Preparing for Sea Level Rise through Hazard Mitigation:

Analysis of Risks & Recommendations

Prepared for:
City of Ocean Springs by

Eco·Systems, Inc.
Consultants, Engineers, and Scientists

Funded through a grant of the

Sea Grant
Mississippi-Alabama

Table of Contents

Tables

Figures

1.0 Executive Summary: Sea Level Rise Proposed Action Plan for Ocean Springs and Mitigation Alternatives

The scientific literature on sea level rise indicates future sea level increases ranging from .84 inches per year on a global level to a potentially much smaller local impact of a .1 inch per year on natural and man-made environments along the Mississippi Gulf Coast. By examining these historic trends in combination with the cumulative impacts of increased flood levels, higher storm surges, and generally higher tide levels, it has been determined that the Ocean Springs area is at moderate risk of the impacts of sea level rise.

While the impacts may be modest, Ocean Springs' vulnerability to the impacts of increasingly severe weather events should be a factor in future land use and capital planning efforts. Variables such as land form and soil type, coastal slope, historic sea levels, shoreline erosion, mean tide range, and mean wave height indicate that long-term change is sure to occur on the City's coastline as well as frontages along Davis and Old Fort Bayous and other smaller waterways. Gulf Coast residents from Mississippi and throughout the region report increased awareness of changes in their climate, and their increased interest in having local governments include these changes in their long-term plans.[1] Several systems have potential to be affected, including natural areas, roadways and evacuation routes and the water, wastewater, electrical lines and the stormwater drainage infrastructure serving waterfront neighborhoods. Future city investment in zoning and land use decisions, water and wastewater infrastructure, roadways and evacuation routes can all be informed by projected changes in the 25, 50 and even 100-year time horizons.

This report builds upon Ocean Springs' Hazard Mitigation Plan and emphasizes the mitigation alternatives in the City's current plan that are best suited to minimizing its risks and vulnerabilities. Recommendations for long-term actions focus on adapting, retreating from the shoreline and armoring the shoreline as a last resort. Taken together, they provide Ocean Springs officials the potential to more effectively manage future impacts of sea level rise while addressing management goals for natural resource protection. By taking moderate steps to prepare for changes in the waterways that define Ocean Springs, the City can preserve the ongoing safety and attractiveness of Ocean Springs for its current and future residents.

[1] Mississippi-Alabama Sea Grant. *2012 Gulf Coast Climate Change Survey: Executive Summary*. Kirby Goidel, Christopher Kenny, Michael Climek, Maxwell Means, LaDon Swann, Tracie Sempier, and Melissa Schneider.

2.0 Introduction to the Planning Process

In 1699, French explorers first set foot on the Mississippi Gulf Coast, establishing a settlement on the site of what is now Ocean Springs. In the centuries since, their descendents have weathered tropical storms, floods and hurricanes thanks in part to their location on high ground and a robust natural protection system of barrier islands and coastal marshes. Nourishment of the City's white sand beach by Jackson County provides additional protection from natural hazards, while also drawing tourists from all 50 states. Today, Ocean Springs is one of Mississippi's most prosperous small communities. Because the City wishes to protect both its citizens and its investments along the Gulf of Mexico's Mississippi Sound, it has undertaken this study to determine the potential effects of sea level rise within its boundaries.

Building upon the findings and strategies of Ocean Springs' recently adopted Hazard Mitigation Plan, this Sea Level Rise Action plan will discuss long-term risks and vulnerabilities to sea level rise on its coastline and inland areas as well as strategies to reduce those risks. The plan will begin by describing the natural and manmade character of Ocean Springs. The next section will summarize research on larger trends in sea levels might be affecting the Ocean Springs and Jackson County coastlines. Using the U.S. Geological Survey Method for Vulnerability Assessment, the study uses local data to determine the likelihood of future sea level rise impacts. Finally, the plan proposes solutions based upon the *Ocean Springs 2012 Hazard Mitigation Plan* to adapt to potential changes and reduce risks to the city's population, businesses and critical infrastructure.

