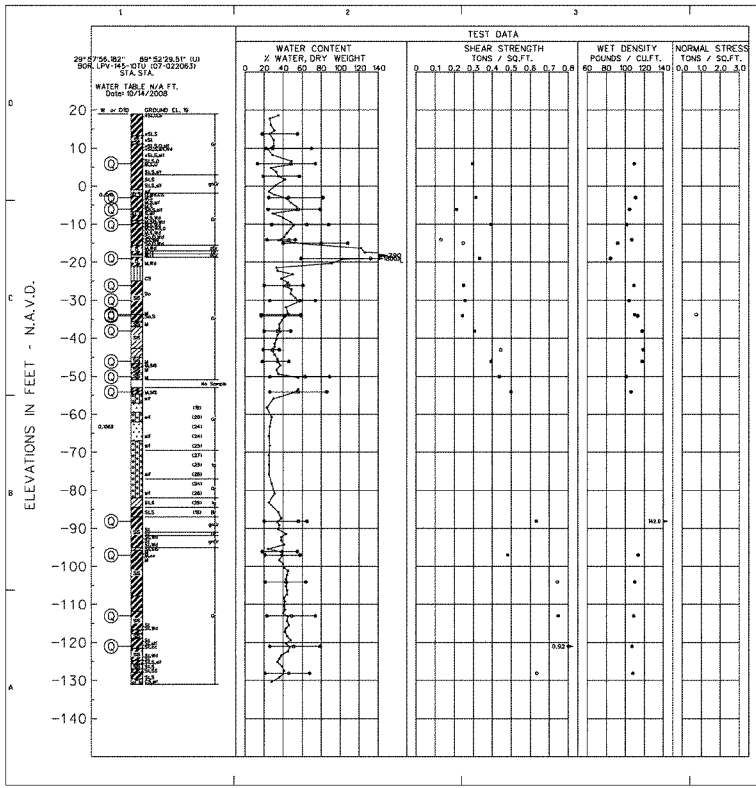
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

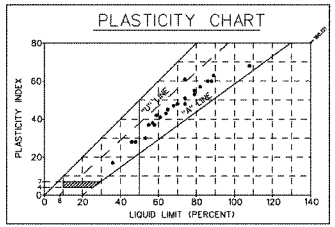
US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

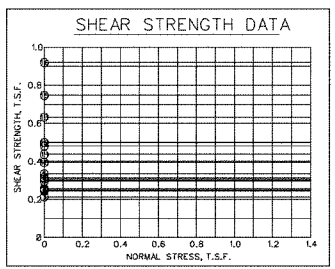
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER

985







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH c - TSF	CLASS
1	5.9	Q	0.0	0.295	CH
2	-3.0	Q	0.0	0.314	CH
3	-6.1	Q	0.0	0.213	CH
4	-10.1	Q	0.0	0.354	CH
5	-19.0	Q	0.0	0.334	CH
6	-26.1	Q	0.0	0.250	CH
7	-30.1	Q	0.0	0.296	CH
8	-34.1	Q	0.0	0.244	CH
9	-38.1	Q	0.0	0.307	CL
10	-46.1	Q	0.0	0.354	CL
11	-50.1	Q	0.0	0.437	CH
12	-54.1	Q	0.0	0.498	CH
13	-88.1	Q	0.0	0.632	CH
14	-97.0	Q	0.0	0.481	CH
15	-113.0	Q	0.0	0.747	CH
16	-121.0	Q	0.0	0.520	CH
17	-33.8	C	0.0	0.000	CH

NOTES

- o - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- □ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ωp ωN ωL - ATTERBERG LIMITS

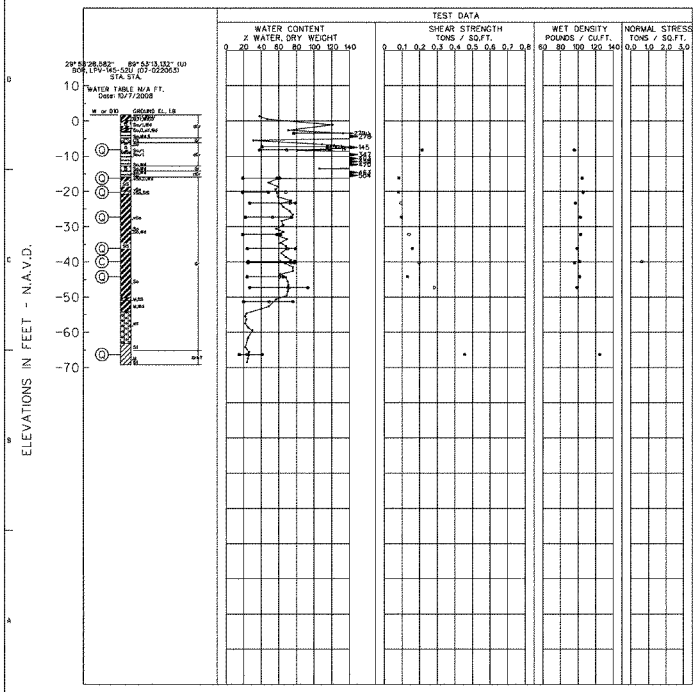
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

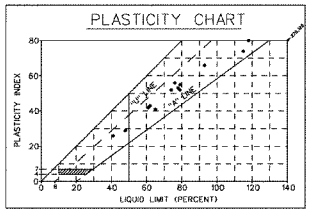
US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

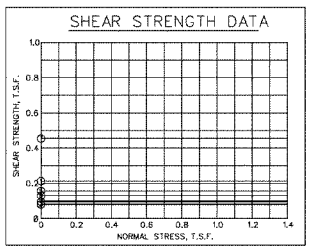
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER

986







TABULAR TEST DATA

ENVELOPE NO.	ENVELOPE EL.	TYPE	STRENGTH ϕ	STRENGTH c - TSF	CLASS
1	-6.2	D	0.0	0.213	CH
2	-16.2	D	0.0	0.082	CH
3	-20.2	D	0.0	0.080	CL
4	-27.3	D	0.0	0.096	CH
5	-36.2	D	0.0	0.157	CH
6	-44.2	D	0.0	0.131	CH
7	-66.3	D	0.0	0.455	CL
8	-39.9	C	0.0	0.000	CH

NOTES

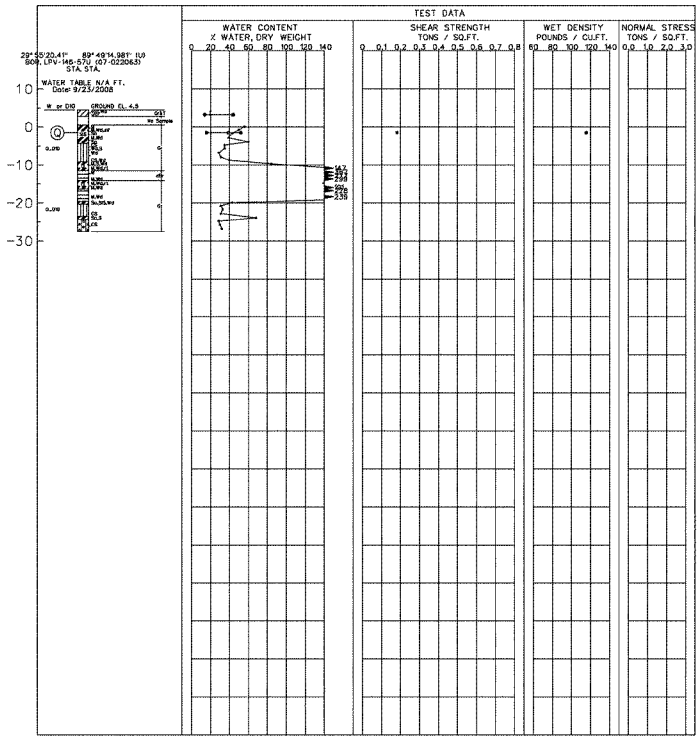
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
ω_P ω_N ω_L ATTERBERG LIMITS

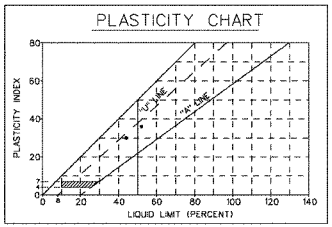
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

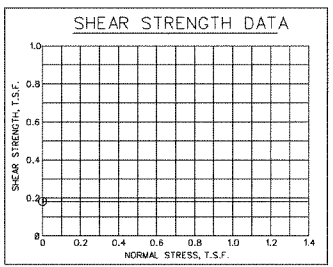
U.S. ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH c - TSF	CLASS
1	-1.5	Q	0.0	0.182	CH

NOTES

o - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
□ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
ω_P ω_N ω_L ATTERBERG LIMITS

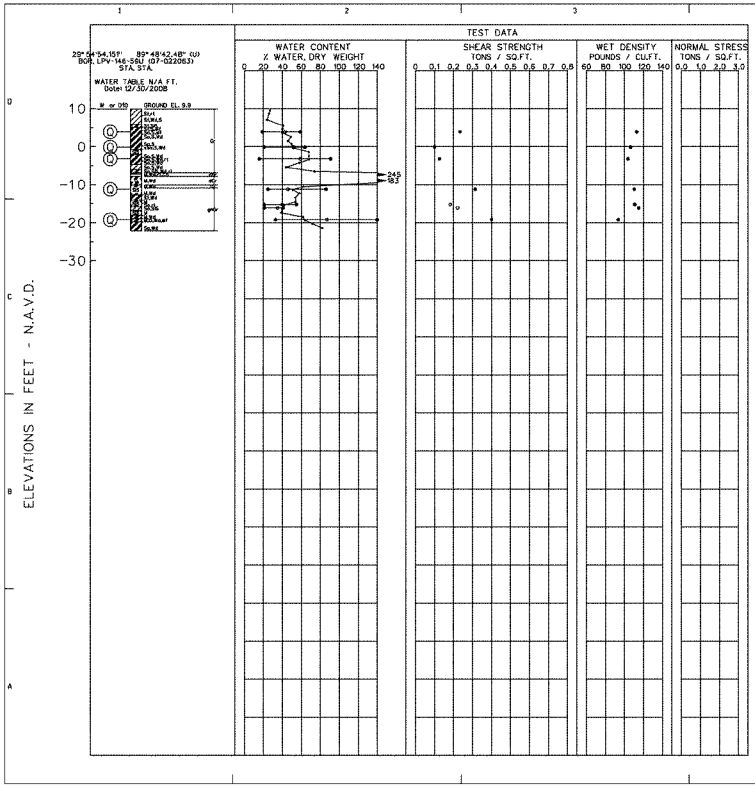
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

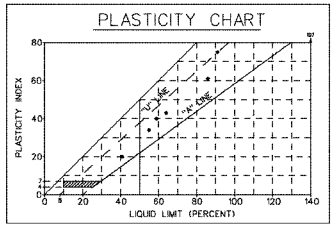
US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

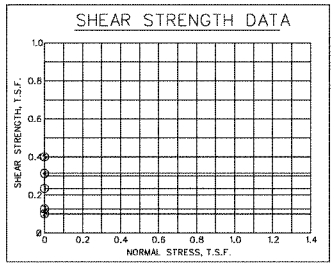
NO.	DESCRIPTION	DATE	APPD.	DRWN.	DATE

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH c - TSF	CLASS
1	3.3	Q	0.0	0.235	CH
2	-0.1	Q	0.0	0.102	CH
3	-3.2	Q	0.0	0.127	CH
4	-11.2	Q	0.0	0.314	CH
5	-19.2	Q	0.0	0.401	CH

NOTES

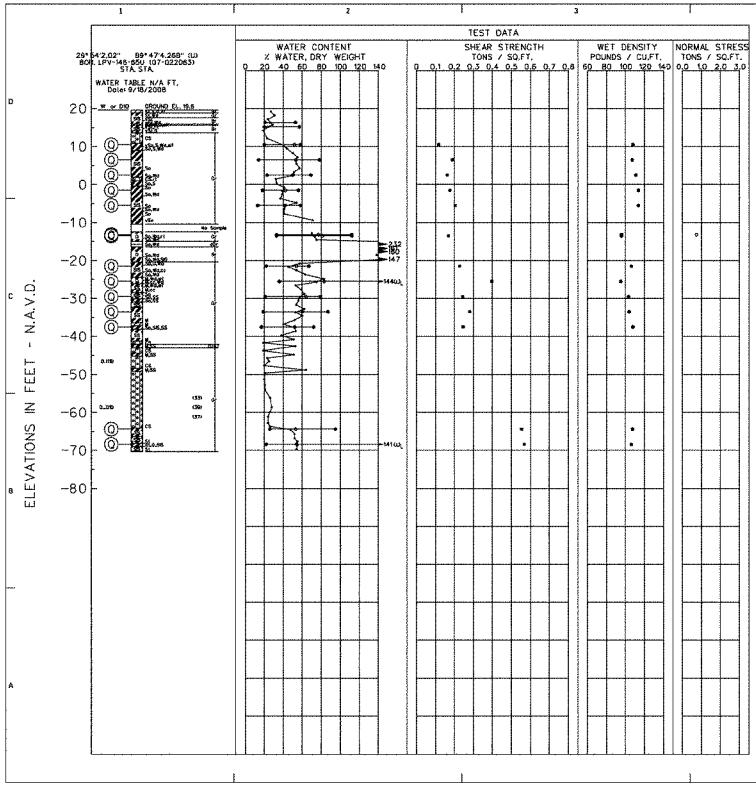
- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ωP ωN ωL ATTERBERG LIMITS

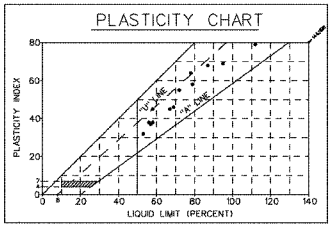
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

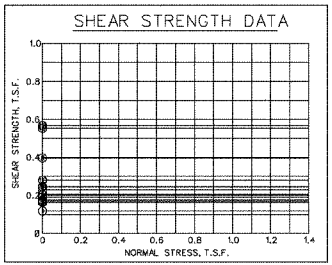
US ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE		TYPE	STRENGTH		CLASS
NO.	EL.		Φ	C - TSF	
1	10.5	Q	0.0	0.118	CH
2	6.5	Q	0.0	0.190	CH
3	2.5	Q	0.0	0.163	CH
4	-1.5	Q	0.0	0.176	CH
5	-5.5	Q	0.0	0.204	CH
6	-13.5	Q	0.0	0.169	CH
7	-21.5	Q	0.0	0.228	CH
8	-25.5	Q	0.0	0.397	CH
9	-29.5	Q	0.0	0.244	CH
10	-33.5	Q	0.0	0.280	CH
11	-37.5	Q	0.0	0.246	CH
12	-64.4	Q	0.0	0.553	CH
13	-68.4	Q	0.0	0.568	CH
14	-13.2	C	0.0	0.000	CH

NOTES

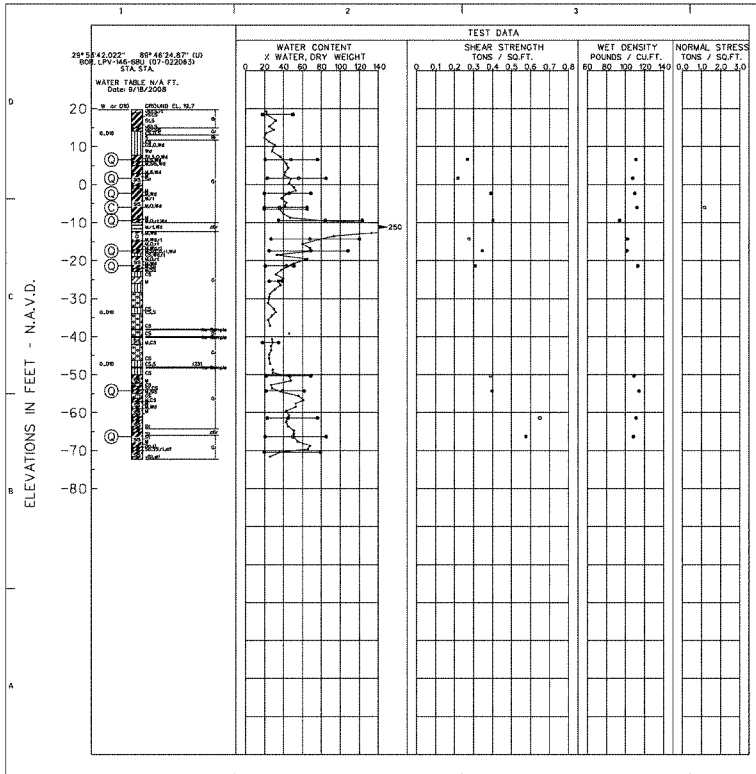
- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- □ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ω_P ω_N ω_L ATTERBERG LIMITS

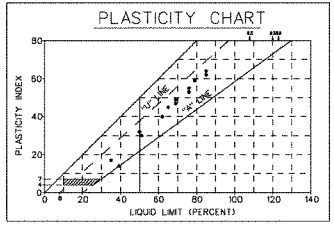
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

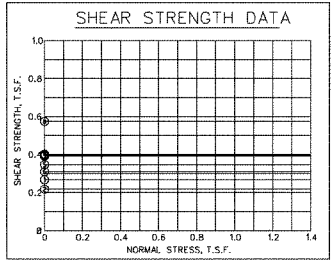
US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	ENVELOPE EL.	TYPE	STRENGTH Φ	STRENGTH C - TSF	CLASS
1	6.6	Q	0.0	0.268	CH
2	1.7	Q	0.0	0.218	CH
3	-2.3	Q	0.0	0.392	CH
4	-9.4	Q	0.0	0.402	CH
5	-17.4	Q	0.0	0.347	CH
6	-21.4	Q	0.0	0.310	CH
7	-54.3	Q	0.0	0.397	CH
8	-66.3	Q	0.0	0.575	CH
9	-6.0	C	0.0	0.000	CH

NOTES

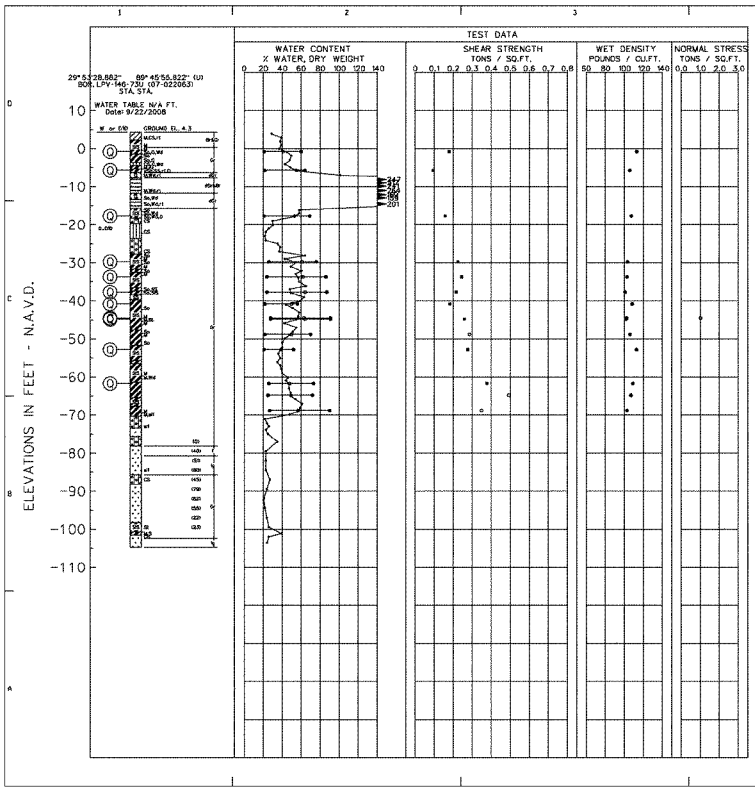
- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- □ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ω_P ω_N ω_L ATTERBERG LIMITS

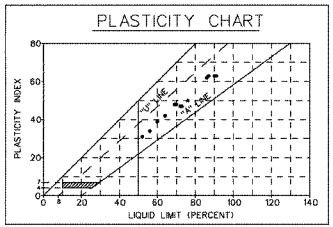
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

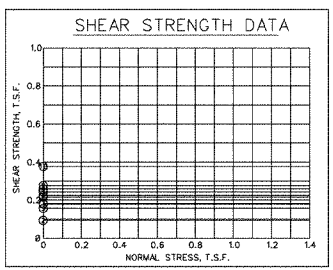
US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH c - TSF	CLASS
1	-0.8	Q	0.0	0.179	CH
2	-5.7	Q	0.0	0.084	CH
3	-17.7	Q	0.0	0.157	CH
4	-29.7	Q	0.0	0.225	CH
5	-33.7	Q	0.0	0.244	CH
6	-37.7	Q	0.0	0.216	CH
7	-40.8	Q	0.0	0.192	CH
8	-44.8	Q	0.0	0.259	CH
9	-52.8	Q	0.0	0.277	CH
10	-61.7	Q	0.0	0.377	CH
11	-44.5	C	0.0	0.000	CH

NOTES

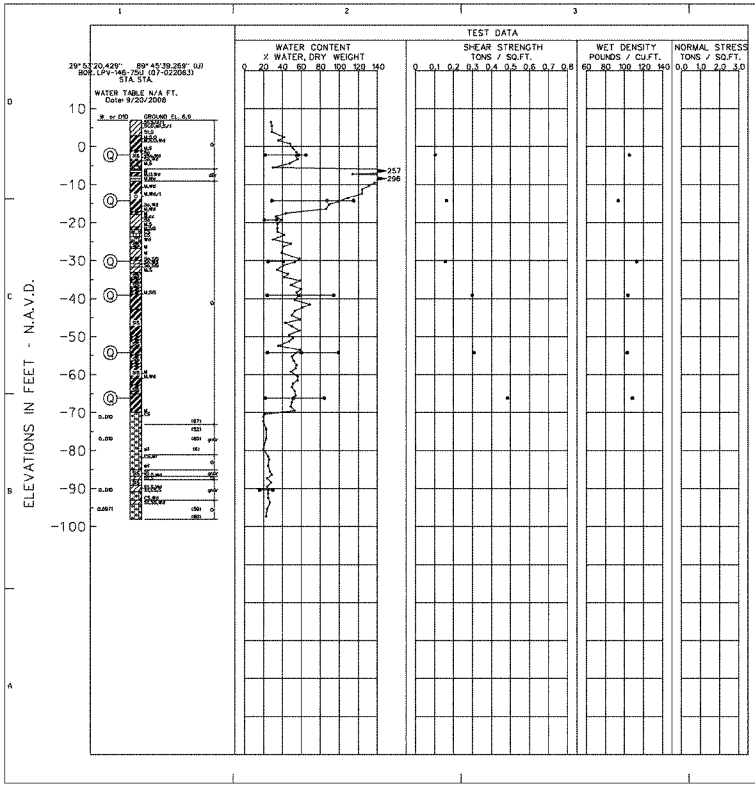
- o - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- □ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ω_P ω_N ω_L ATTERBERG LIMITS

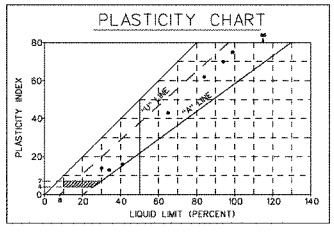
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

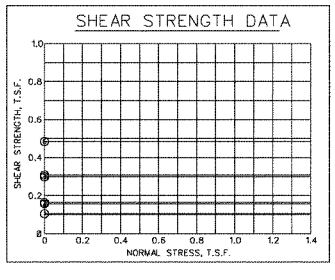
US ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH C - TSF	CLASS
1	-2.2	Q	0.0	0.105	CH
2	-14.2	Q	0.0	0.164	CH
3	-30.2	Q	0.0	0.157	CL
4	-39.1	Q	0.0	0.295	CH
5	-54.2	Q	0.0	0.308	CH
6	-66.2	Q	0.0	0.485	CH