As identified in Ocean Springs' 2012 Hazard Mitigation Plan, land uses along the shoreline fall primarily in the categories of residential, recreational and habitat preservation. Accordingly, particular attention will be paid to the social and ecological toll that changing sea levels might take on these environments. Where available, this study examines information on changing sea levels in Mississippi, flood zones, erosion potential, ground water level increases, and salinity to determine the impacts of Sea Level Rise on the City of Ocean Springs.

The following risks have all been identified as potential impacts of Sea Level Rise, and all are considered for any impact they may have on Ocean Springs:

- Higher tides and stronger storm surges
- Coastal erosion and loss of wetlands
- Reduced ability of barrier islands to shield coastal areas from higher storm surges
- Ground subsidence caused by rise in sea level
- Greater instability of beaches and inlets
- Slower drainage of freshwaters through flooded estuaries
- Marsh and sea grass loss due to deeper waters
- Increased salinity in aquifers and groundwater
- Land use changes due to populations being pushed inland
- Reduction in amount of land available for conservation

- Existing insurance and FEMA risk models becoming obsolete, and
- Economic consequences for:
    - Commercial and sport fishing
    - Coastal tourism
    - Coastal development
    - Transportation development
    - Critical facilities[2]

This plan identifies the issues and areas of greatest risk, considers them in light of future natural hazards and proposes a series of mitigation actions to protect Ocean Springs from rising waters.

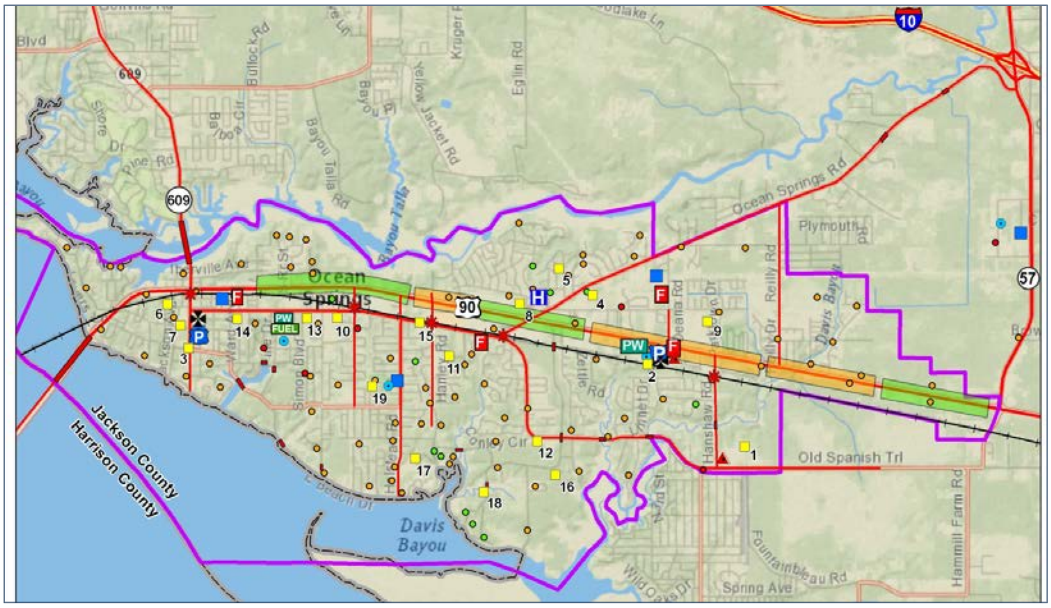
Based on historical data reflecting sea level rise in the last several decades, we mapped two scenarios of potential sea level rise within the boundaries of Ocean Springs. We will examine the relationship of rising sea levels to homes, infrastructure and shoreline, and determine areas most likely to be affected. Because of the rapid pace of Jackson County marshland loss over the last 40 years, we will also examine the health of the City's natural protective systems.[3] The conclusion identifies mitigation alternatives to address future changes in sea level.

[2] Calvin Giordano and Associates for the Florida Department of Community Affairs. *Recommended Methodology for Calculating Sea Level Rise*. January 31, 2011.

[3] Schmid, Keil for Mississippi Department of Environmental Quality. *Coastal Change in Mississippi: A Review of 1850 to 1999.* March 15, 2001.

3.0 Description of the Planning Area

This study area is defined by the municipal boundaries of the City of Ocean Springs, with a particular focus on the City's coastline and inland flood zones. Ocean Springs is home to a rich ecosystem of estuaries and marshes and coastal wetlands bordering the Mississippi Sound.



The original founders of Ocean Springs had the foresight to locate their central business district on higher ground and further inland. Subsequent city leaders have maintained this settlement pattern, and with the wetlands and marshland along its southern border, the City has been relatively resistant to the impacts of coastal storms and hurricanes. Since Hurricane Katrina, the City has taken a number of additional mitigation actions to protect its population – including adopting stronger building code standards and requiring homes to elevate one foot higher than the National Flood Insurance Program's Base Flood Elevation.[4]

Evidence suggests that sea level is slowly rising along the Mississippi Gulf Coast. Ocean Springs wishes to account for sea level rise over at least a 50-year horizon as an outgrowth of its 2012 Hazard Mitigation Plan. The greatest risks to the City are the potential impacts of sea level rise on residential areas, damage to infrastructure (including streets, water and sewer lines and lift stations) and to critical facilities. Changes in sea level could alter flood patterns, putting waterfront homes and the infrastructure supporting them at risk. Some of the City's critical facilities and infrastructure remain in the low-lying waterfront areas which could be affected by the loss and degradation of wetlands and marshes on or near the Coast. Jackson County has

[4] Eco-Systems, Inc. for the City of Ocean Springs 2012 Ocean Springs Hazard Mitigation Plan.

lost 4,600 acres of marshland over the last 40 years, weakening the natural protective system that increases the city's resiliency to storms.[5]

3.1 Residential and Commercial Growth

This coastal town has almost doubled in size since 1970. Ocean Springs attracts a growing number of tourists and local employment with its expanding restaurant and retail industries. Population growth gained momentum with the annexation of adjoining land between 1970 and 1980. Although the number of residents remained relatively stable in the following decade, the introduction of casinos to the Mississippi Gulf Coast in the early 1990s fueled another increase.[6] Ocean Springs consistently outpaced the county's growth rate over the last 30 years, but slowed somewhat in the last decade. The impact of Hurricane Katrina in 2005 led to a slight population decrease of 4% in the year following the storm. By 2008, Census Bureau estimates indicated the city had regained its pre-storm population. The 2010 Census shows a slight growth over Ocean Springs' population in 2000.[7]

TABLE 3.1 HISTORIC GROWTH RATE OF OCEAN SPRINGS, 1980 - 2010[8], [9], [10]

	2010	2008	2000	1990	1980	1970
Ocean Springs	17,442	17,149	17,225	14,658	14,504	9,580
Growth Rate	2%	0%	15%	1%	34%	N/A
Jackson County	139,668	130,694	131,420	115,243	118,015	87,975
Growth Rate	6%	-0.56%	12%	-2%TY	25%	N/A

Population growth in Ocean Springs is expected to continue on an upward trend well into the next decades, barring future natural disasters. In fact, the community is projected to grow at a more rapid rate than Biloxi or Pascagoula, the largest municipalities and employers in the vicinity. This population pressure means the City must continue to seek opportunities to house this population, whether through reusing under-developed or vacant sites in historic Ocean Springs or through increased development at the city's fringes.