NOTES

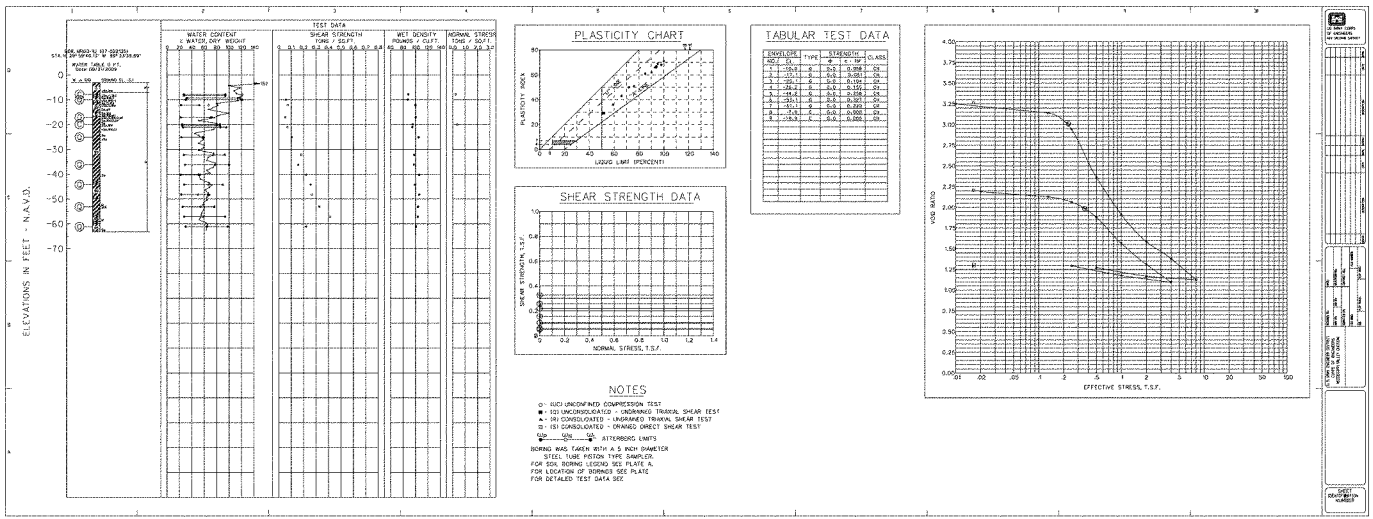
- o - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- □ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- (LP) (LN) (LL) ATTERBERG LIMITS

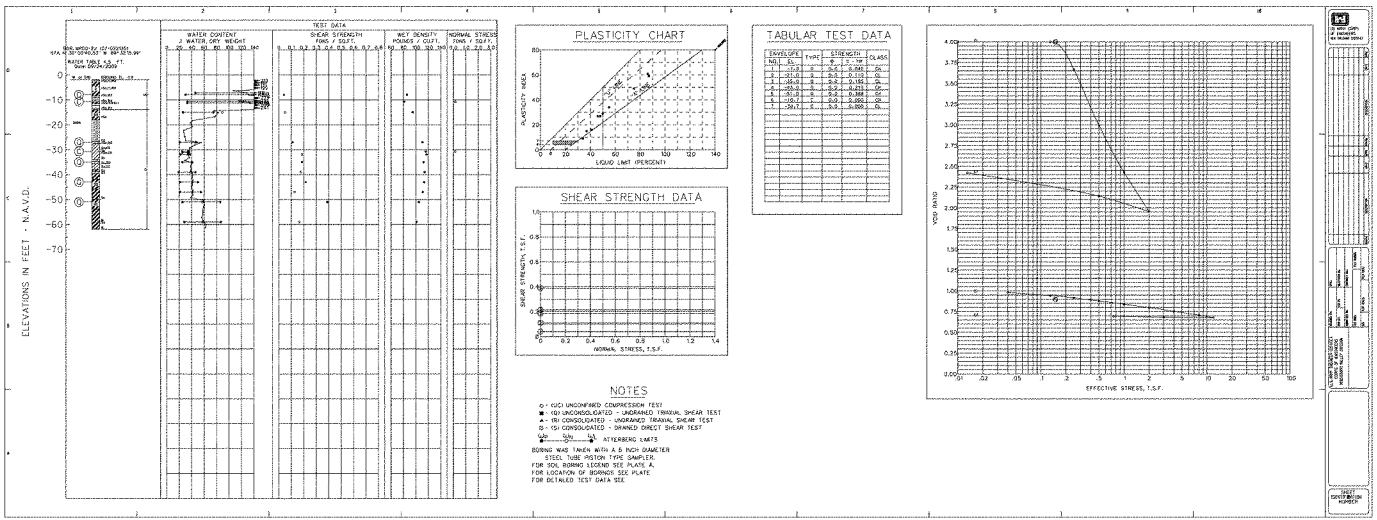
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

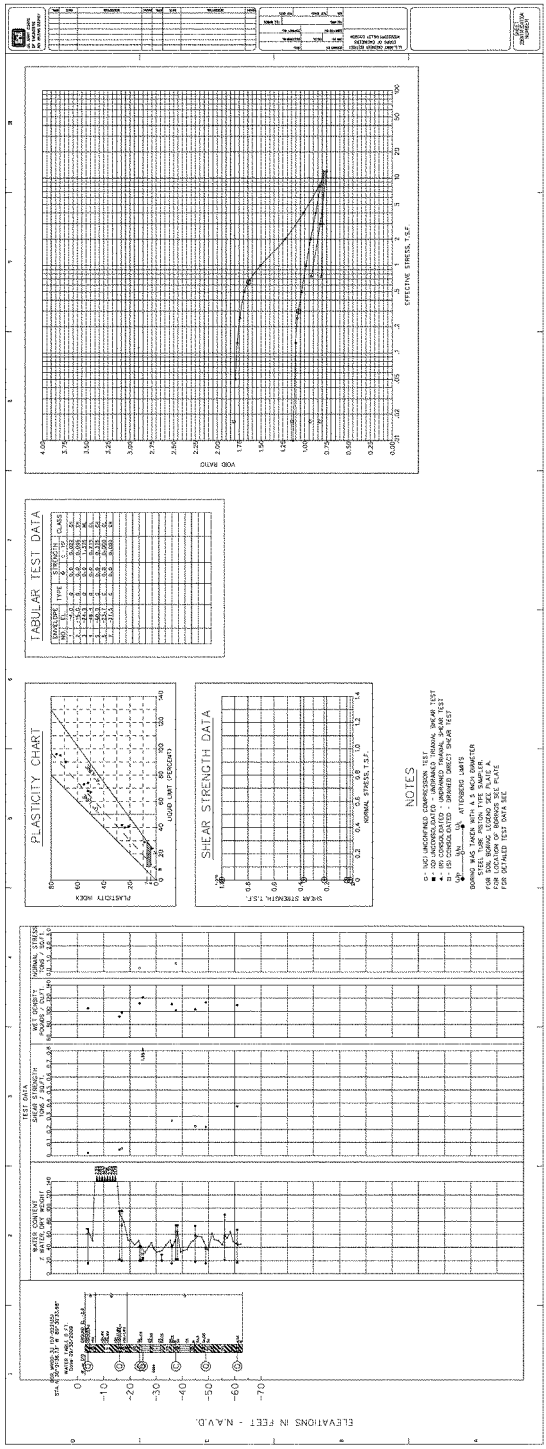
US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

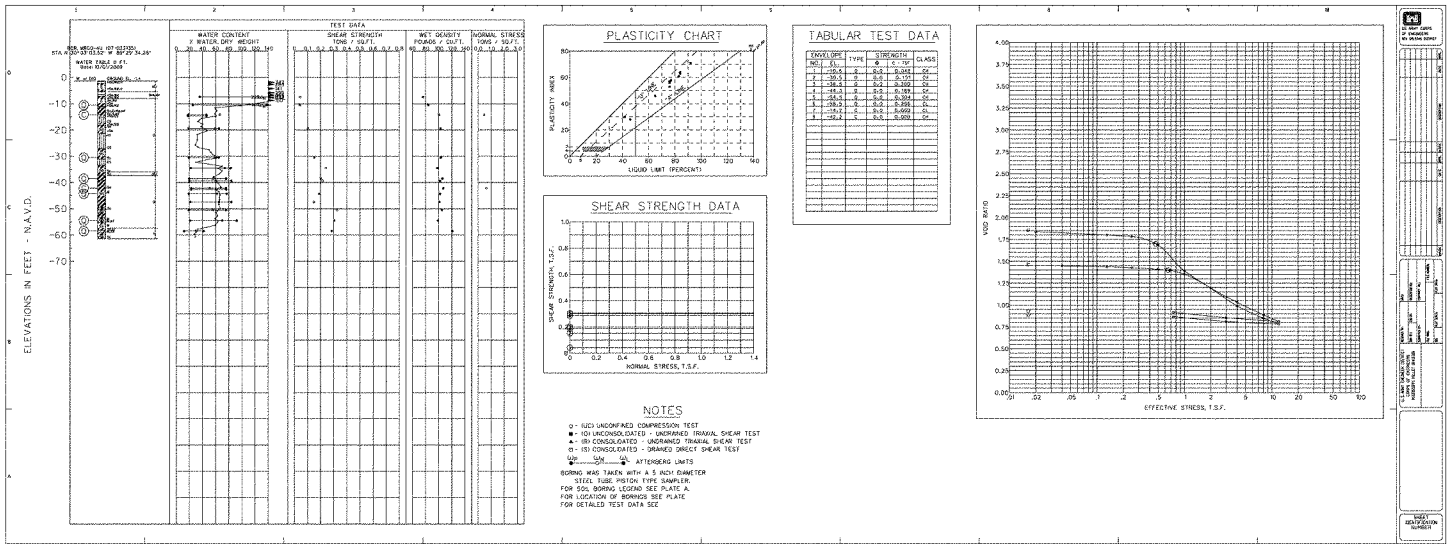
CLEARWATER PROJECT
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER

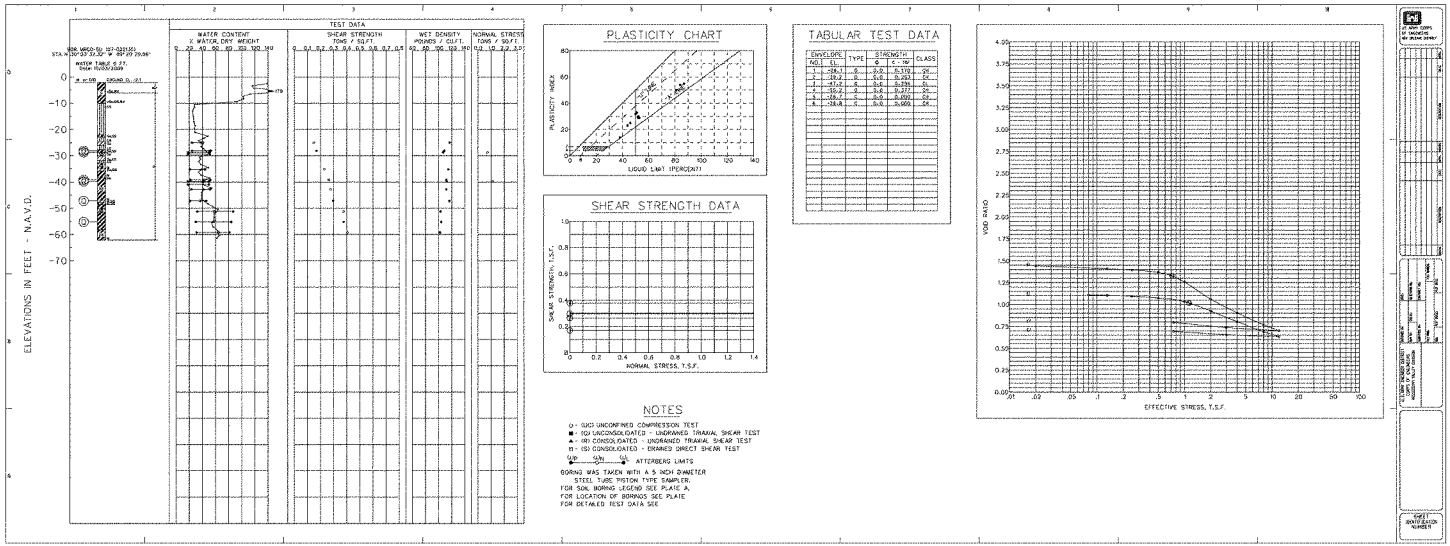

ELEVATIONS IN FEET - N.A.V.D.
TEST DATA
WATER CONTENT
SHEAR STRENGTH
WET DENSITY
NORMAL STRESS
PLASTICITY CHART
LIQUID LIMIT (PERCENT)
PLASTICITY INDEX
TABULAR TEST DATA
SHEAR STRENGTH DATA
NORMAL STRESS, T.S.F.
SHEAR STRENGTH, T.S.F.
NOTES
EFFECTIVE STRESS, T.S.F.
VOID RATIO

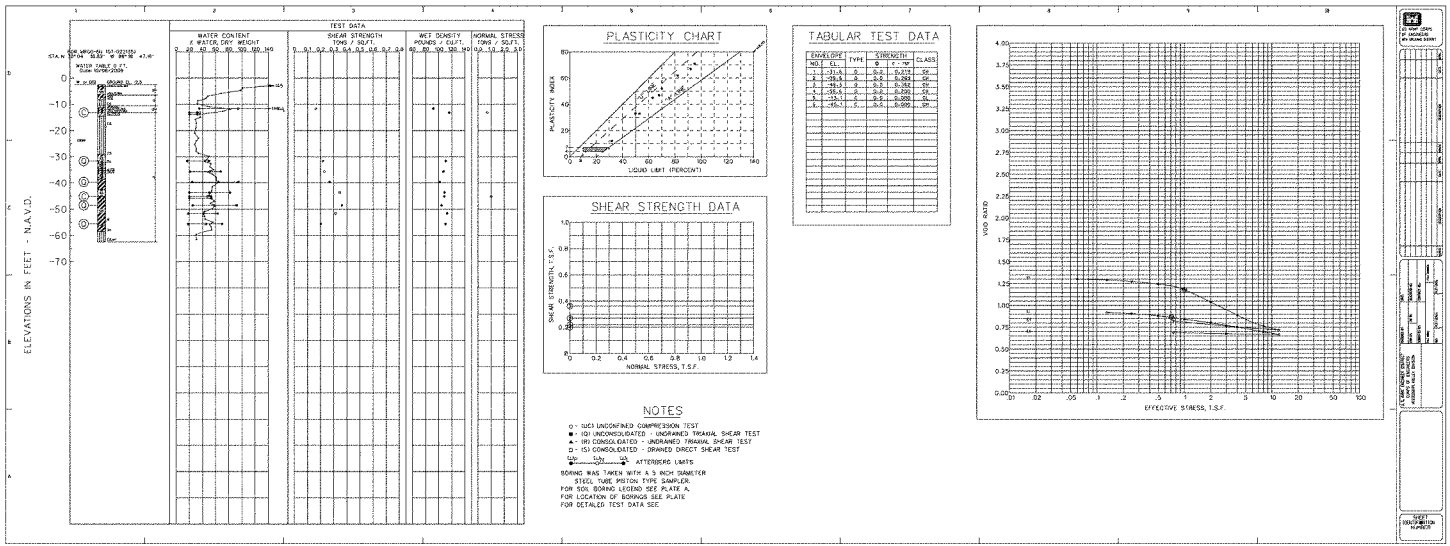

ELEVATIONS IN FEET - N.A.V.D.
TEST DATA
WATER CONTENT
% WATER DRY WEIGHT
SHEAR STRENGTH
TONS / SQ.FT.
WET DENSITY
POUNDS / CU.FT.
NORMAL STRESS
TONS / SQ.FT.
PLASTICITY CHART
PLASTICITY INDEX
LIQUID LIMIT (PERCENT)
SHEAR STRENGTH DATA
SHEAR STRENGTH, T.S.F.
NORMAL STRESS, T.S.F.
TABULAR TEST DATA
ENVELOPE NO.
TYPE
STRENGTH
CLASS
VOID RATIO
EFFECTIVE STRESS, T.S.F.
NOTES
(UC) UNCONFINED COMPRESSION TEST
(UD) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
(R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
(S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
ATTERBERG LIMITS
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

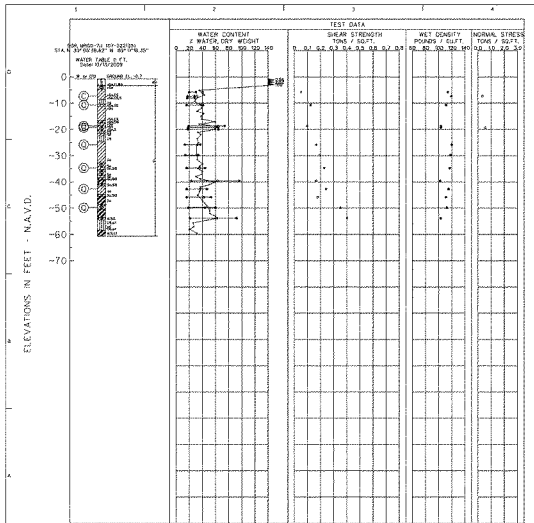

PLASTICITY CHART
LIQUID LIMIT (PERCENT)
PLASTICITY INDEX
SHEAR STRENGTH DATA
NORMAL STRESS, T.S.F.
SHEAR STRENGTH, T.S.F.
TABULAR TEST DATA
VOID RATIO
EFFECTIVE STRESS, T.S.F.
NOTES
ELEVATIONS IN FEET - N.A.V.D.

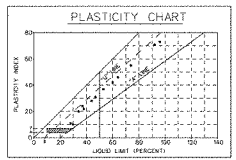

ELEVATIONS IN FEET - N.A.V.D.
TEST DATA
WATER CONTENT % WATER, DRY WEIGHT
SHEAR STRENGTH TONS / SQ.FT.
WET DENSITY POUNDS / CU.FT.
NORMAL STRESS TONS / SQ.FT.
PLASTICITY CHART
PLASTICITY INDEX
LIQUID LIMIT (PERCENT)
TABULAR TEST DATA
ENVELOPE NO.
EL.
TYPE
STRENGTH
CLASS
SHEAR STRENGTH DATA
SHEAR STRENGTH, T.S.F.
NORMAL STRESS, T.S.F.
VOID RATIO
EFFECTIVE STRESS, T.S.F.
NOTES
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

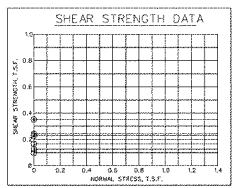
997


ELEVATIONS IN FEET - N.A.V.D.
TEST DATA
WATER CONTENT
% WATER, DRY WEIGHT
SHEAR STRENGTH
TONS / SQ.FT.
WET DENSITY
POUNDS / CU.FT.
NORMAL STRESS
TONS / SQ.FT.
PLASTICITY CHART
PLASTICITY INDEX
LIQUID LIMIT (PERCENT)
SHEAR STRENGTH DATA
SHEAR STRENGTH, T.S.F.
NORMAL STRESS, T.S.F.
TABULAR TEST DATA
ENVELOPE NO.
EL.
TYPE
STRENGTH
CLASS
VOID RATIO
EFFECTIVE STRESS, T.S.F.
NOTES
O - (UC) UNCONFINED COMPRESSION TEST
■ - (C) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
□ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
ATTERBERG LIMITS
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE


ELEVATIONS IN FEET - N.A.V.D.
TEST DATA
WATER CONTENT
% WATER, DRY WEIGHT
SHEAR STRENGTH
TONS / SQ.FT.
WET DENSITY
POUNDS / CU.FT.
NORMAL STRESS
TONS / SQ.FT.
PLASTICITY CHART
PLASTICITY INDEX
LIQUID LIMIT (PERCENT)
TABULAR TEST DATA
SHEAR STRENGTH DATA
SHEAR STRENGTH, T.S.F.
NORMAL STRESS, T.S.F.
VOID RATIO
EFFECTIVE STRESS, T.S.F.
NOTES
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (U) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
□ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
ATTERBERG LIMITS
BORING WAS TAKEN WITH A 3 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

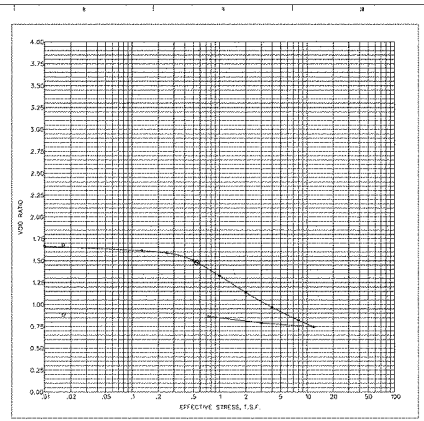






TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH c - TSF	CLASS
1	-10.7	Q	0.0	0.125	CL
2	-19.7	Q	0.0	0.097	CL
3	-25.7	Q	0.0	0.188	CL
4	-34.7	Q	0.0	0.228	CL
5	-42.7	Q	0.0	0.242	CL
6	-49.3	Q	0.0	0.351	CL
7	-7.3	S	0.9	0.000	SP
8	-13.3	S	0.6	0.000	SP

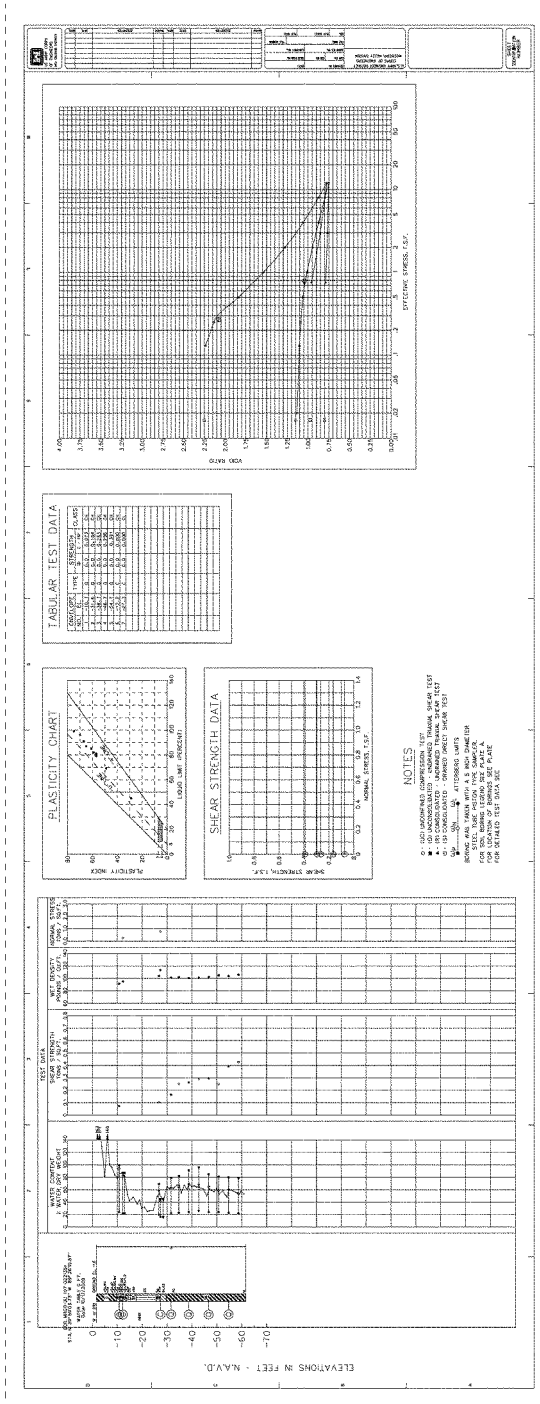


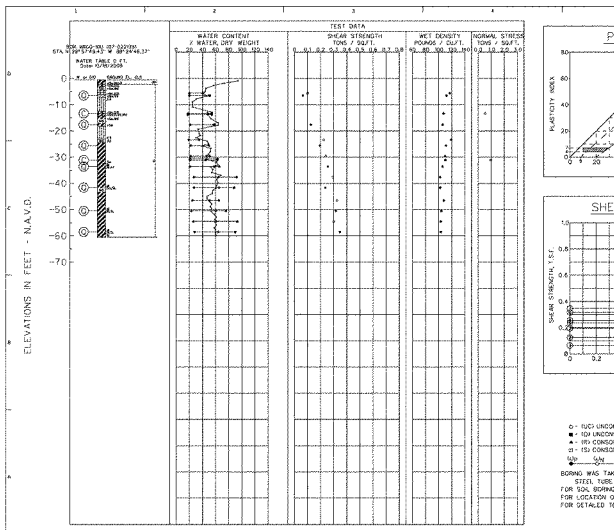
NOTES

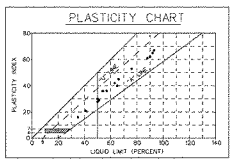
- Q - (UC) UNCONFINED COMPRESSION TEST
- ■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ⊠ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ⊢⊣ - ATTERBERG LIMITS

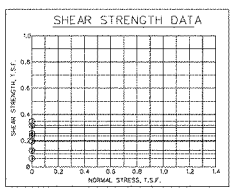
BORING WAS TAKEN WITH A 3 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

1000


TABULAR TEST DATA
PLASTICITY CHART
SHEAR STRENGTH DATA
NOTES
ELEVATIONS IN FEET - N.A.V.D.

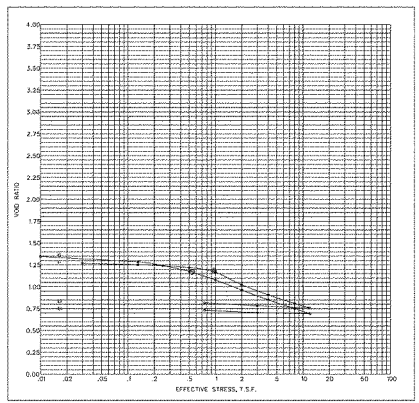






TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH ϕ	STRENGTH C - PSF	CLASS
1	-6.5	D	0.0	0.084	CL
2	-13.8	D	0.0	0.155	CH
3	-23.6	D	0.0	0.195	CH
4	-33.6	D	0.0	0.236	CH
5	-41.5	D	0.0	0.136	CH
6	-50.5	D	0.0	0.216	CH
7	-58.5	D	0.0	0.149	CH
8	-13.1	C	0.0	0.000	CL
9	-33.1	C	0.0	0.000	CH



NOTES

- O - (UC) UNCONFINED COMPRESSION TEST
- ■ - (U) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ◻ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
- ◆ - ATTERBERG LIMITS

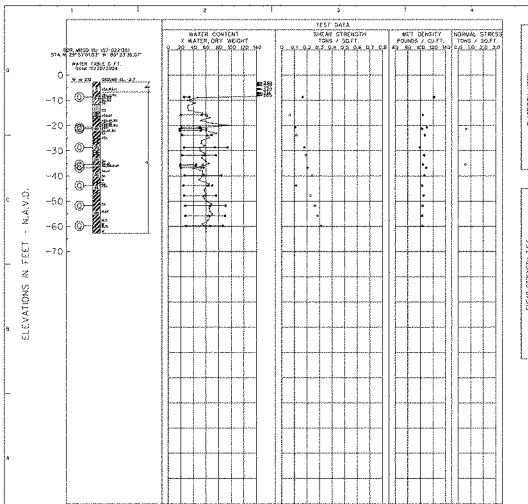
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

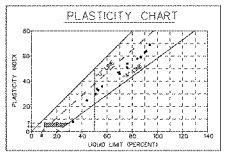
US ARMY CORPS OF ENGINEERS
NY DISTRICT

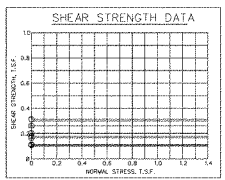
SOIL BORING REPORT
HUDSON-RARITAN ESTUARY
JERSEY CITY, NEW JERSEY

SHEET
SOIL BORING NUMBER

1002

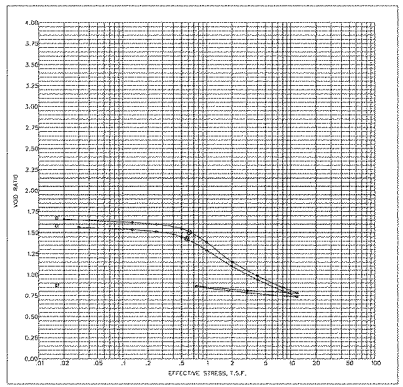






TABULAR TEST DATA

ENVELOPE		STRENGTH		
NO.	EL.	TYPE	φ	C - TSF	CLASS
1	-5.1	Q	0.0	0.167	CH
2	-20.1	Q	0.0	0.185	CH
3	-28.1	Q	0.0	0.178	CH
4	-35.1	Q	0.0	0.204	CH
5	-43.8	Q	0.0	0.114	CH
6	-51.8	Q	0.0	0.363	CH
7	-59.8	Q	0.0	0.313	CH
8	-71.3	Q	0.0	0.000	CH
9	-76.3	Q	0.0	0.000	CL



NOTES

Q - (UC) UNCONFINED COMPRESSION TEST
■ - (CU) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
D - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

Qu Qm Qc
●——○——● ATTERBERG LIMITS

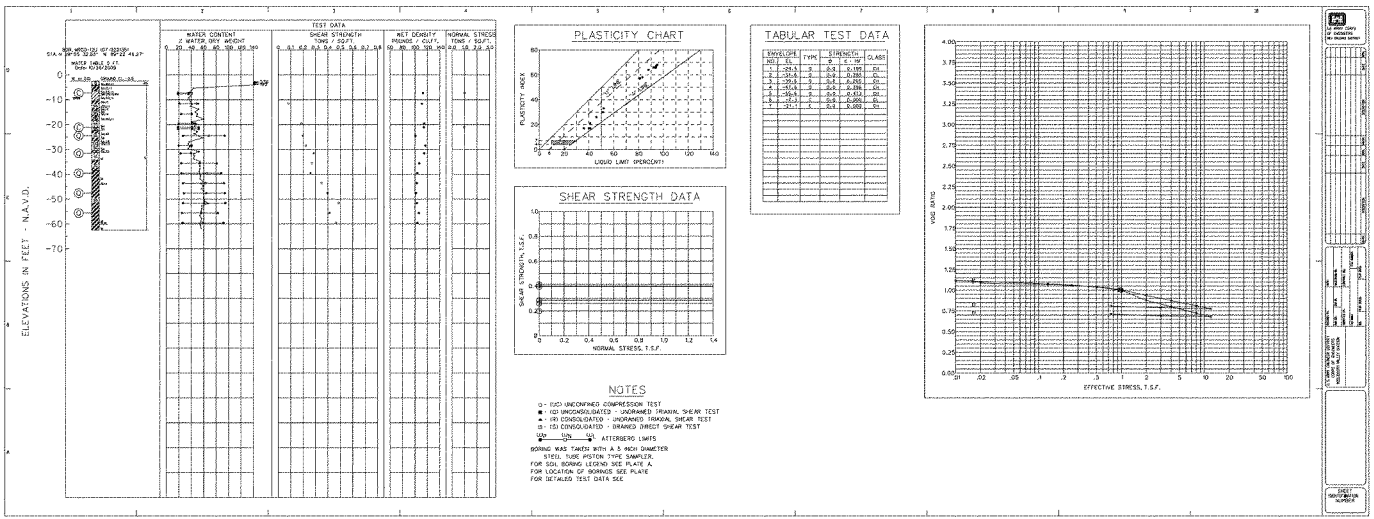
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
MISSISSIPPI RIVER GULF OUTLET

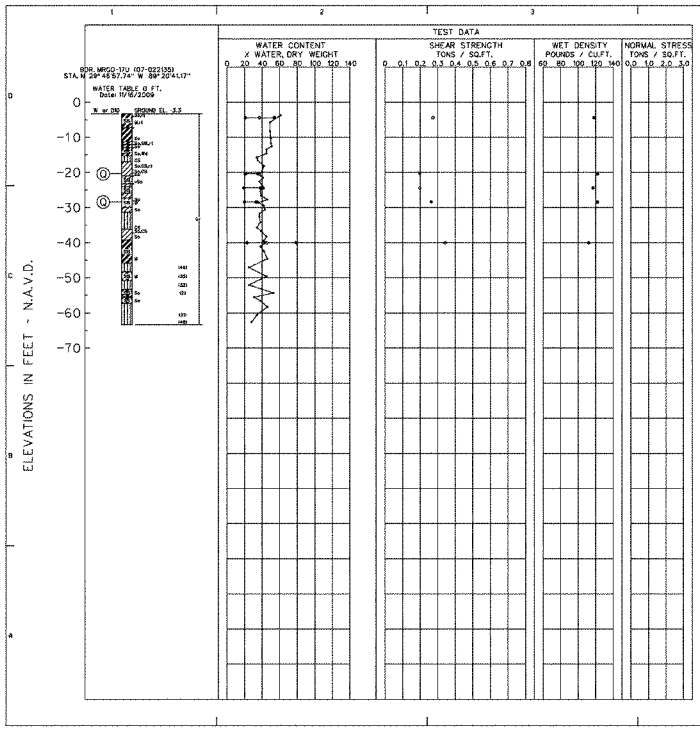
DRAWN: DM
DESIGNED: DM
CHECKED: DM
SUBMITTED: DM
DATE: 1/14/2003

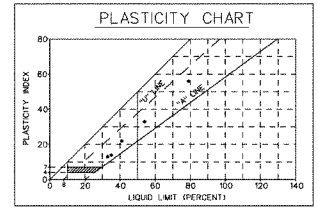
SOIL DESCRIPTION NUMBER

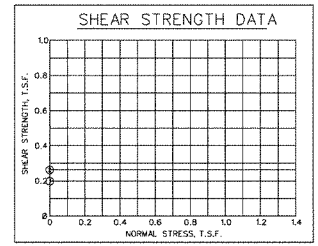
1003


ELEVATIONS IN FEET - N.A.V.D.
TEST DATA
WATER CONTENT
% WATER DRY WEIGHT
SHEAR STRENGTH
TONS / SQ.FT.
WET DENSITY
POUNDS / CU.FT.
NORMAL STRESS
TONS / SQ.FT.
PLASTICITY CHART
PLASTICITY INDEX
LIQUID LIMIT (PERCENT)
TABULAR TEST DATA
ENVELOPE NO.
EL.
TYPE
STRENGTH
Φ
C - PSF
CLASS
SHEAR STRENGTH DATA
SHEAR STRENGTH, T.S.F.
NORMAL STRESS, T.S.F.
VOID RATIO
EFFECTIVE STRESS, T.S.F.
NOTES
BORING WAS TAKEN WITH A 3 INCH DIAMETER
STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

1004







TABULAR TEST DATA

ENVELOPE		TYPE	STRENGTH		CLASS
NO.	EL.		Φ	c - TSF	
1	-20.4	Q	0.0	0.138	CL
2	-28.4	Q	0.0	0.283	CL

NOTES

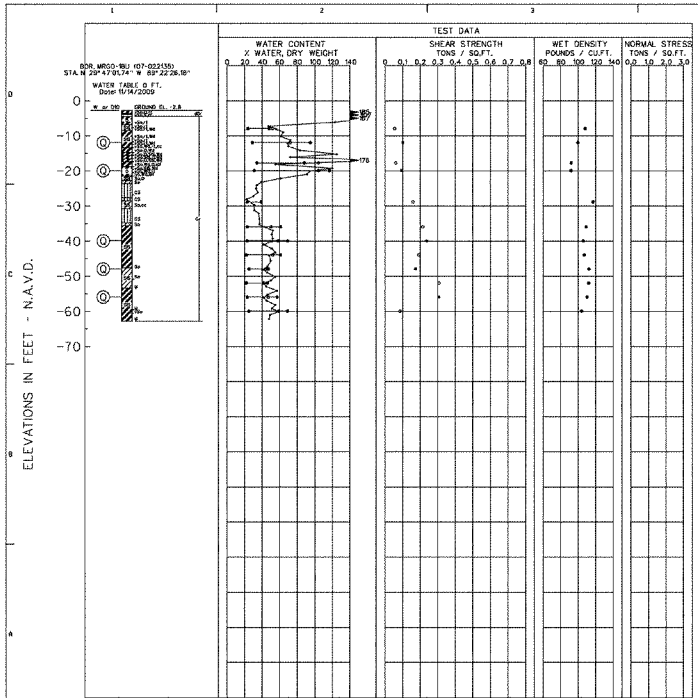
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
W_P W_N W_L ATTERBERG LIMITS

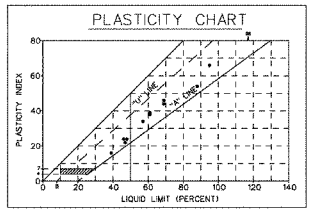
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

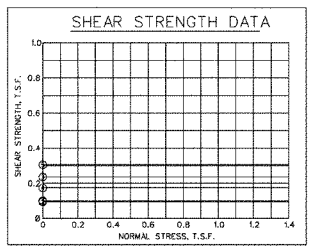
US ARMY CORPS OF ENGINEERS NEW ORLEANS DISTRICT

U.S. ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT
MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH c - TSF	CLASS
1	-11.5	Q	0.0	0.101	CH
2	-19.5	Q	0.0	0.095	CH
3	-35.5	Q	0.0	0.236	CH
4	-47.5	Q	0.0	0.174	CL
5	-55.5	Q	0.0	0.306	CH

NOTES

○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

ω_P ω_N ω_L ATTERBERG LIMITS

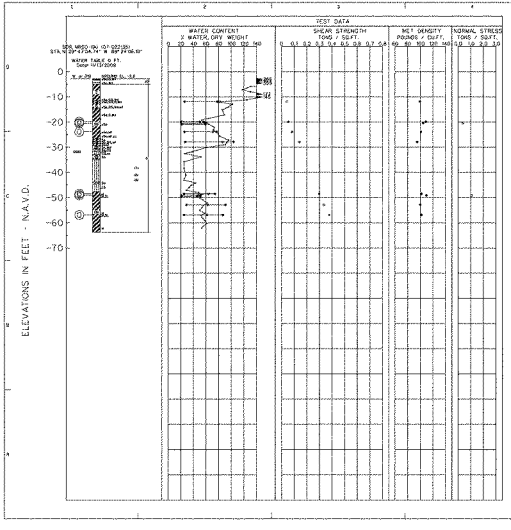
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

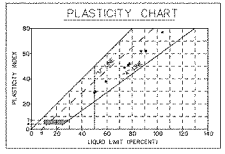
U.S. ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT

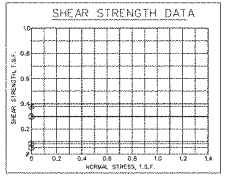
U.S. DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

SHEET IDENTIFICATION NUMBER

1006







NOTES

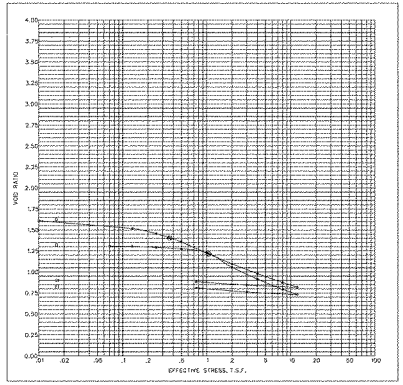
- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (CU) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- □ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

LQL PL NAT LL ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

TABULAR TEST DATA

ENVELOPE NO.	EL	TYPE	STRENGTH φ	STRENGTH c TSF	CLASS
1	-15.5	R	0.0	0.80	CH
2	-23.0	R	0.0	0.68	CH
3	-28.0	R	0.0	0.59	CH
4	-36.0	R	0.0	0.73	CH
5	-39.5	R	0.0	0.85	CH
6	-51.0	R	0.0	0.95	CH



U.S. ARMY CORPS OF ENGINEERS
NW BALTIMORE

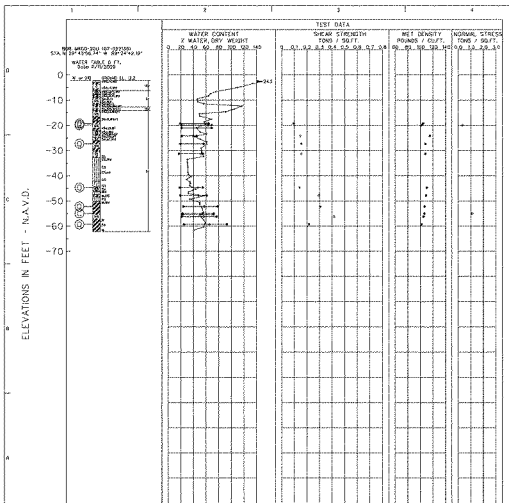
MARK	REVISION	DATE	BY	CHK
A				
B				
C				
D				
E				

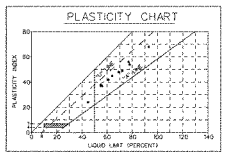
DESIGN
DRAWN
CHECKED
SUBMITTED
DATE
SCALE

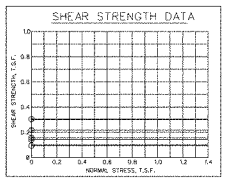
PATUXENT RIVER SERVICE CENTER
INDIAN HEAD, MARYLAND

SHEET 2 OF 2
PLATE NUMBER

1007

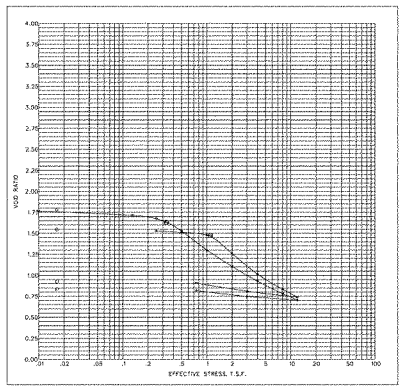






TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH ϕ	STRENGTH c - psf	CLASS
1	-19.3	S	0.0	0.064	CH
2	-27.5	S	0.0	0.155	CH
3	-44.1	S	0.0	0.147	CH
4	-52.8	S	0.0	0.375	CH
5	-59.3	S	0.0	0.211	CH
6	-13.3	S	0.0	0.000	CH
7	-34.5	S	0.0	0.292	CH



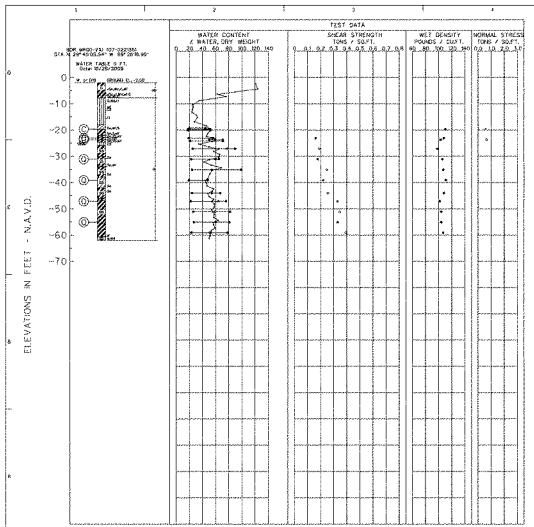
NOTES

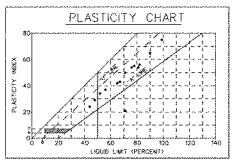
- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (CU) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ◇ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

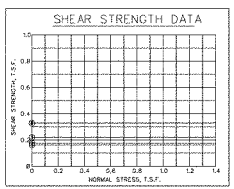
Color ○——○——● ATTERBERG LIMITS

BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

1008

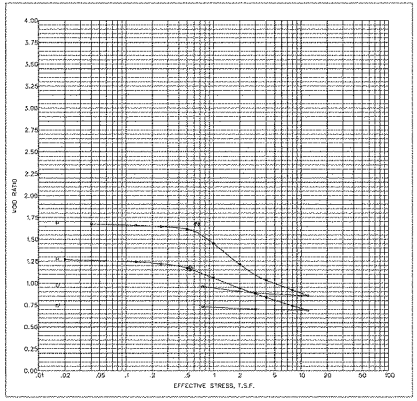






TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH φ	STRENGTH C	CLASS
1	-23.1	G	0.0	0.162	CH
2	-31.1	G	0.0	0.172	CH
3	-39.1	G	0.0	0.220	CL
4	-47.1	G	0.0	0.308	CH
5	-55.1	G	0.0	0.373	CH
6	-15.7	C	0.0	0.000	CH
7	-23.1	C	0.0	0.000	CH



NOTES

- (UC) UNCONFINED COMPRESSION TEST
- (U) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

ATTENBERG LIMITS

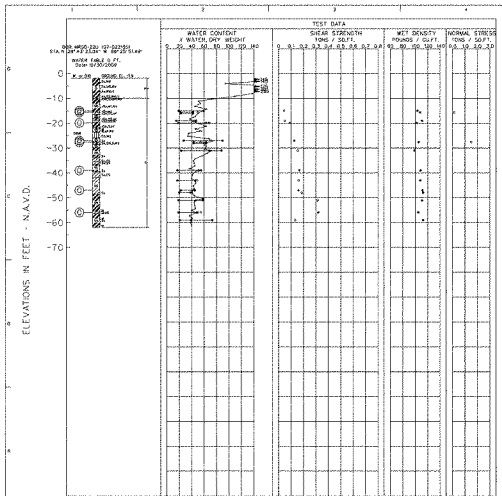
BORING WAS TAKEN With A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

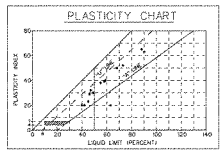
US ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT

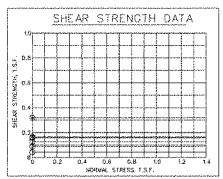
PLAQUEMINE WATERWAY PROJECT
PLAQUEMINE, LOUISIANA
BORROW PIT FILLET STATION

SOIL BORING DATA

1009

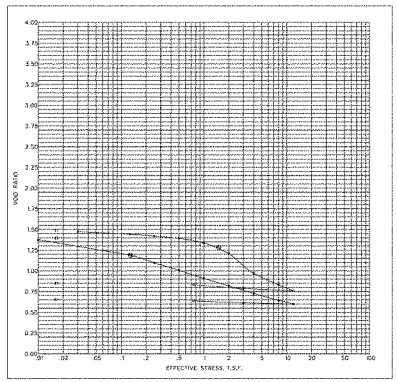






TABULAR TEST DATA

ENVELOPE NO.	ELEV.	TYPE	STRENGTH ϕ	STRENGTH C - PSF	CLASS
1	-14.0	Q	0.0	0.183	CH
2	-19.0	Q	0.0	0.085	CH
3	-27.0	Q	0.0	0.170	CH
4	-29.0	Q	0.0	0.159	CH
5	-41.0	Q	0.0	0.159	CH
6	-55.0	Q	0.0	0.128	CH
7	-59.0	Q	0.0	0.092	CH
8	-67.0	Q	0.0	0.095	CH



NOTES

- (UC) UNCONFINED COMPRESSION TEST
- (QT) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- (D) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

PL ATTERBERG LIMITS

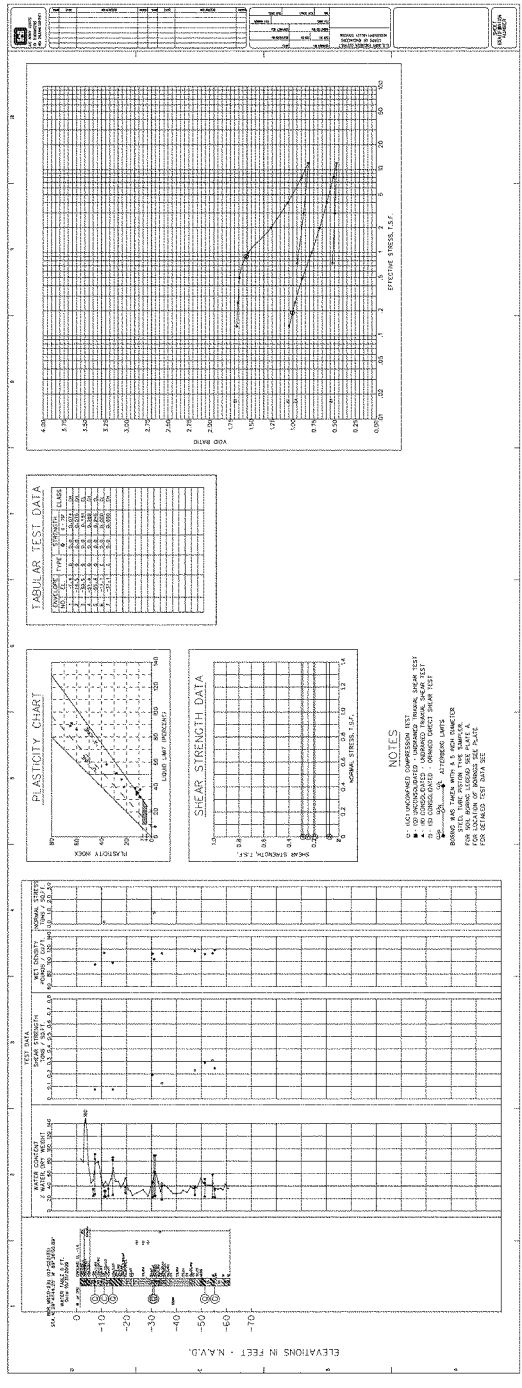
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

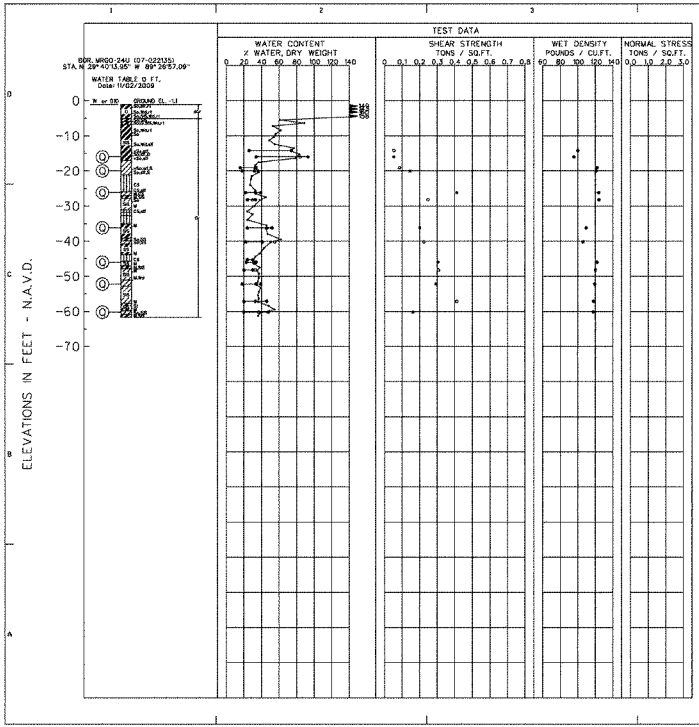
U.S. ARMY CORPS OF ENGINEERS
CHARLESTON, SOUTH CAROLINA

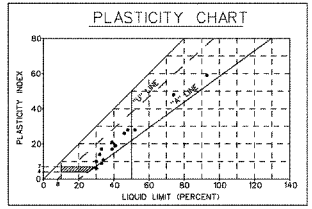
CHARLESTON HARBOR DEEPENING
CHARLESTON, SOUTH CAROLINA

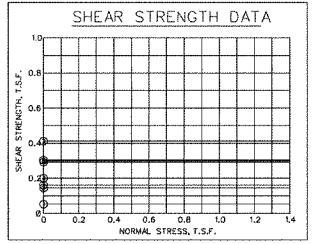
PLATE
LEGEND & BORING SUMMARY

1010


TABULAR TEST DATA
PLASTICITY CHART
SHEAR STRENGTH DATA
NOTES
VOID RATIO
EFFECTIVE STRESS, T.S.F.
ELEVATIONS IN FEET - N.A.V.D.







TABULAR TEST DATA

ENVELOPE NO.	EL.	TYPE	STRENGTH Φ	STRENGTH C - TSF	CLASS
1	-16.0	D	0.0	0.053	CH
2	-20.0	D	0.0	0.145	CL
3	-28.2	D	0.0	0.412	CL
4	-36.2	D	0.0	0.201	CH
5	-46.0	D	0.0	0.304	CL
6	-52.2	D	0.0	0.292	CL
7	-60.2	D	0.0	0.162	CL

NOTES

- ○ - (UC) UNCONFINED COMPRESSION TEST
- ■ - (U) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
- ⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST

●—○—● ATTERBERG LIMITS

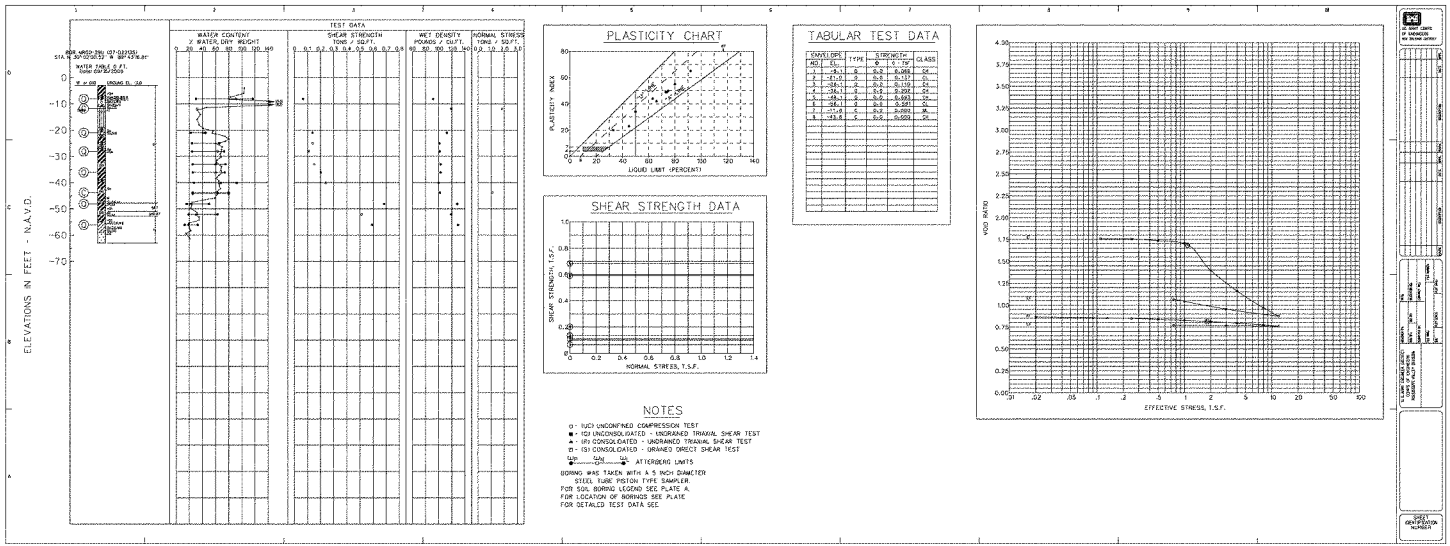
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

US ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT

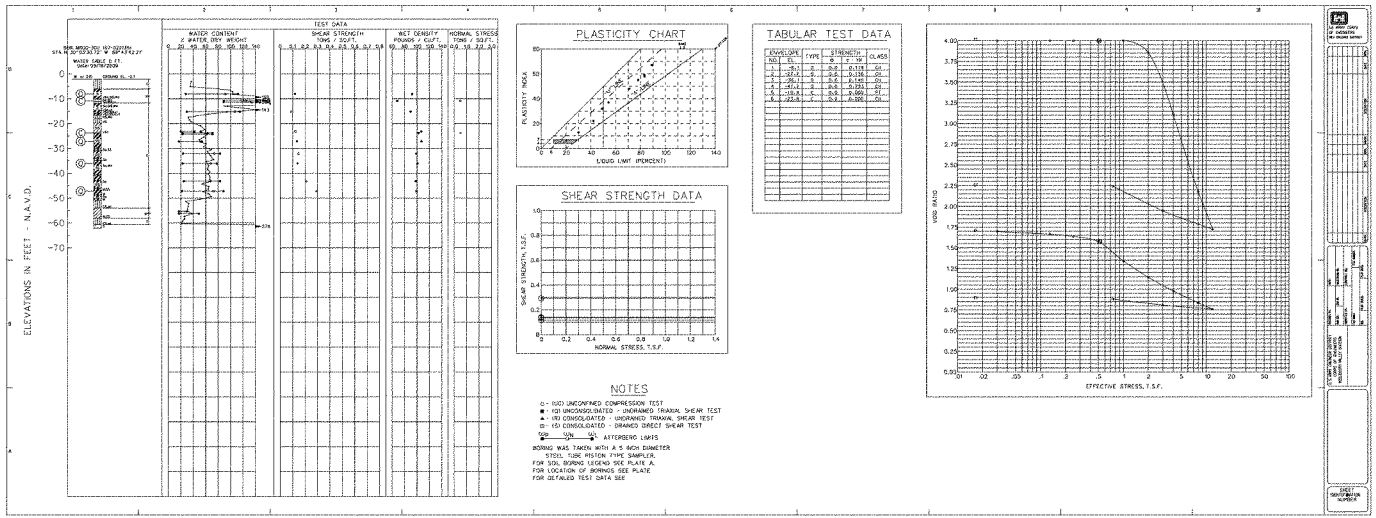
DATE | DESCRIPTION | BY | CHK'D | APP'D

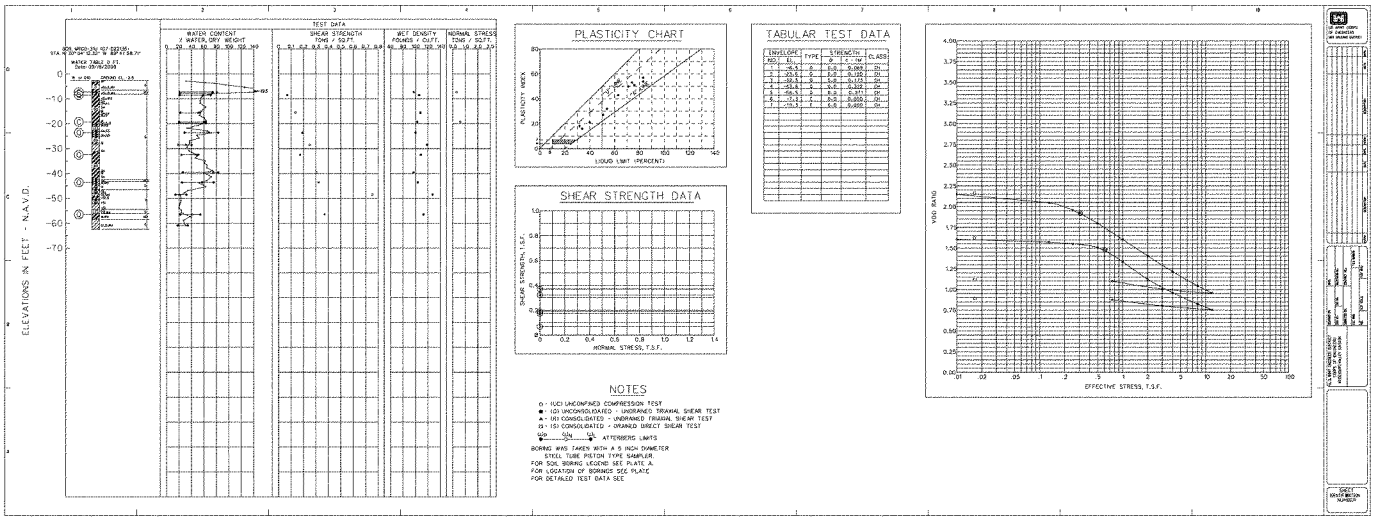
SHEET IDENTIFICATION NUMBER

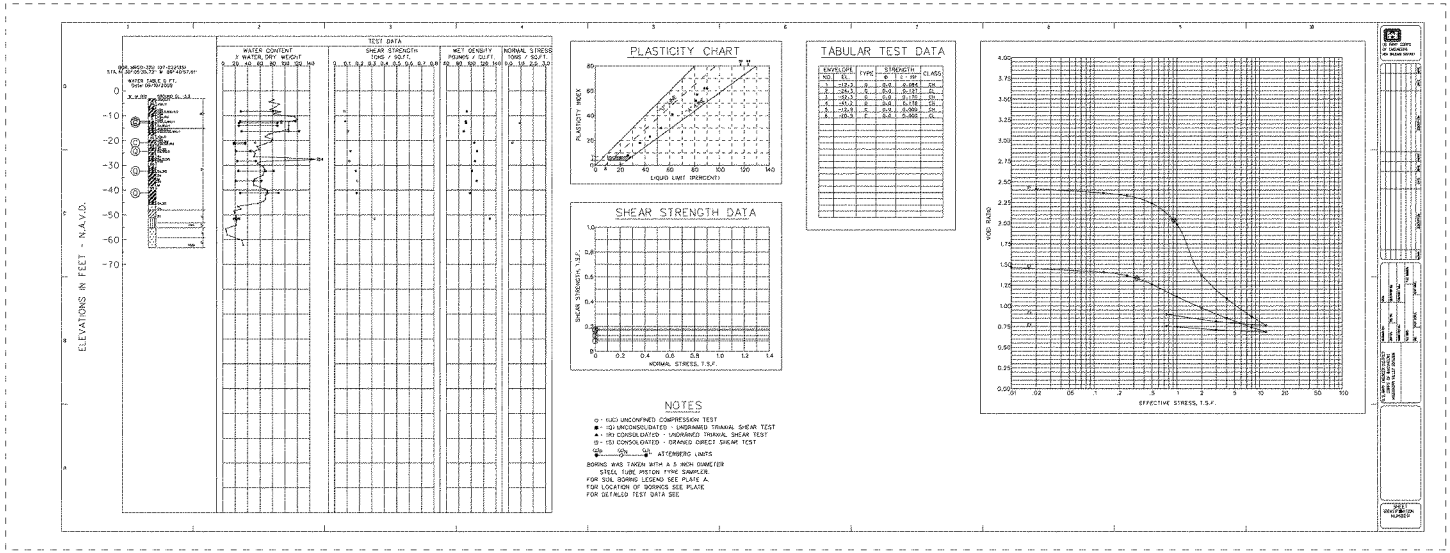
1012

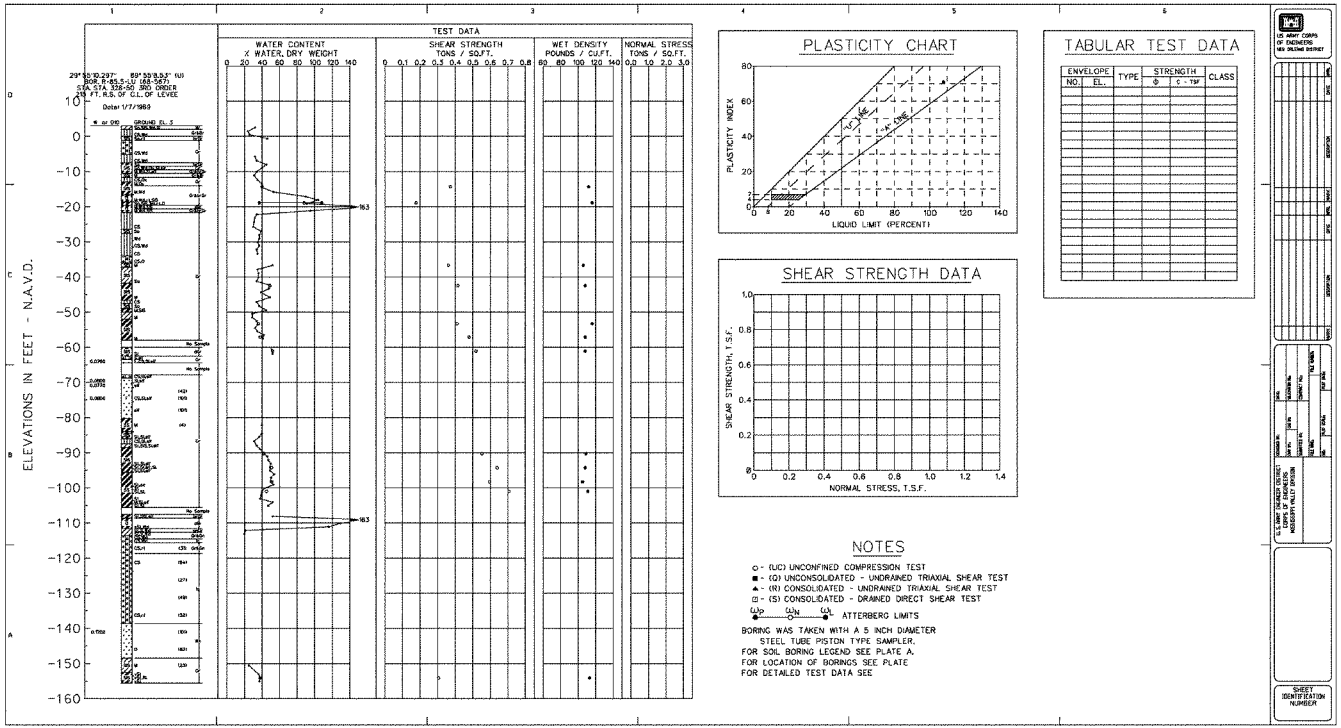

ELEVATIONS IN FEET - N.A.V.D.
TEST DATA
WATER CONTENT
% WATER, DRY WEIGHT
SHEAR STRENGTH
TONS / SQ.FT.
WET DENSITY
POUNDS / CU.FT.
NORMAL STRESS
TONS / SQ.FT.
PLASTICITY CHART
PLASTICITY INDEX
LIQUID LIMIT (PERCENT)
TABULAR TEST DATA
ENVELOPES
TYPE
STRENGTH
CLASS
SHEAR STRENGTH DATA
SHEAR STRENGTH, T.S.F.
NORMAL STRESS, T.S.F.
VOID RATIO
EFFECTIVE STRESS, T.S.F.
NOTES
(UC) UNCONFINED COMPRESSION TEST
(CU) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
(CR) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
(CS) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
ATTERBERG LIMITS
BORING WAS TAKEN WITH A 5 INCH DIAMETER STEEL TURE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE

1013


ELEVATIONS IN FEET - N.A.V.D.
TEST DATA
WATER CONTENT
SHEAR STRENGTH
WET DENSITY
NORMAL STRESS
PLASTICITY CHART
PLASTICITY INDEX
LIQUID LIMIT (PERCENT)
TABULAR TEST DATA
SHEAR STRENGTH DATA
SHEAR STRENGTH, T.S.F.
NORMAL STRESS, T.S.F.
VOID RATIO
EFFECTIVE STRESS, T.S.F.
NOTES
BORING WAS TAKEN WITH A 5 INCH DIAMETER
STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE


ELEVATIONS IN FEET - N.A.V.D.
TEST DATA
WATER CONTENT
% WATER DRY WEIGHT
SHEAR STRENGTH
TSF
WET DENSITY
POUNDS / CU.FT.
NORMAL STRESS
TSF
PLASTICITY CHART
PLASTICITY INDEX
LIQUID LIMIT (PERCENT)
TABULAR TEST DATA
SHEAR STRENGTH DATA
SHEAR STRENGTH, T.S.F.
NORMAL STRESS, T.S.F.
VOID RATIO
EFFECTIVE STRESS, T.S.F.
NOTES
BORING WAS TAKEN WITH A 5 INCH DIAMETER
STEEL TUBE PISTON TYPE SAMPLER
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE


ELEVATIONS IN FEET - N.A.V.D.
TEST DATA
WATER CONTENT
% WATER DRY WEIGHT
SHEAR STRENGTH
TONS / SQ.FT.
WET DENSITY
POUNDS / CU.FT.
NORMAL STRESS
TONS / SQ.FT.
PLASTICITY CHART
PLASTICITY INDEX
LIQUID LIMIT (PERCENT)
TABULAR TEST DATA
ENVELOPE
NO.
EL.
TYPE
STRENGTH
CLASS
SHEAR STRENGTH DATA
SHEAR STRENGTH, T.S.F.
NORMAL STRESS, T.S.F.
VOID RATIO
EFFECTIVE STRESS, T.S.F.
NOTES
(1) - (UC) UNCONFINED COMPRESSION TEST
(2) - (QU) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
(3) - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
(4) - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
ATTERBERG LIMITS
BORING WAS TAKEN WITH A 3 INCH DIAMETER
STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE


TEST DATA
WATER CONTENT
% WATER, DRY WEIGHT
SHEAR STRENGTH
TONS / SQ.FT.
WET DENSITY
POUNDS / CU.FT.
NORMAL STRESS
TONS / SQ.FT.
ELEVATIONS IN FEET - N.A.V.D.
PLASTICITY CHART
PLASTICITY INDEX
LIQUID LIMIT (PERCENT)
"U" LINE
"A" LINE
SHEAR STRENGTH DATA
SHEAR STRENGTH, T.S.F.
NORMAL STRESS, T.S.F.
TABULAR TEST DATA
ENVELOPE
NO.
EL.
TYPE
STRENGTH
CLASS
NOTES
○ - (UC) UNCONFINED COMPRESSION TEST
■ - (Q) UNCONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
▲ - (R) CONSOLIDATED - UNDRAINED TRIAXIAL SHEAR TEST
⊡ - (S) CONSOLIDATED - DRAINED DIRECT SHEAR TEST
ATTERBERG LIMITS
BORING WAS TAKEN WITH A 5 INCH DIAMETER
STEEL TUBE PISTON TYPE SAMPLER.
FOR SOIL BORING LEGEND SEE PLATE A.
FOR LOCATION OF BORINGS SEE PLATE
FOR DETAILED TEST DATA SEE
US ARMY CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION
SHEET IDENTIFICATION NUMBER

ANNEX 5

CONE PENETROMETER LOGS AND SHEAR VANE TESTS

APPENDIX ED-F-2

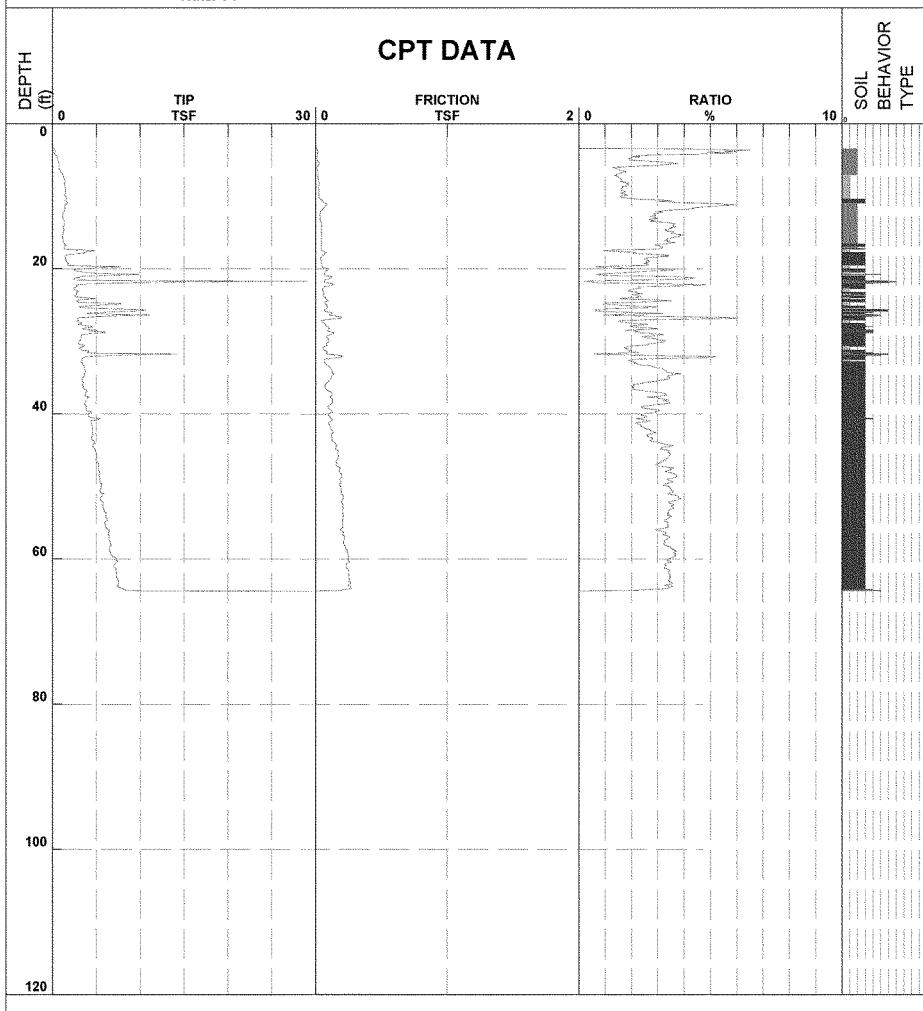
CONE PENETROMETER LOGS AND SHEAR VANE TESTS

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_001C	Location	15.4'N 89 33' 09.1'E
Operator	Glenn Johnson	Date and Tim	27-Oct-2009 10:57:39	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-0.4		

Water 3'7"



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

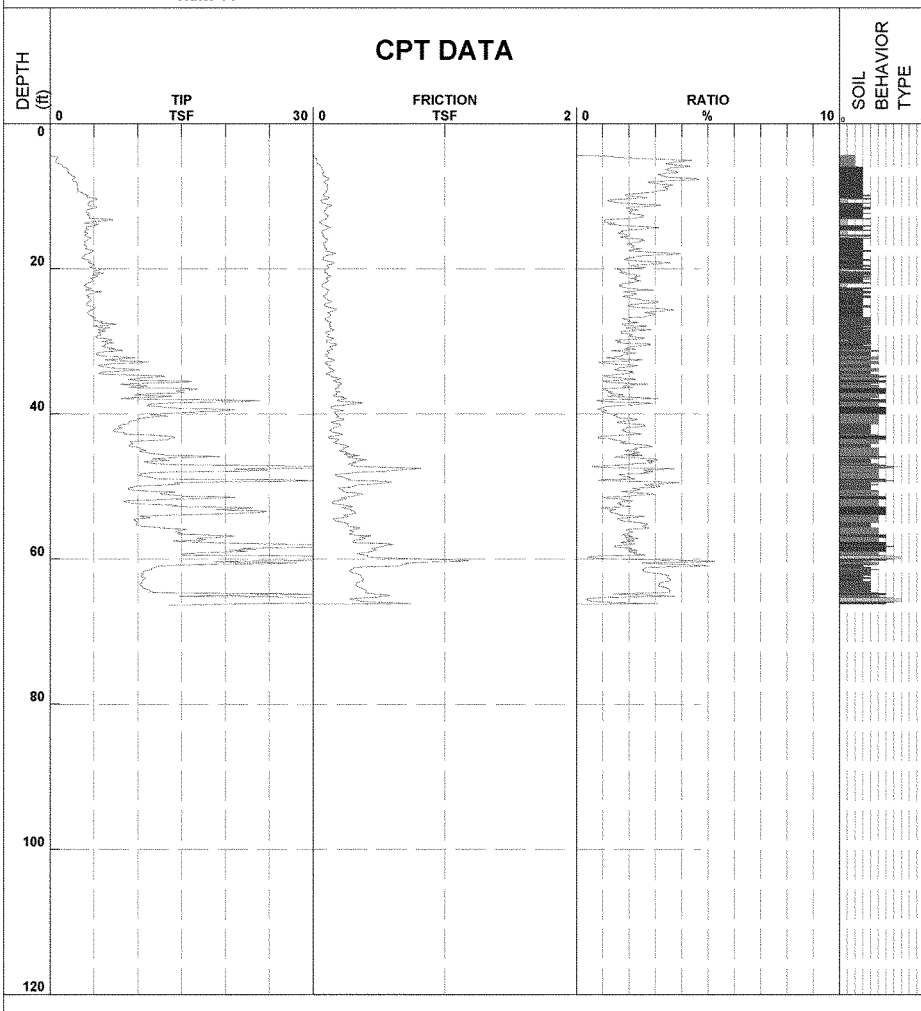
Robertson et al. 1986 * Overconsolidated or Cemented

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_002C	Location	30 01'09.3'N 89 31' 26.6"E
Operator	Glenn Johnson	Date and Tim	26-Oct-2009 13:58:39	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-2.1		

Water 4'5"



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

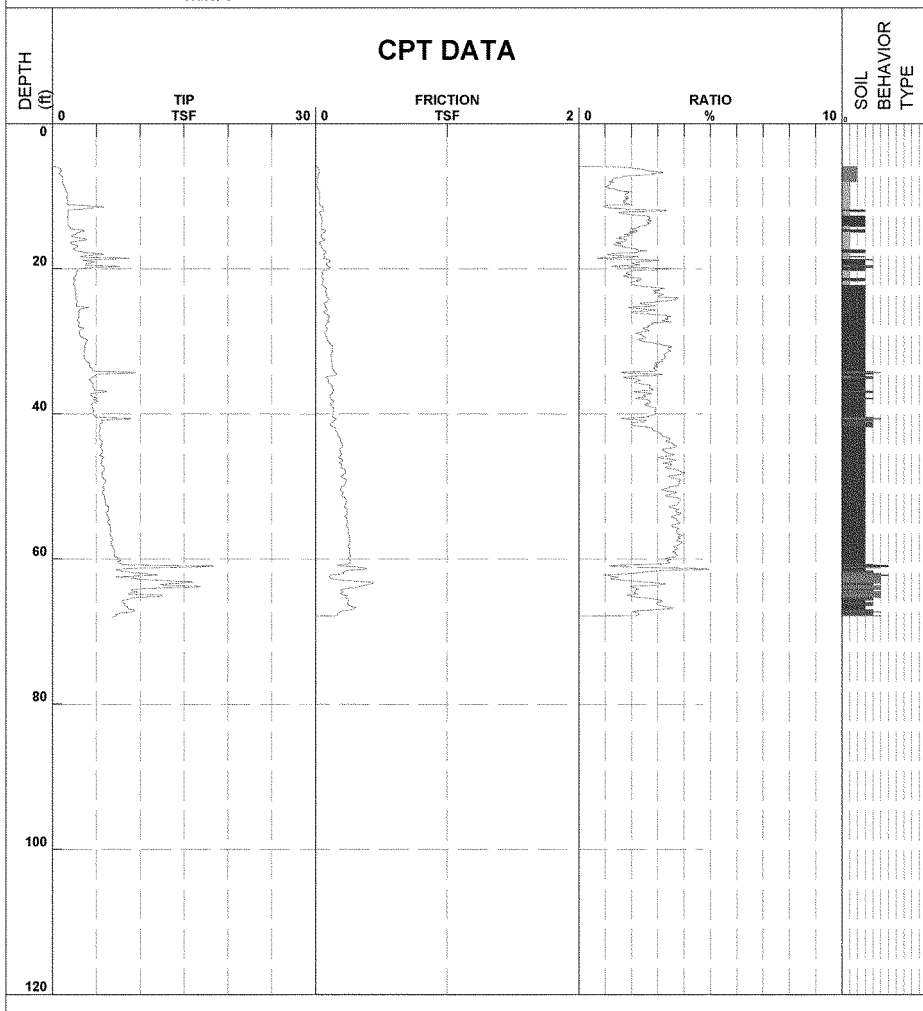
Robertson et al. 1986 * Overconsolidated or Cemented

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_003C	Location	30 02' 11.7"N 89 29'47.8"E
Operator	Glenn Johnson	Date and Tim	26-Oct-2009 11:37:13	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-1.9		

***Water 6"**



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

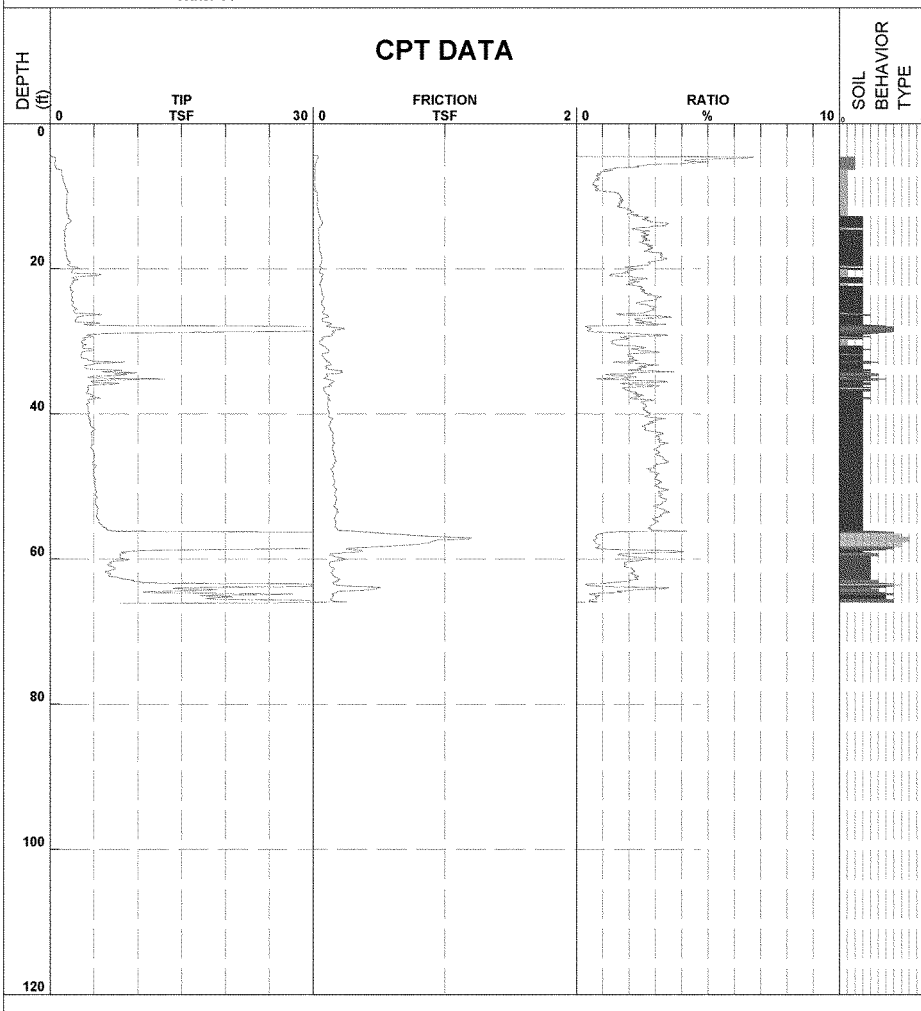
Robertson et al. 1986 * Overconsolidated or Cemented

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_04C	Location	30 03' 55.1"N 89 29' 33.6'E
Operator	Glenn Johnson	Date and Tim	26-Oct-2009 07:53:32	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-2.3		

Water 4'7"



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

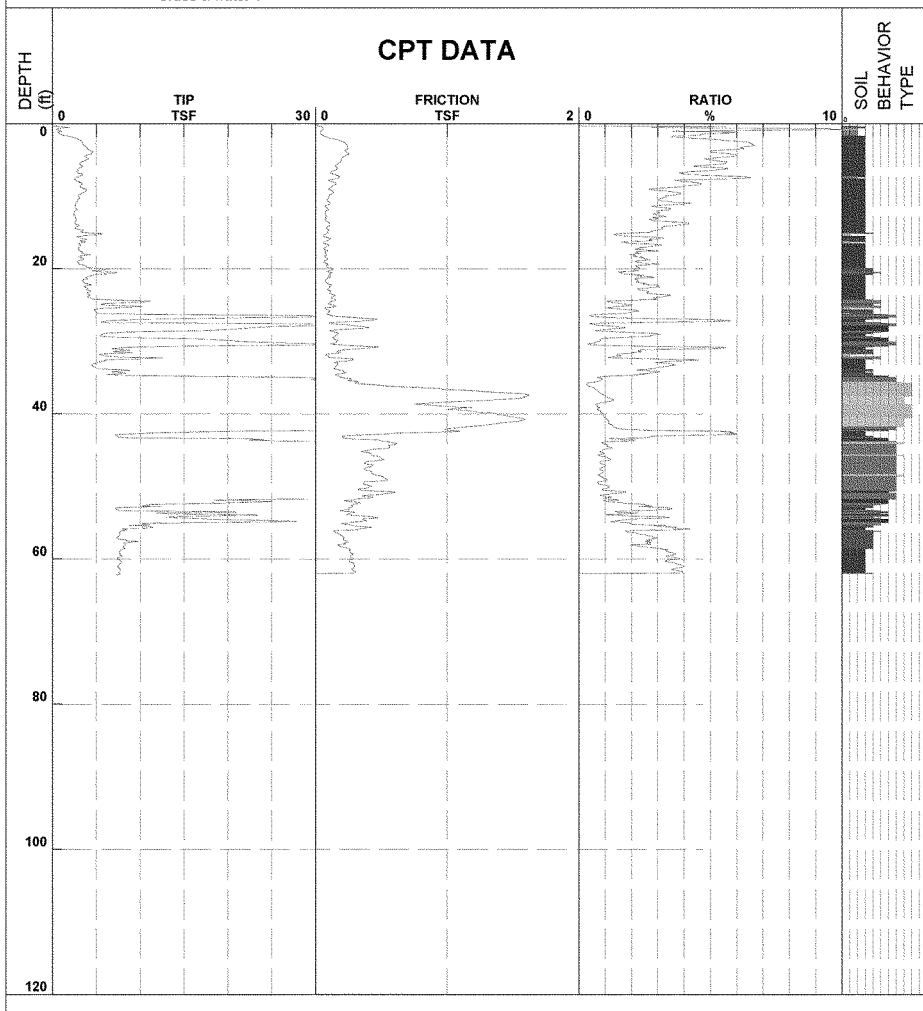
Robertson et al. 1986 * Overconsolidated or Cemented

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_005C	Location	29 52' 28 8"N 89 29' 20.0"E
Operator	Glenn Johnson	Date and Tim	12-Oct-2009 08:15:54	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	N/A		

Grass & water 4"



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

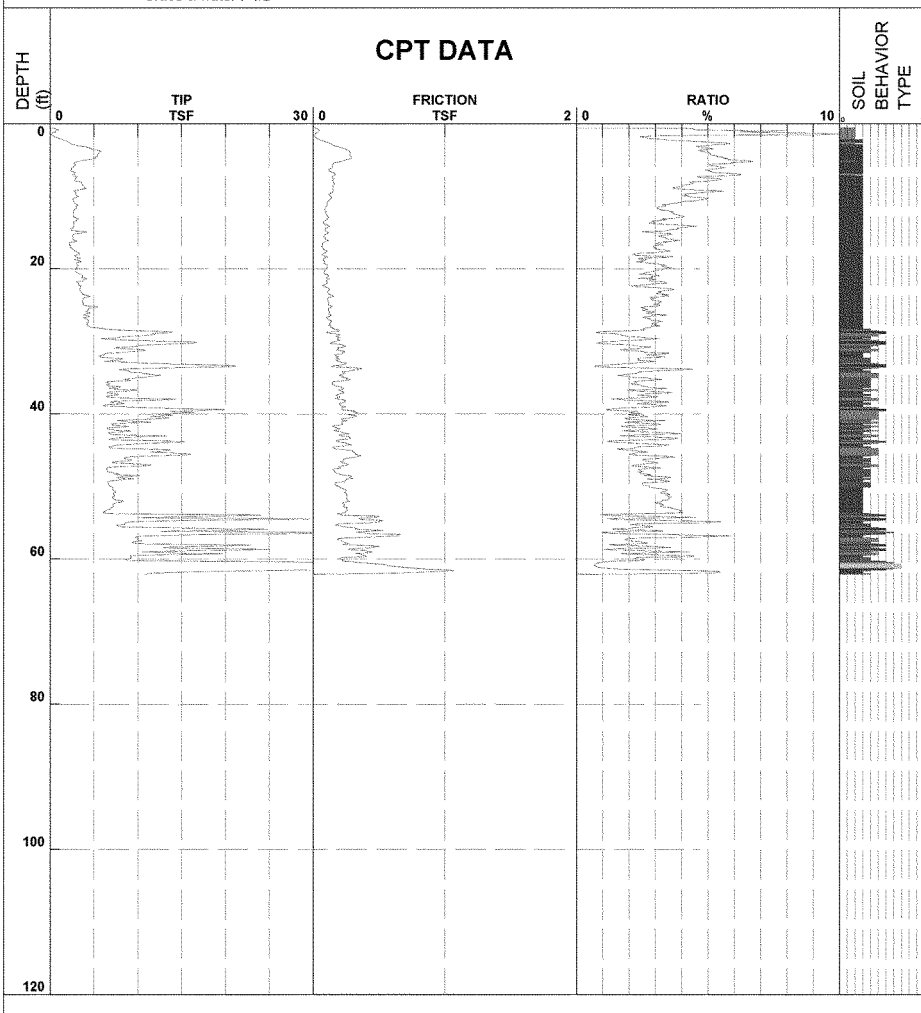
Robertson et al. 1986 * Overconsolidated or Cemented

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_006C	Location	29 50' 44.7"N 89 28' 56.5"E
Operator	Glenn Johnson	Date and Tim	11-Oct-2009 13:35:03	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	N/A		

Grass & water 7 1/2"



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

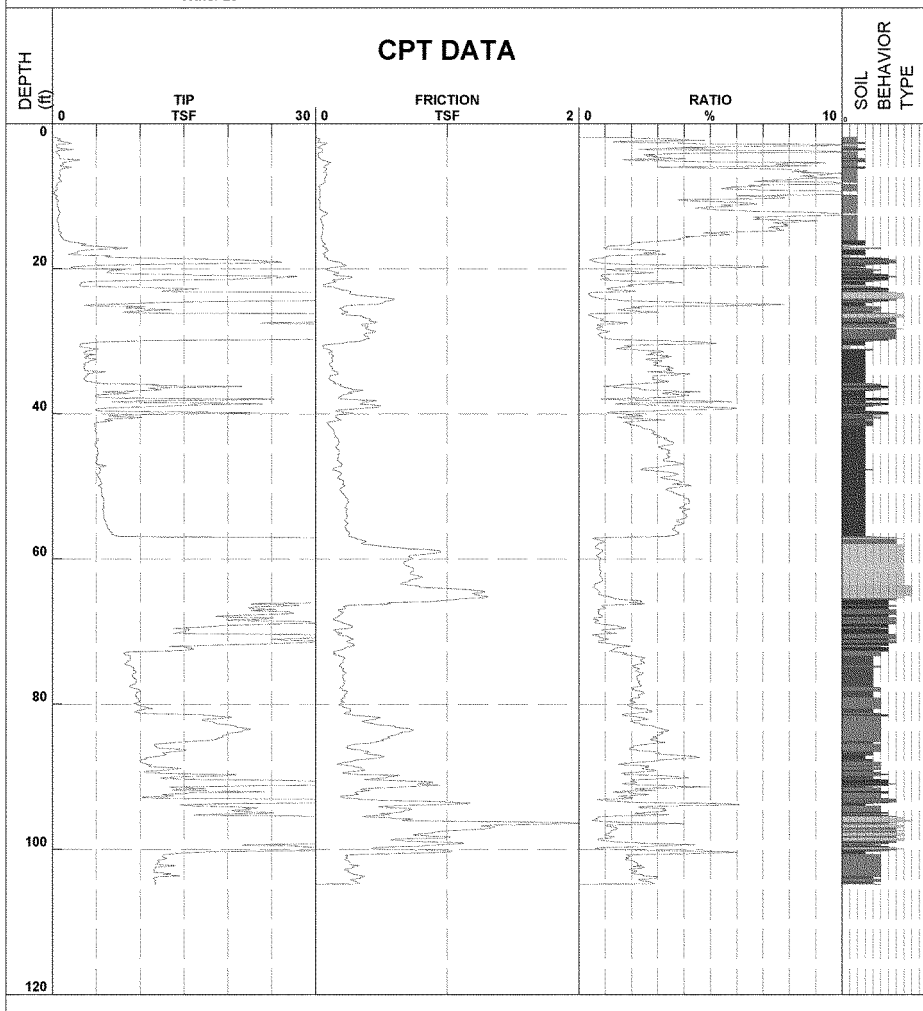
Robertson et al. 1986 * Overconsolidated or Cemented

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_007C	Location	29 56' 16.5"N 89 53' 48.6"E
Operator	Glenn Johnson	Date and Tim	14-Oct-2009 08:45:31	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	N/A		

Water 23"



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

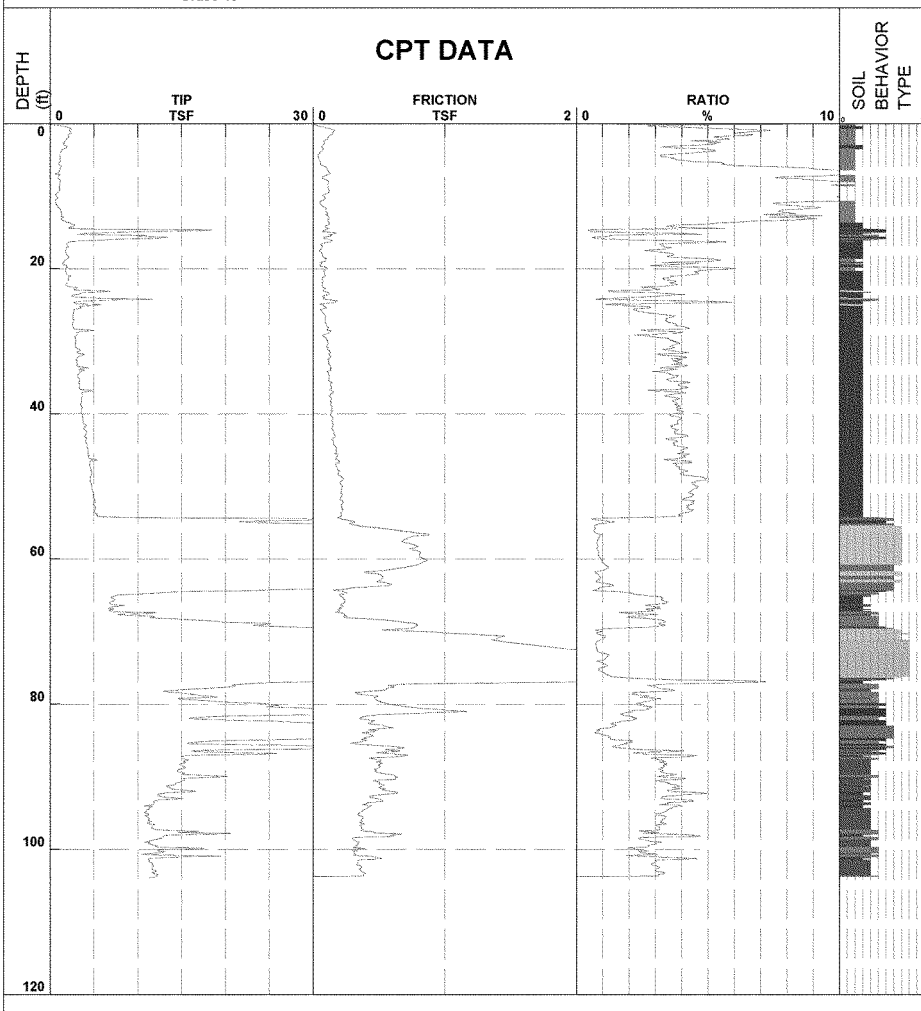
Robertson et al. 1986 * Overconsolidated or Cemented

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_008C	Location	29 57' 14.9"N 89 52' 31.5"E
Operator	Glenn Johnson	Date and Tim	13-Oct-2009 09:04:33	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	N/A		

Grass 10



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

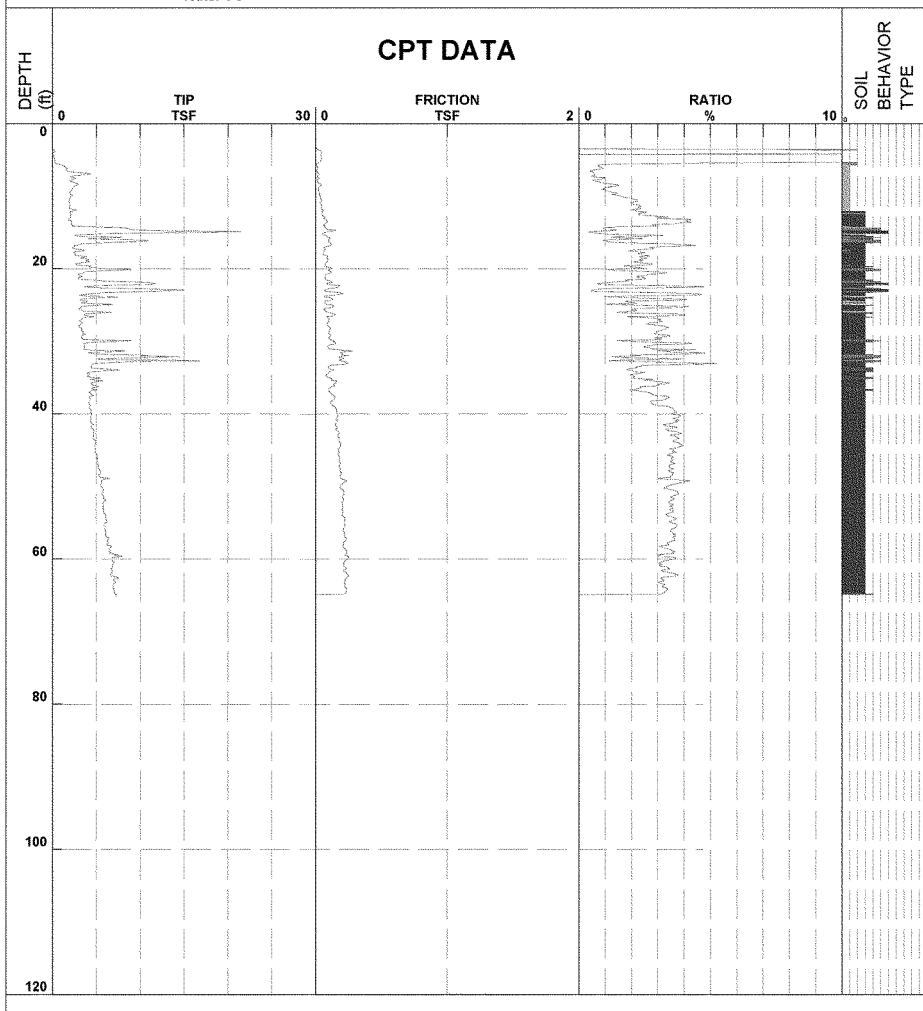
Robertson et al. 1986 * Overconsolidated or Cemented

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_9C	Location	29 58' 17.9"N 89 25' 41.0"E
Operator	Glenn Johnson	Date and Tim	20-Oct-2009 12:45:09	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-1.9		

Water 3'6"*



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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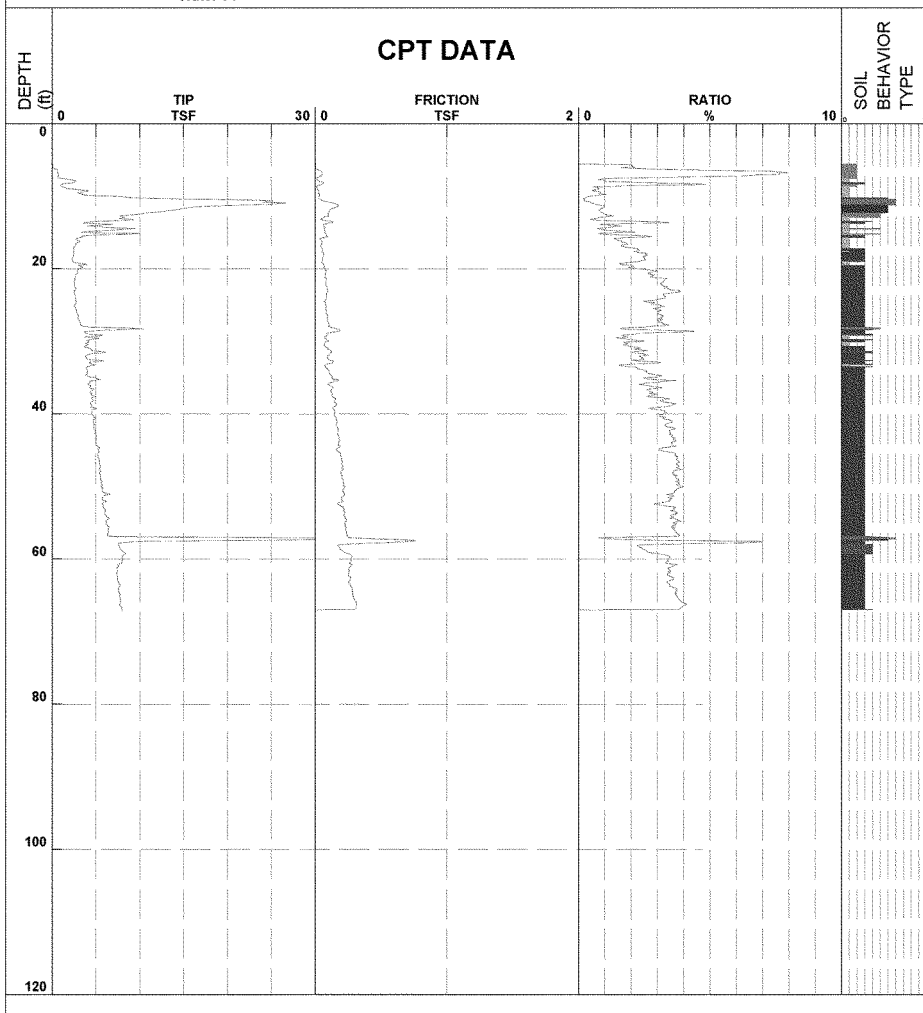
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_10C	Location	29 57' 50.4" N 89 23' 49.6" E
Operator	Glenn Johnson	Date and Tim	21-Oct-2009 09:03:02	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-2.5		

Water 5'7"



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

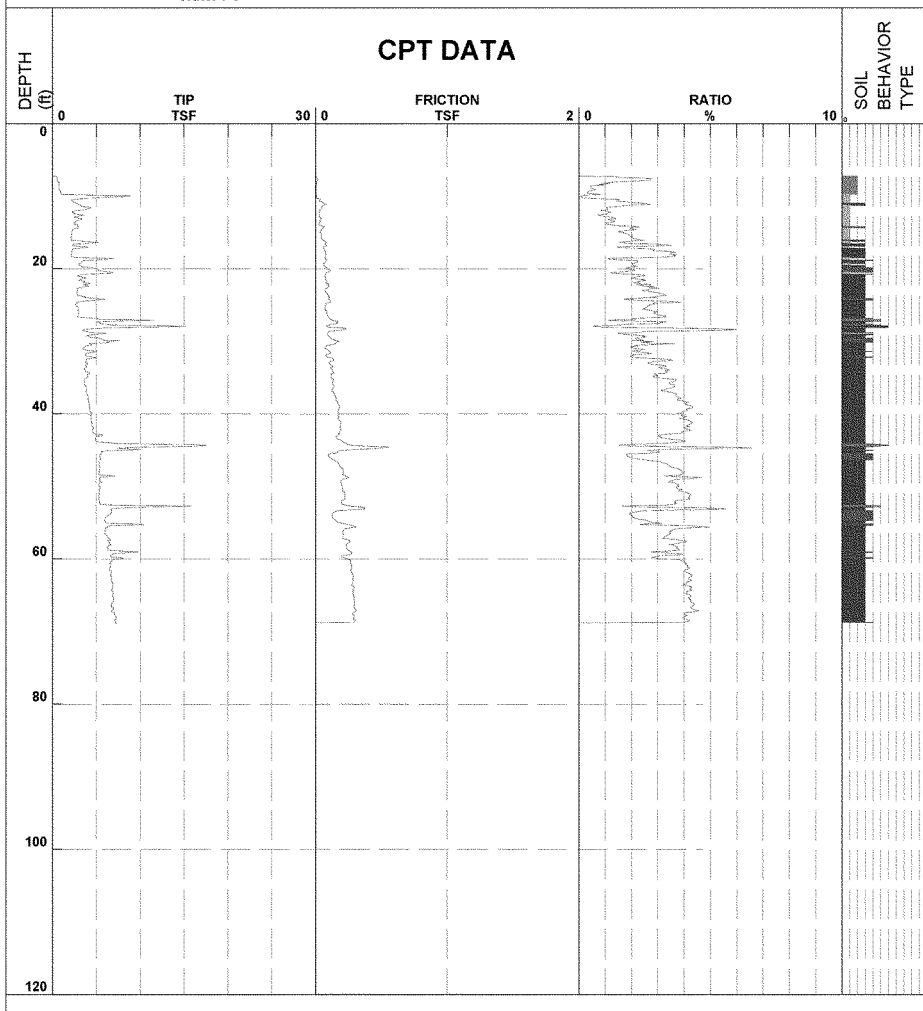
Robertson et al. 1986 * Overconsolidated or Cemented

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_11C	Location	29 56' 26.7"N 89 22' 47.1"E
Operator	Glenn Johnson	Date and Tim	21-Oct-2009 12:02:03	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-2.9		

Water 7'3"



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

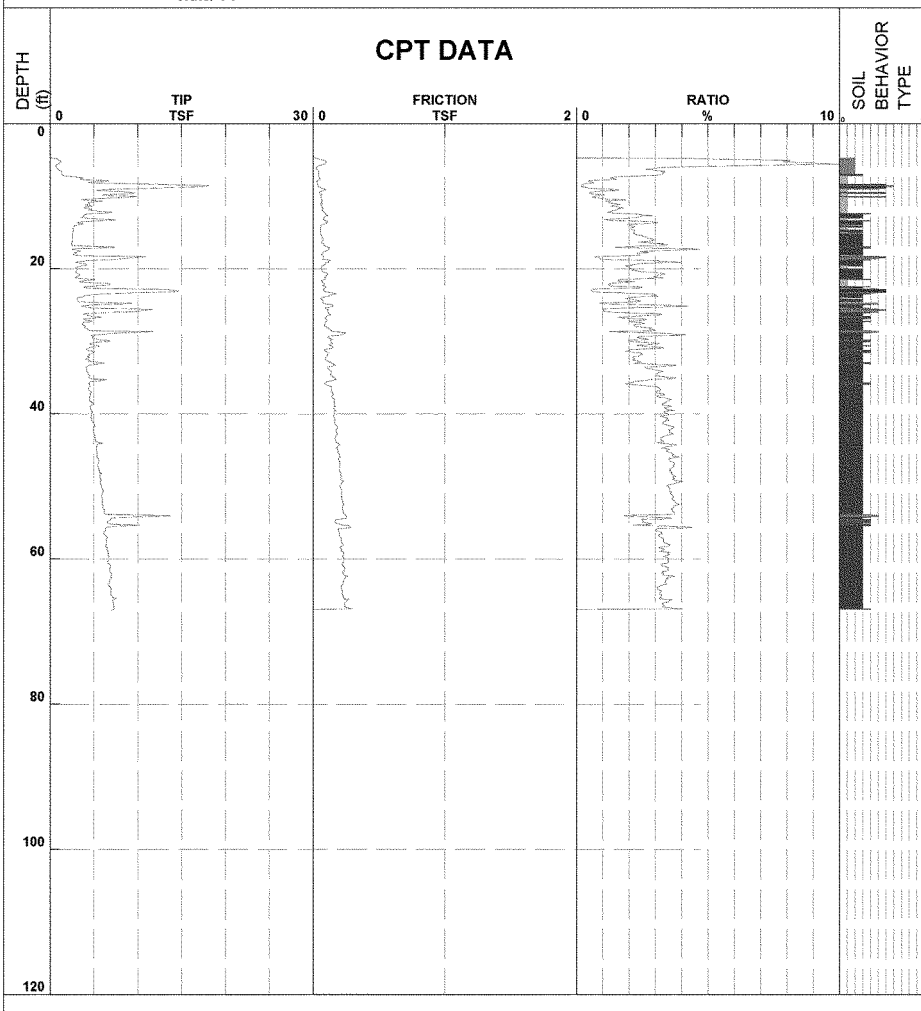
Robertson et al. 1986 * Overconsolidated or Cemented

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_12C	Location	29 54' 40.1"N 89 22' 40.8"E
Operator	Glenn Johnson	Date and Tim	21-Oct-2009 14:10:32	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-2.4		

Water 5'3"



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

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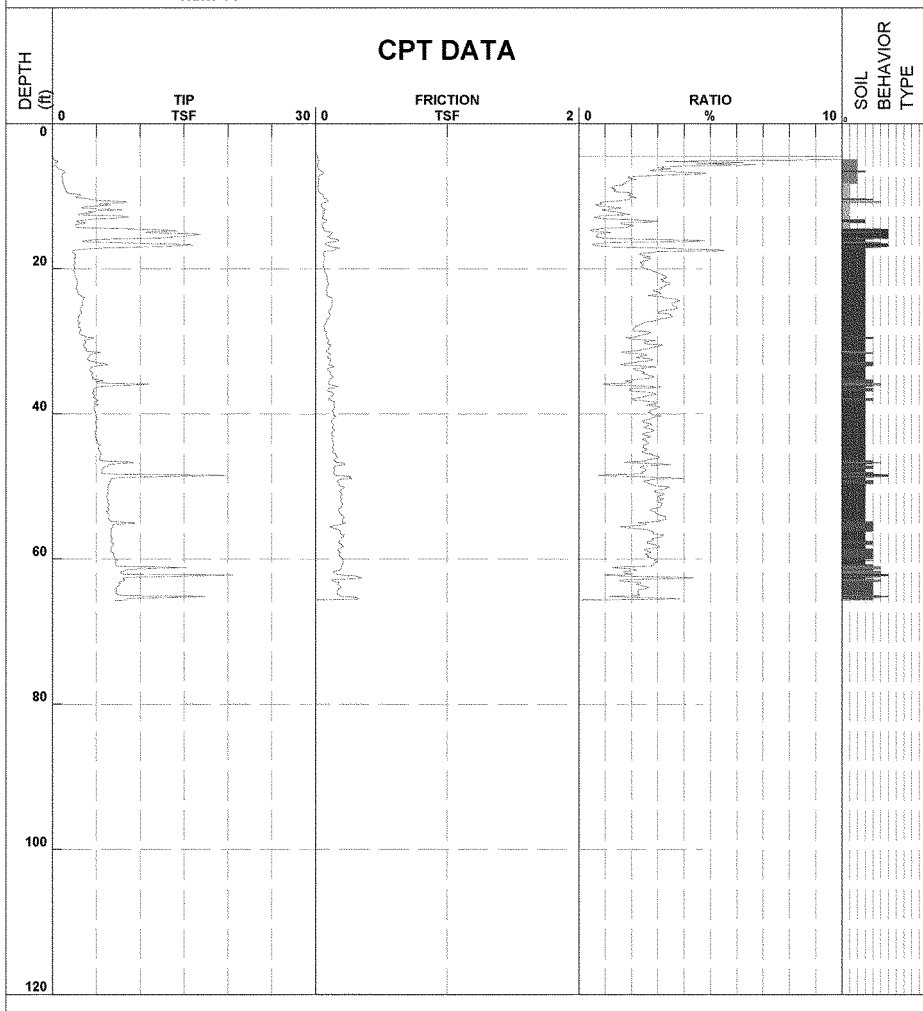
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_013C	Location	29 51' 38.7"N 89 20' 49.2"E
Operator	Glenn Johnson	Date and Tim	12-Nov-2009 08:54:04	Cone Number	F7.5CKE2HAW21513
Client	USACE	Elevation	-2.5		

Water 4'5"



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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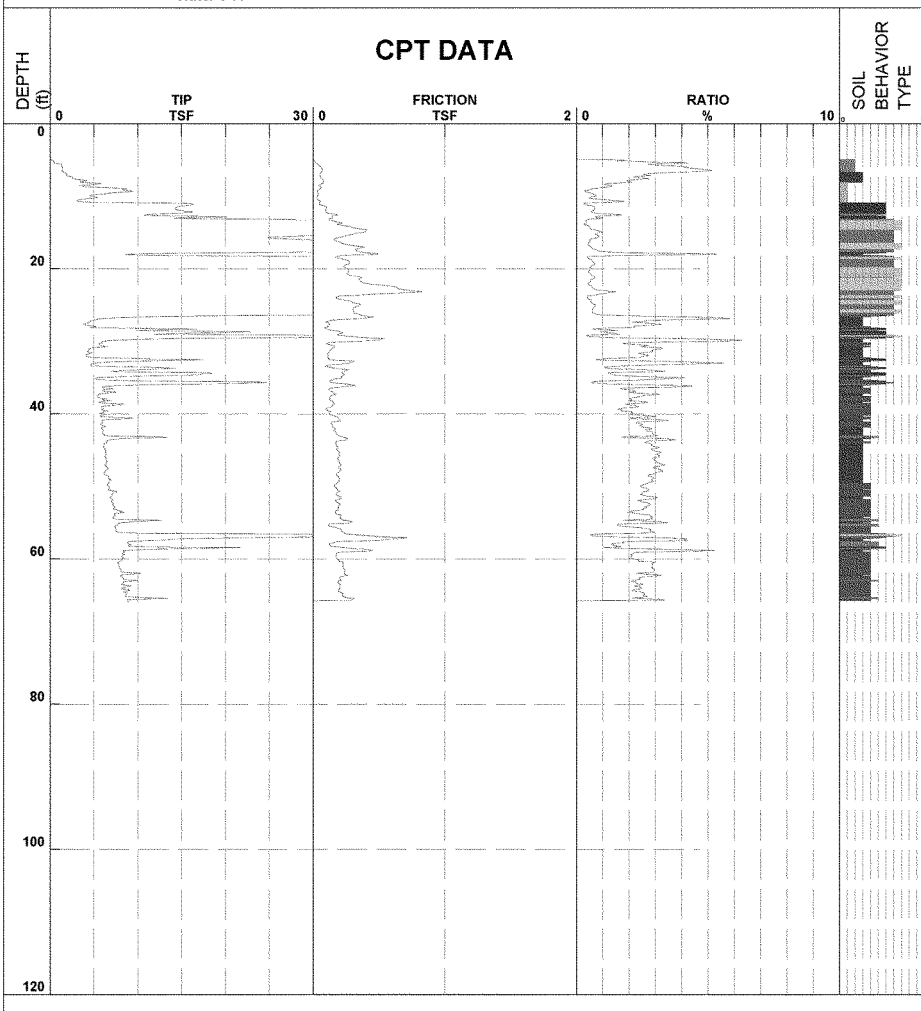
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_014C	Location	29 50' 37.3"N 89 22' 17.9'E
Operator	Glenn Johnson	Date and Tim	12-Nov-2009 11:17:17	Cone Number	F7.5CKE2HAW21513
Client	USACE	Elevation	-2.2		

Water 4'11"*



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

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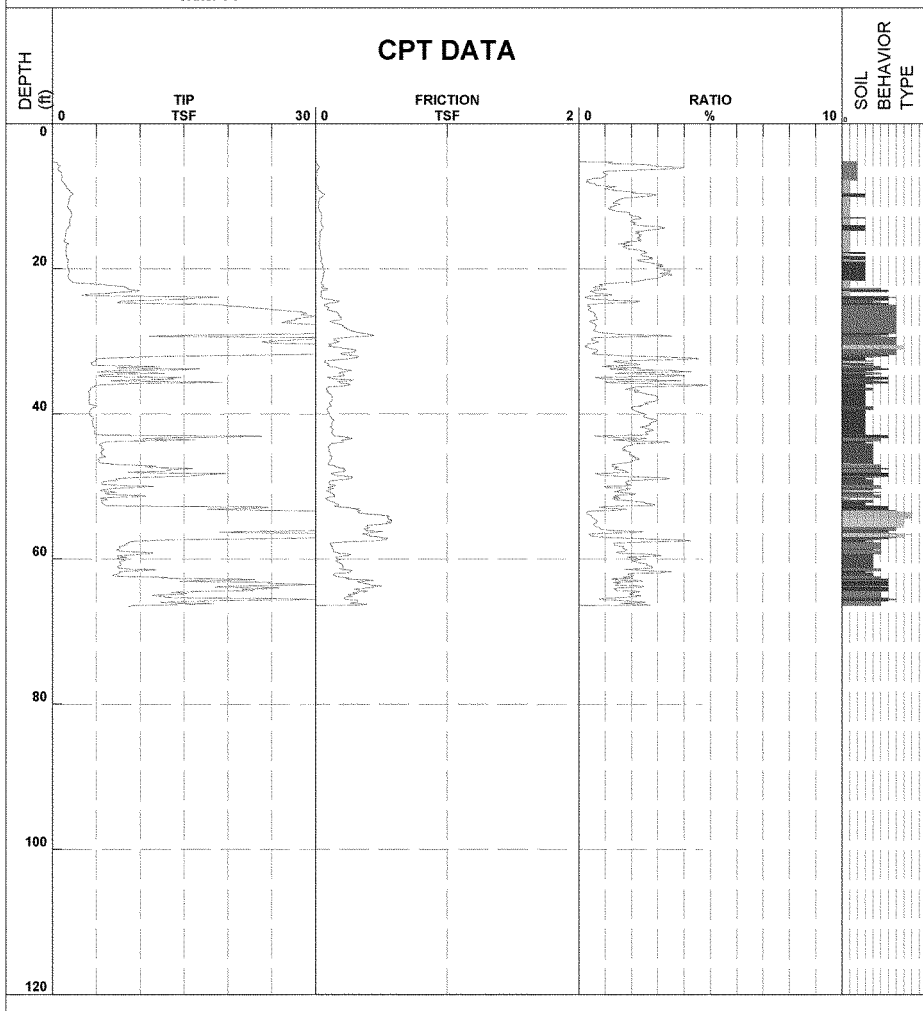
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_015C	Location	29 49' 19.1"N 89 22' 44.0"E
Operator	Glenn Johnson	Date and Tim	12-Nov-2009 13:33:11	Cone Number	F7.5CKE2HAW21513
Client	USACE	Elevation	-0.2		

Water 5'3"



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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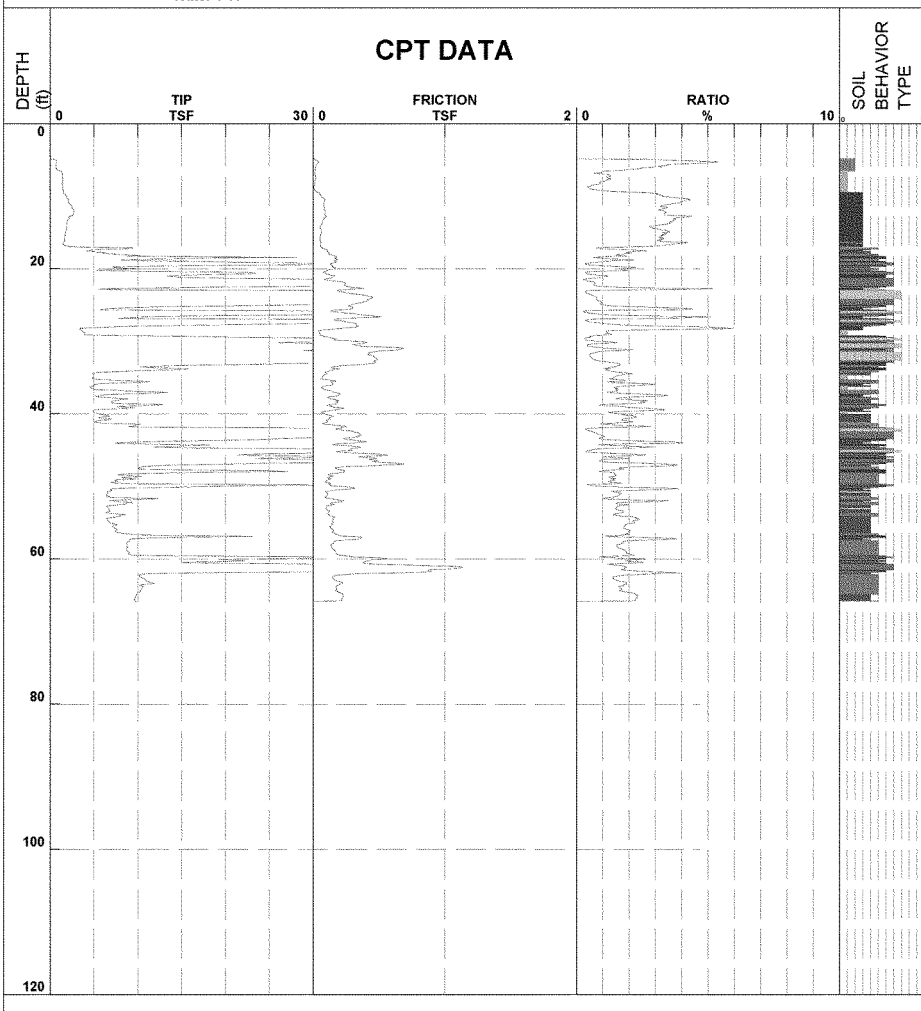
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_016C	Location	29 48' 40.4"N 89 21'21.9"E
Operator	Glenn Johnson	Date and Tim	13-Nov-2009 09:25:56	Cone Number	F7.5CKE2HAW21513
Client	USACE	Elevation	-2.1		

Water 4'11"*



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

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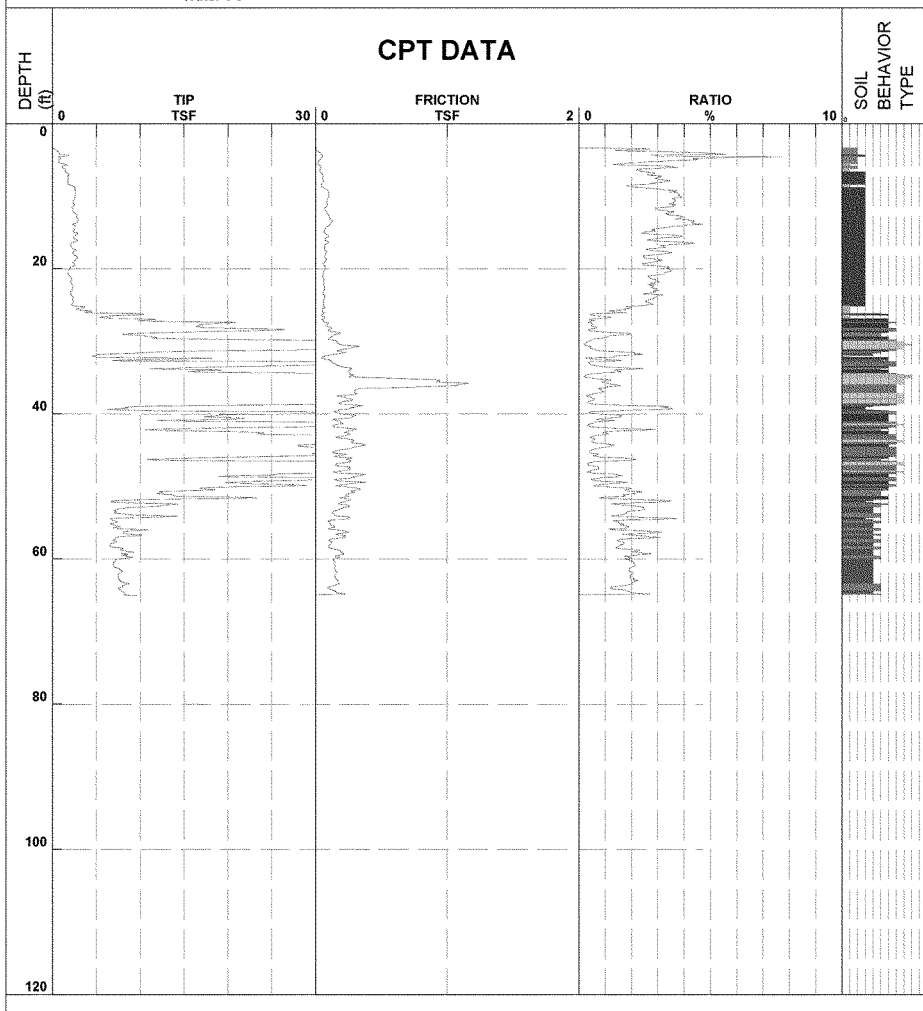
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_017C	Location	29 46' 52.2"N 89 21'41.2"E
Operator	Glenn Johnson	Date and Tim	13-Nov-2009 12:15:21	Cone Number	F7.5CKE2HAW21513
Client	USACE	Elevation	-1.8		

Water 3'6"*



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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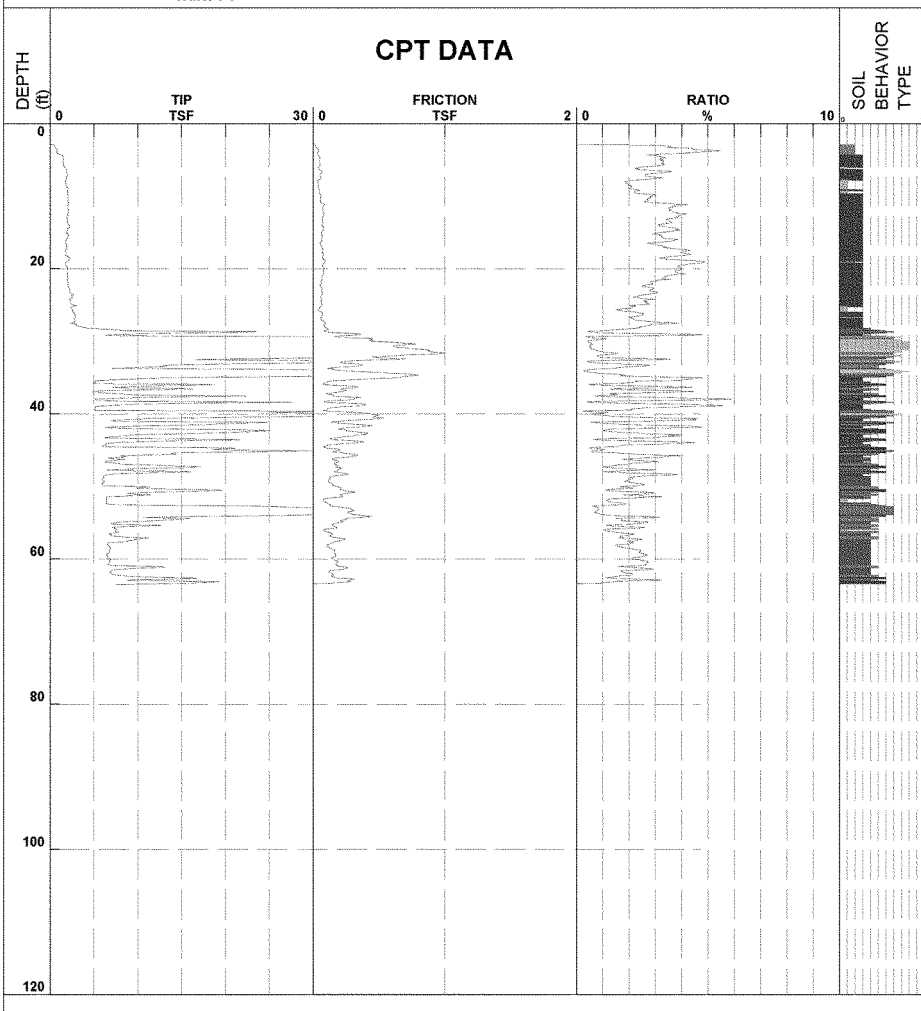
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_018C	Location	29 47' 30.0"N 89 23' 14.5"E
Operator	Glenn Johnson	Date and Tin	14-Nov-2009 09:12:24	Cone Number	F7.5CKE2HAW21513
Client	USACE	Elevation	-2.2		

Water 3'0"*



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

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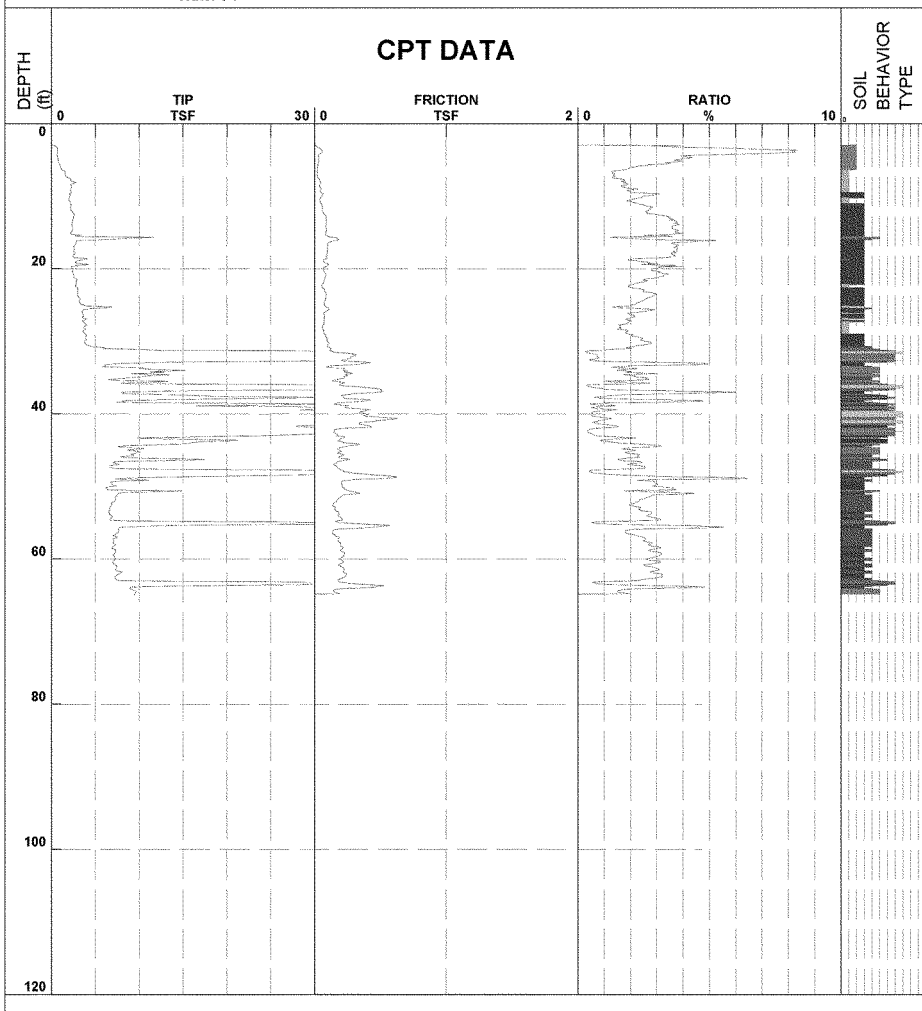
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_019C	Location	29 46'18.8"N 89 24' 21.2"E
Operator	Glenn Johnson	Date and Tim	14-Nov-2009 11:57:17	Cone Number	F7.5CKE2HAW21513
Client	USACE	Elevation	-2.3		

Water 3'0"



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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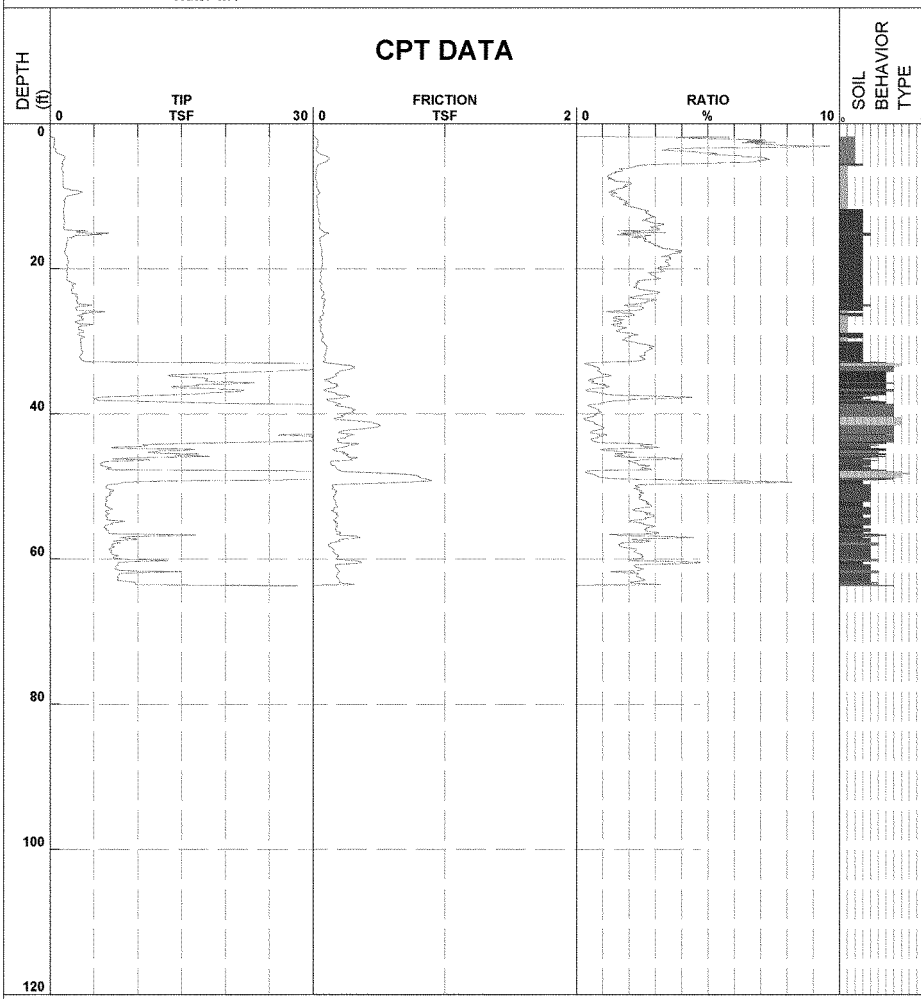
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_020C	Location	29 45' 16.2"N 89 25' 03.4"E
Operator	Glenn Johnson	Date and Tim	15-Nov-2009 08:51:28	Cone Number	F7.5CKE2HAW21513
Client	USACE	Elevation	-2.7		

Water 1.77*



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

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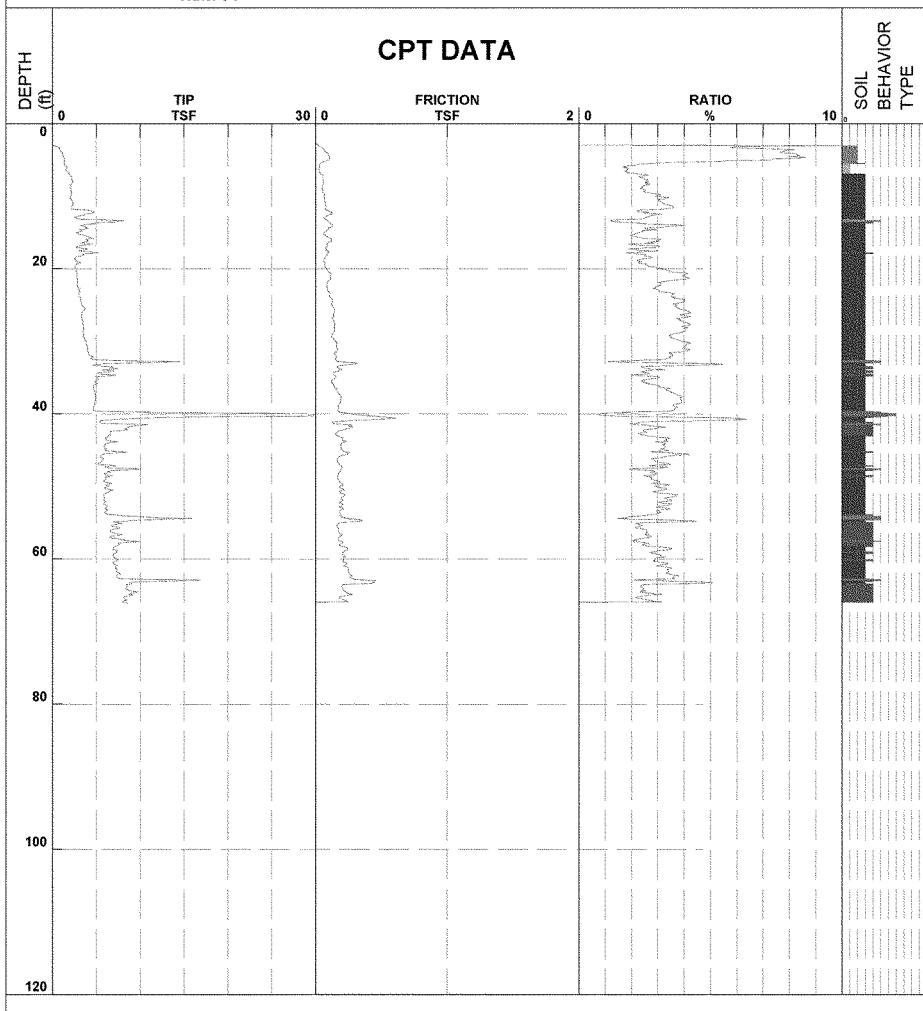
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_21C	Location	29 44'17.8'N 89 25' 51.3"E
Operator	Glenn Johnson	Date and Tim	24-Oct-2009 12:34:33	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-2.2		

Water 3'0"



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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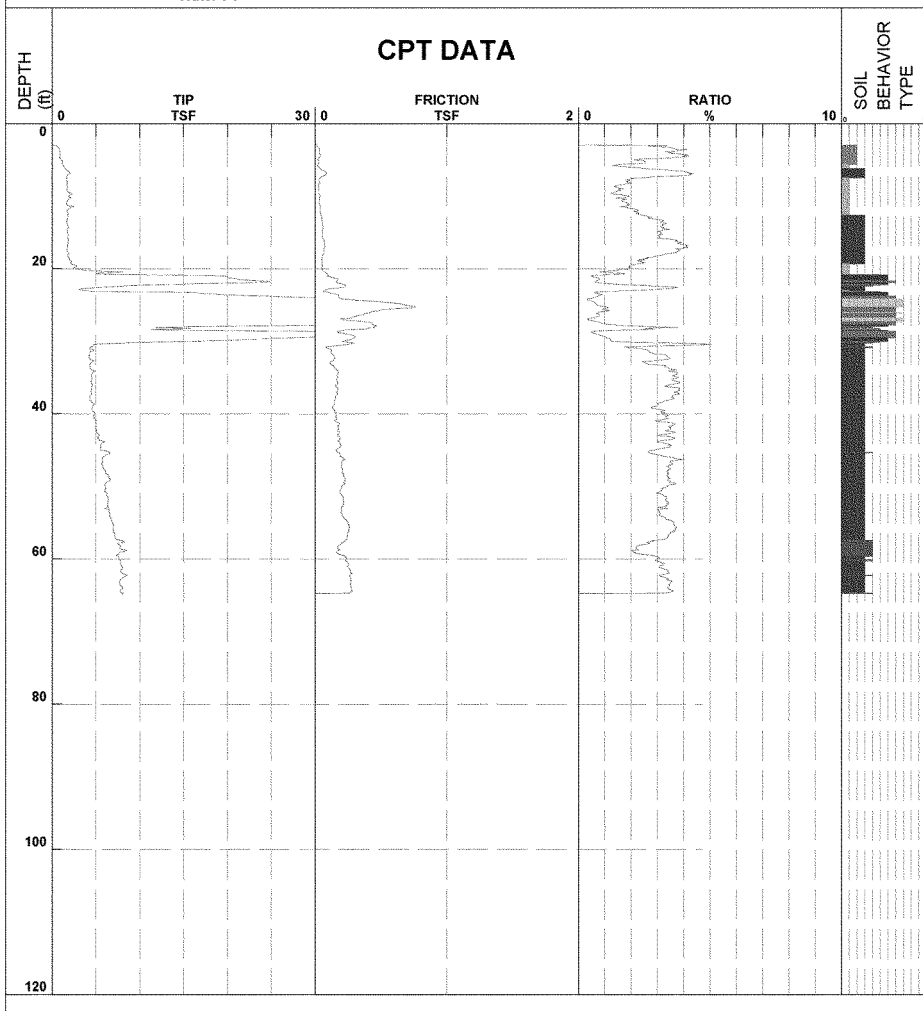
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_22C	Location	29 42' 31.5"N 89 25' 33.4"E
Operator	Glenn Johnson	Date and Tim	24-Oct-2009 09:50:46	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-1.1		

Water 3'0*



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

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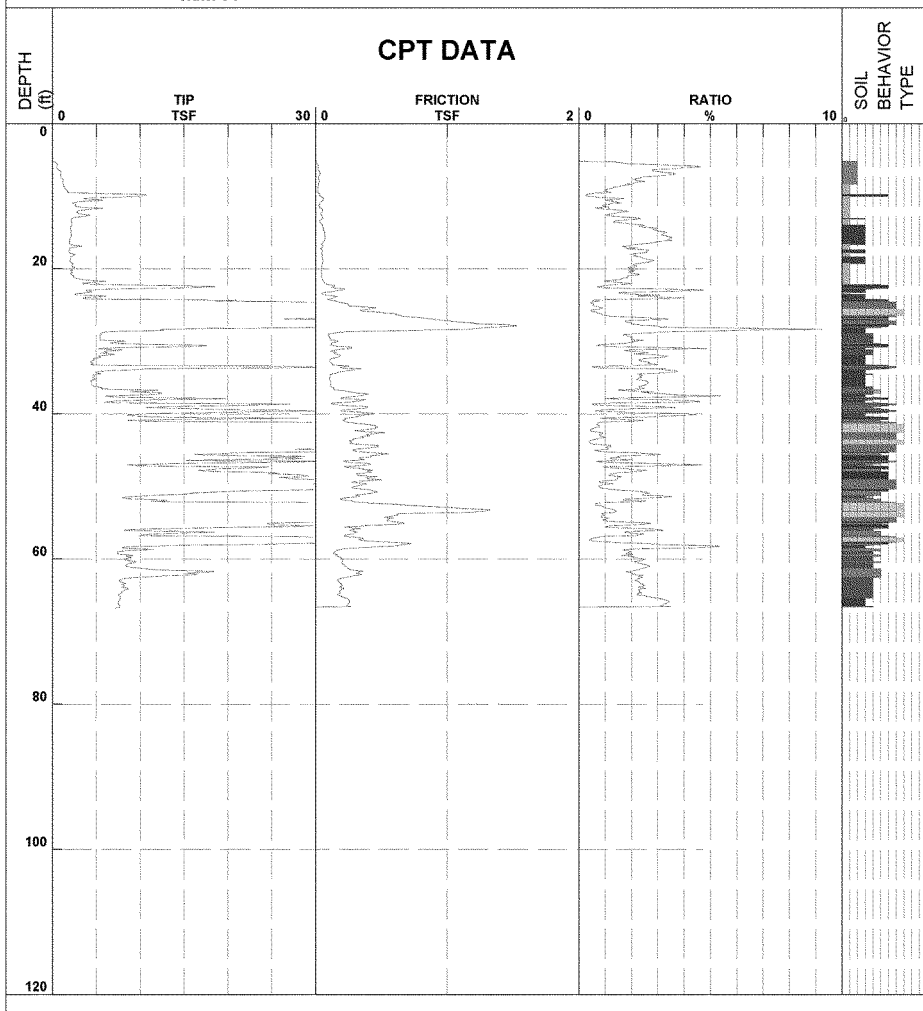
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_23C	Location	29 40' 56.4"N 89 26'24.5"E
Operator	Glenn Johnson	Date and Tim	22-Oct-2009 12:05:19	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-3		

Water 5'5"



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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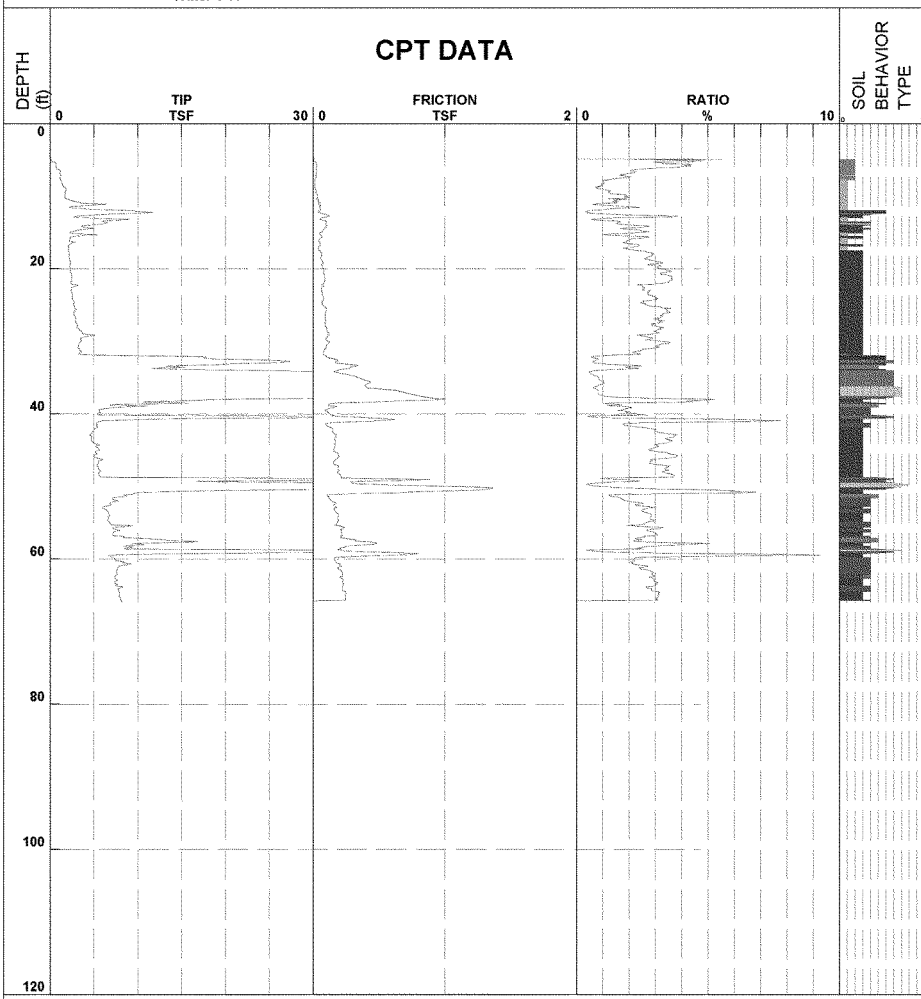
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_24C	Location	29 39' 38.0"N 89 26' 16.2"E
Operator	Glenn Johnson	Date and Tim	23-Oct-2009 15:07:50	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-2.9		

Water 4'11"



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

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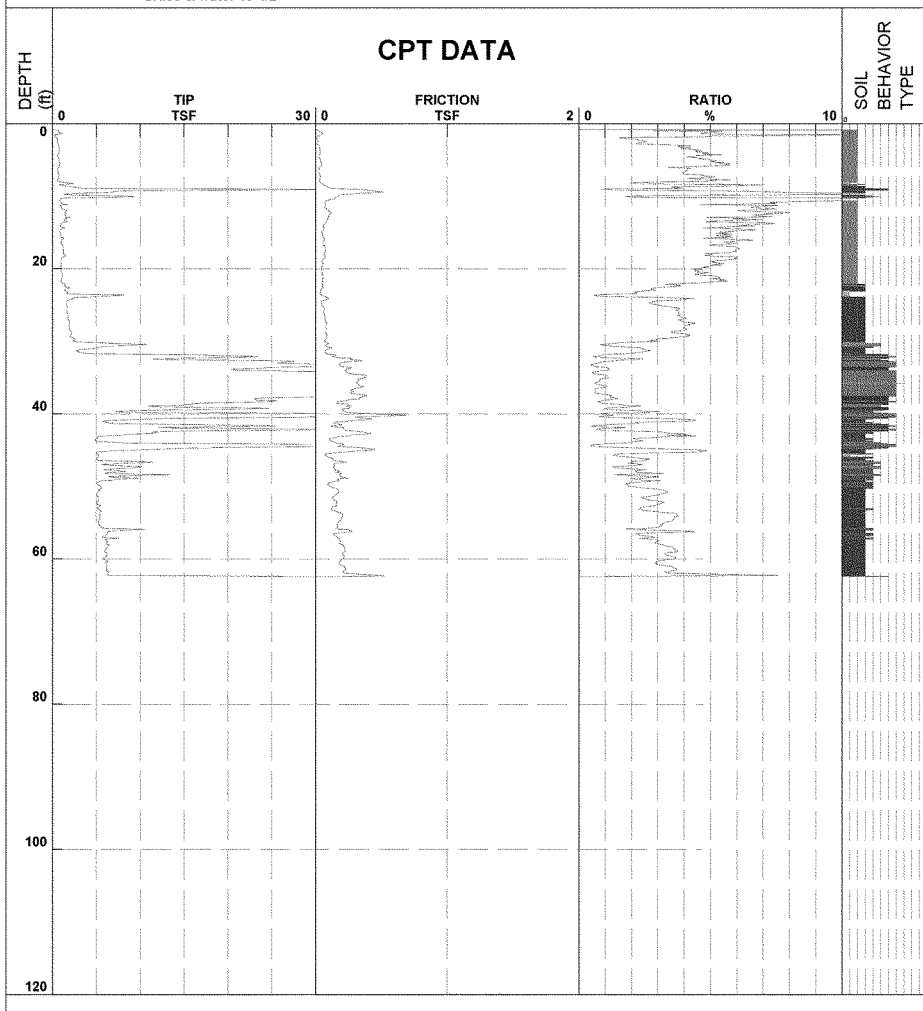
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_025C	Location	29 50'36.7"N 89 34'41.3'E
Operator	Glenn Johnson	Date and Tim	11-Oct-2009 09:17:52	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	N/A		

Grass & water 10 1/2"*



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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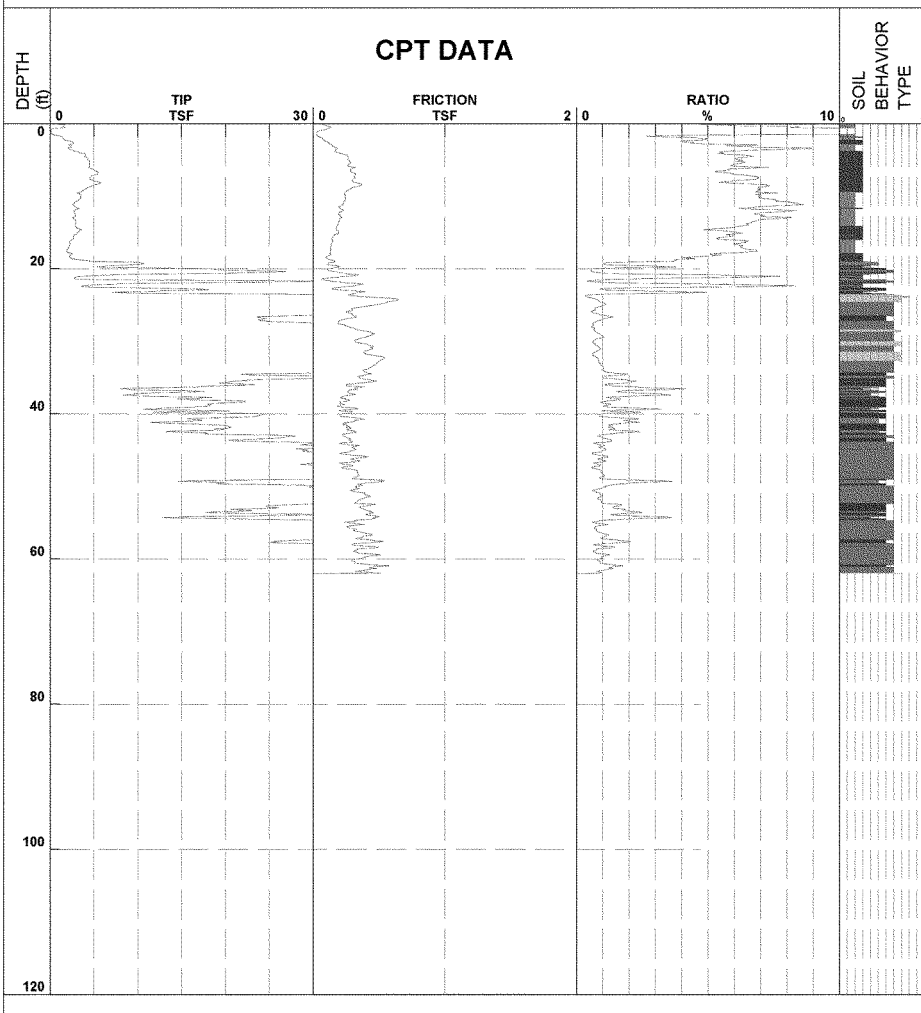
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_026C	Location	29 50' 13.1"N 89 32' 55.3"E
Operator	Glenn Johnson	Date and Tim	10-Oct-2009 12:10:22	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	N/A		



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

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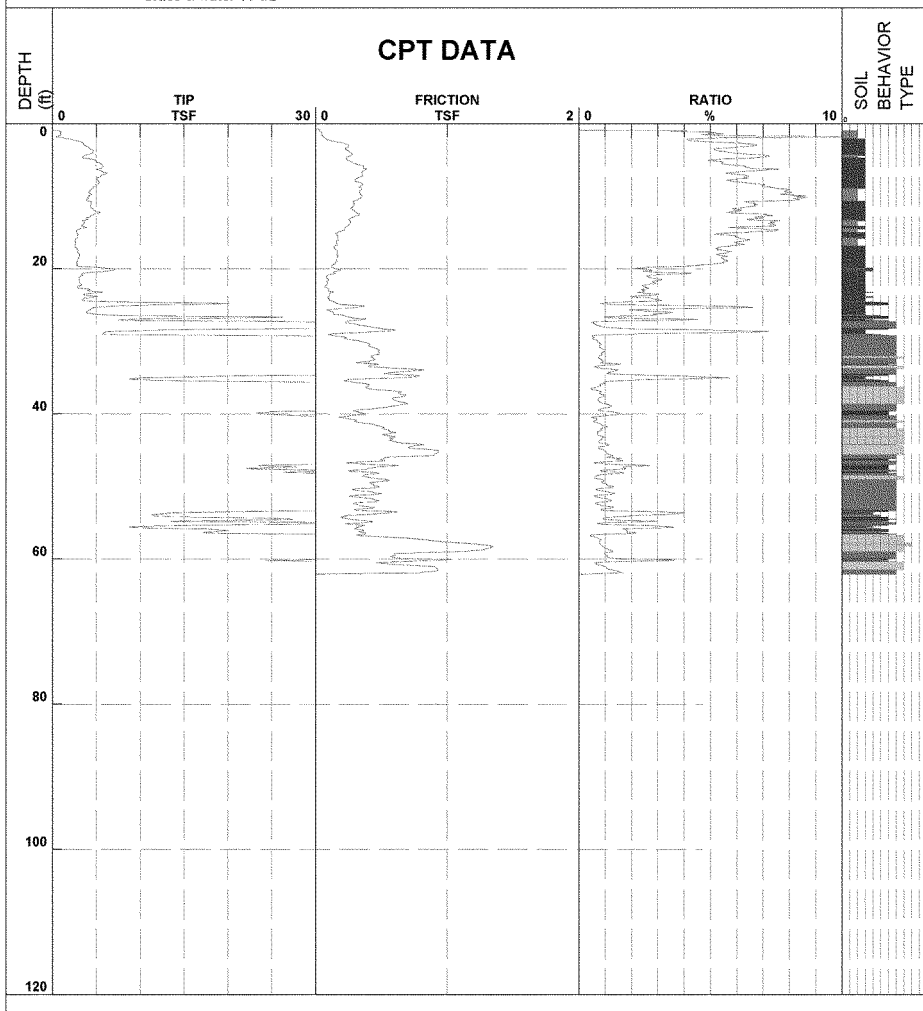
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_027C	Location	29 51' 38.1"N 89 31' 45.8"E
Operator	Glenn Johnson	Date and Tim	10-Oct-2009 09:28:27	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	N/A		

Grass & water 11 1/2"



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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MRGO Ecosystems Restoration

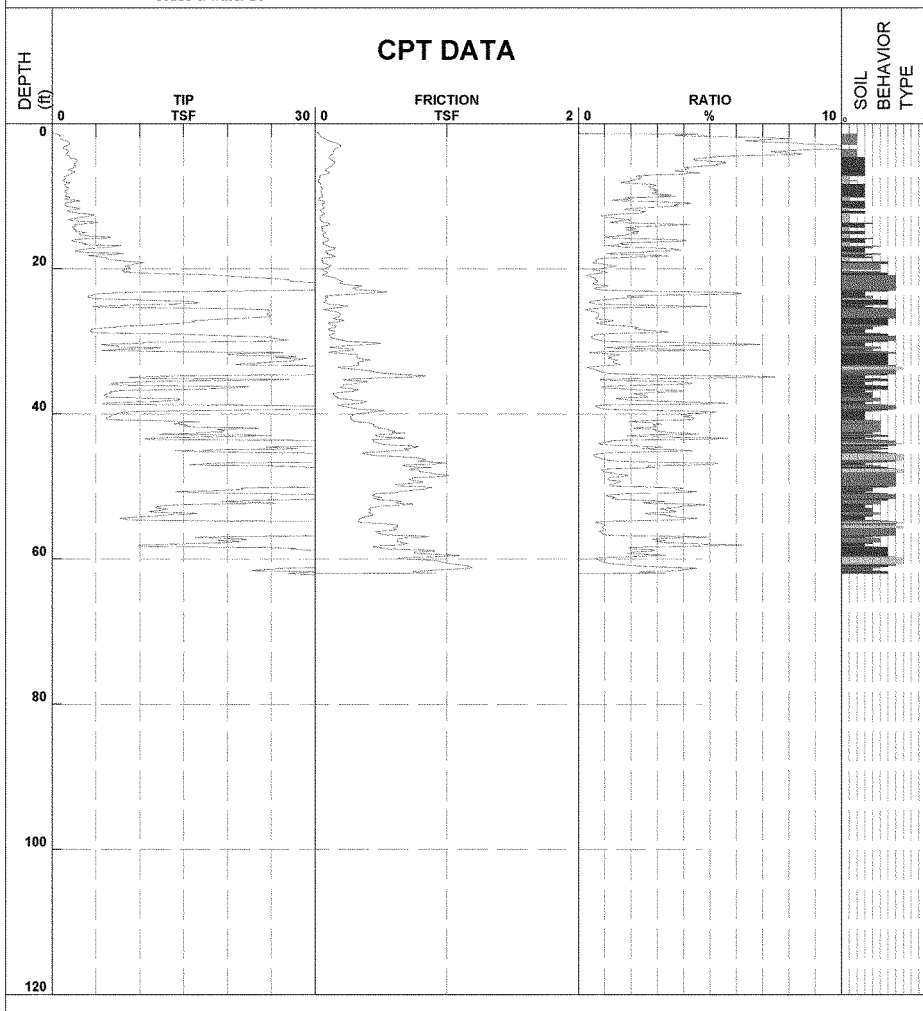
FFEB

Job Number 04.0022-0135 | CPT Number MRGO_028C | Location 29 53' 11.2"N 89 31' 07.2"E

Operator Glenn Johnson | Date and Tim 09-Oct-2009 14:31:59 | Cone Number A15F2.5CKE2H2124

Client USACE | Elevation N/A

Grass & water 20"*



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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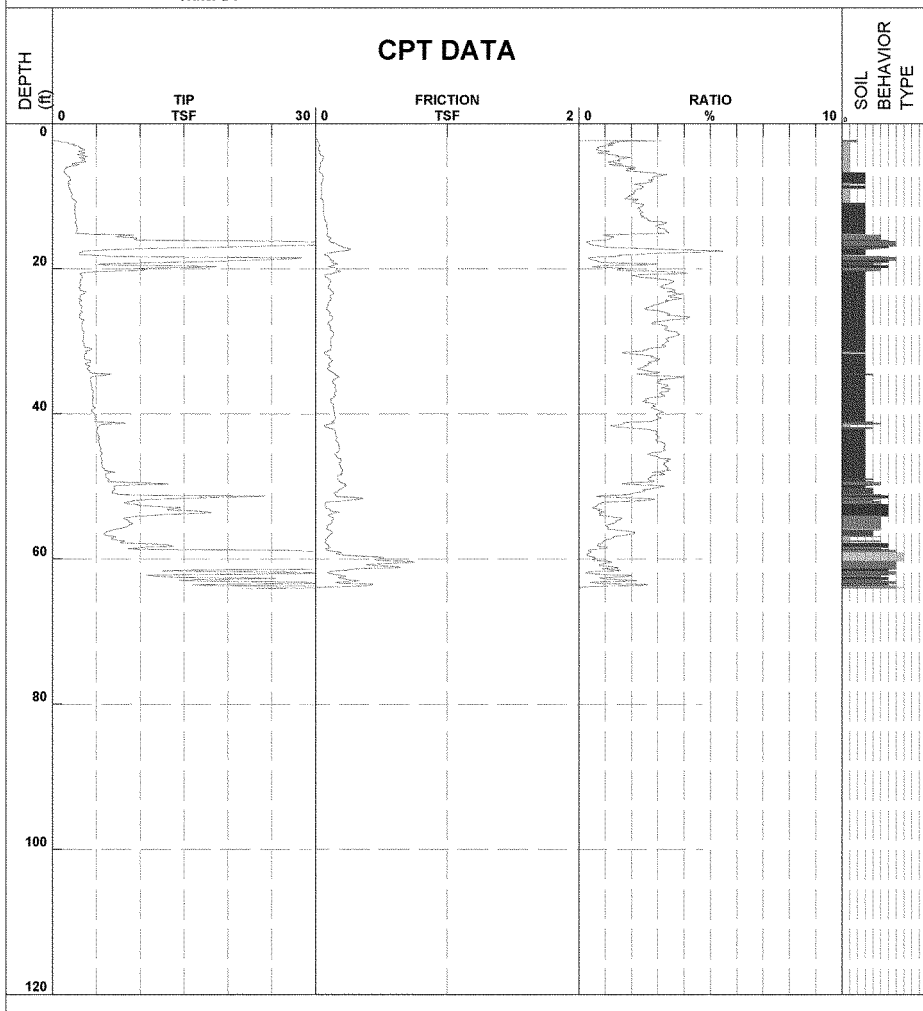
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_029C	Location	30 02' 44.3" N 89 43' 44.3'E
Operator	Glenn Johnson	Date and Tim	07-Nov-2009 12:42:41	Cone Number	F7.5CKE2HAW21513
Client	USACE	Elevation	-0.9		

Water 2'5"



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

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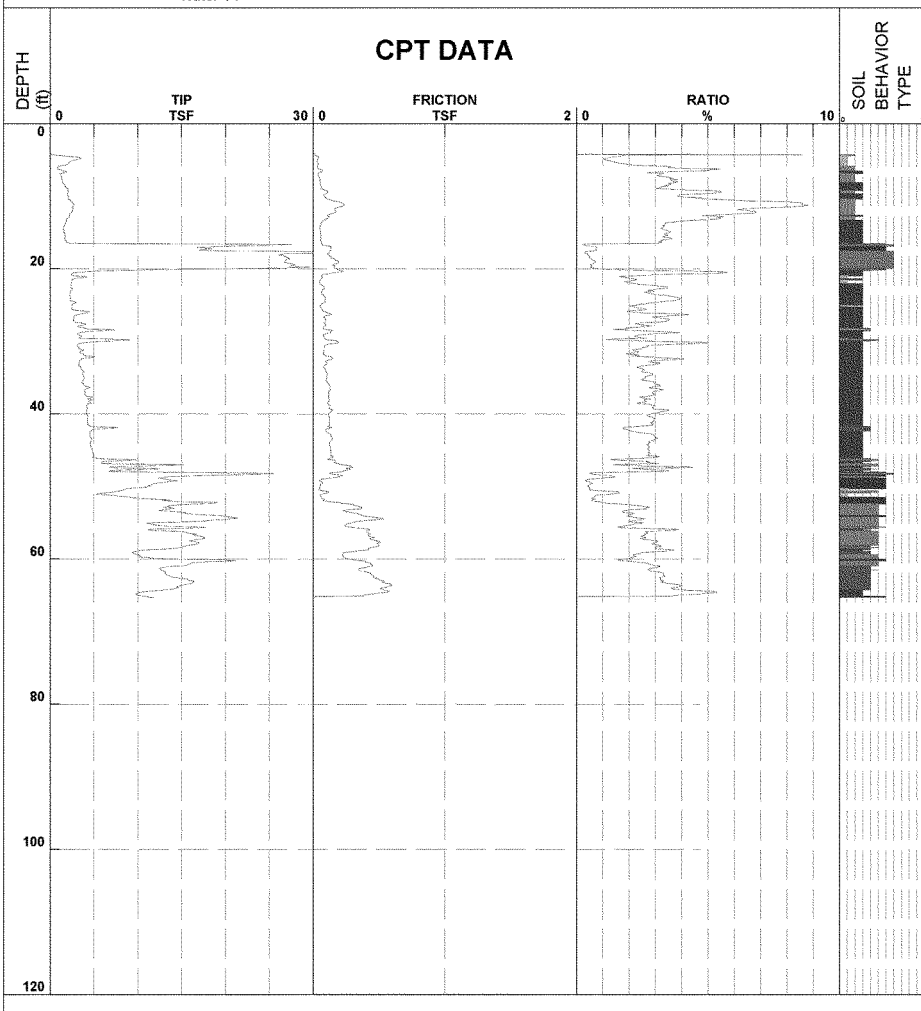
MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_030C	Location	30 04'00.7" N 89 42'58.6"E
Operator	Glenn Johnson	Date and Tin	07-Nov-2009 10:41:01	Cone Number	F7.5CKE2HAW21513
Client	USACE	Elevation	-2.8		

Water 4'3"



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

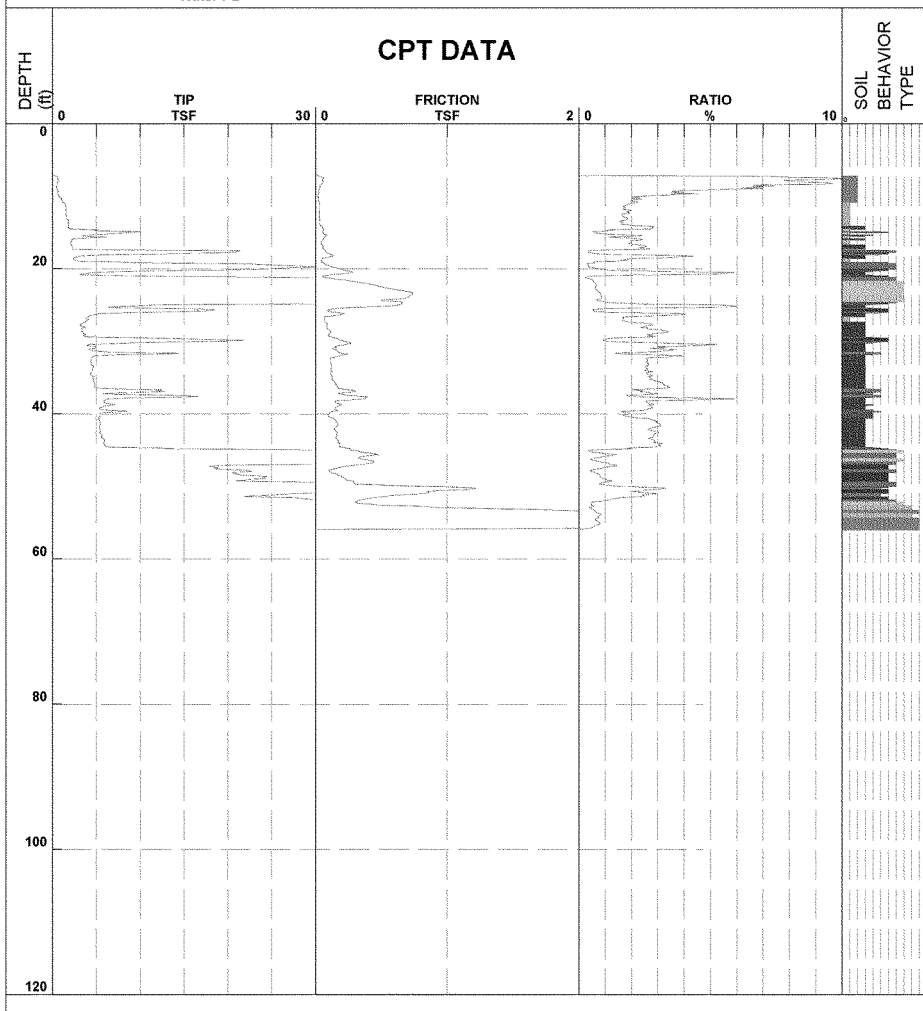
Robertson et al. 1986 * Overconsolidated or Cemented

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_031C	Location	30 04'40.9"N 89 41' 03.8"E
Operator	Glenn Johnson	Date and Tim	05-Nov-2009 09:43:54	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-5.3		

Water 7'2"



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

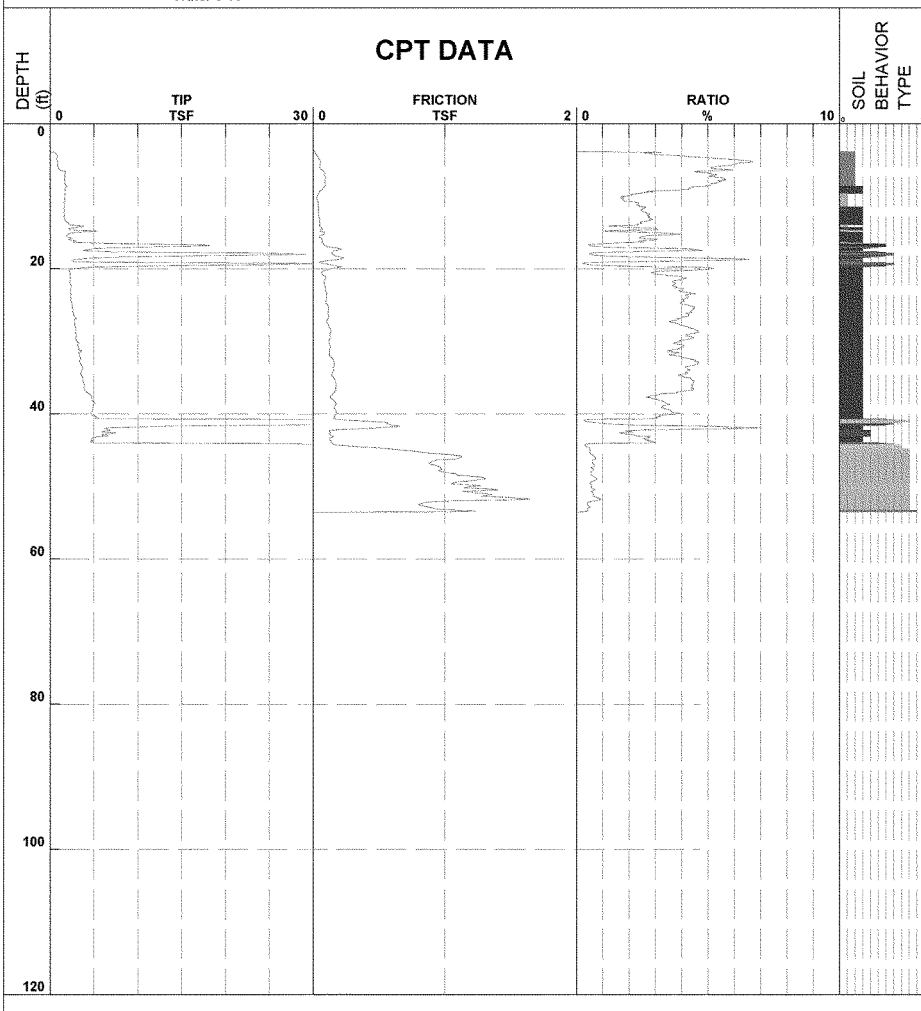
Robertson et al. 1986 * Overconsolidated or Cemented

MRGO Ecosystems Restoration

FFEB

Job Number	04.0022-0135	CPT Number	MRGO_032C	Location	30 06' 28.3"N 89 40' 44.0"E
Operator	Glenn Johnson	Date and Tim	03-Nov-2009 14:21:58	Cone Number	A15F2.5CKE2H2124
Client	USACE	Elevation	-3		

Water 3'11"



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
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Robertson et al. 1986 * Overconsolidated or Cemented

FOR CONTINUATION OF HOUSE DOCUMENT 113-78

MRGO ECOSYSTEM RESTORATION PLAN
FEASIBILITY STUDY

SEE PART 7