---

[5] Schmid, Keil for Mississippi Department of Environmental Quality. *Coastal Change in Mississippi: A Review of 1850 to 1999.* March 15, 2001.

[6] Center for Population Studies, University of Mississippi *Percent Change for Mississippi Counties, 1970, 1980, 1990 & 2000*.

[7] U.S. Census Bureau. American Fact Finder 2: General Population, 2010. Population Estimates, 2000-2008.

[8] Center for Population Studies, University of Mississippi *Percent Change for Mississippi Counties, 1970, 1980, 1990 & 2000*.

[9] U.S. Census Bureau. American Fact Finder: General Population and Housing Characteristics, 1990.

[10] U.S. Census Bureau. American Fact Finder 2: General Population, 2010. Population Estimates, 2000-2008.

Table 3.2 GROWTH RATE & POPULATION PROJECTIONS: OCEAN SPRINGS, JACKSON & ADJACENT HARRISON COUNTY[11]

	JACKSON COUNTY				HARRISON COUNTY	
	Ocean Springs	**Gautier**	**Pascagoula**	**Moss Point**	**Biloxi**	**D'Iberville**
1960	5,025	N/A	17,155	6631	44,053	3,005
1970	9,580	2,087	27,264	19,321	48,486	7,288
1980	14,504	8,917	29,318	18,998	49,311	13,369
1990	14,658	10,088	25,899	17,837	46,319	6,566
2000	17,225	11,681	26,200	15,851	50,644	7,608
2008	17,149	16,306	23,609	13,951	45,670	7,928
2010	19,310	16,424	26,913	17,394	48,353	9,056
2015	20,551	18,043	27,309	17,782	48,539	9,338
2020	21,792	19,663	27,705	18,169	48,724	9,620
2024	22,785	20,959	28,021	18,479	48,873	9,846
2030	24,273	22,902	28,496	18,944	49,095	10,184

While Ocean Springs continues to house workers for Biloxi's casinos and hospitality industry and for the heavier shipbuilding and other industry located in Pascagoula, nearly 9,000 people are employed in the City today. In the last decade, employment has begun to outpace population growth in Ocean Springs. With its expanding retail, restaurant and arts industries, Ocean Springs is becoming a regional destination. At 16.8%, retail employment represents the largest single share of this total, with many of these businesses located in the Central Business District.[12] Larger "Big Box" stores, such as Wal-Mart, represent an even greater share of total retail employment, and are most likely to be found on the Bienville Boulevard / Highway 90 corridor.

[11] Eco-Systems, Inc. for Mississippi Department of Marine Resources. *Sea Level Rise Plan for Coastal Mississippi*. 2011.

[12] ESRI. *Business Summary: City of Ocean Springs, Mississippi, 2012.* Provided via Mississippi Development Authority. http://mesabaoapp1.esri.com/BAO93out/output/reports/business_summary_fy__13609491182754DBBC511-D061-F925-2E27-17BD905F5EBA.pdf

Table 3.3 OCEAN SPRINGS RETAIL EMPLOYMENT, 2012[13]

	Businesses		Employees	
	Percentage	Number	Percentage	Number
Retail Trade	16.8%	175	17.2%	1,547
Miscellaneous	3.3%	34	2.1%	192
Cars & Parts	2.2%	23	2.0%	183
Food & Beverage	2.1%	22	2.0%	184
Clothing & Accessories	2.1%	22	0.9%	84
Bldg Material & Garden Equipment & Supplies	1.3%	14	0.9%	85
Health & Personal Care Stores	1.4%	15	0.8%	75
Sport Goods, Hobby, Book, & Music	1.2%	13	0.4%	40
Gasoline Stations	1.0%	10	0.5%	46
Electronics & Appliances	0.8%	8	0.3%	25
Furniture & Home Furnishing	0.7%	7	0.3%	26
General Merchandise	0.5%	5	6.7%	602
Non-store Retailers	0.2%	2	0.1%	5

The Service Sectors is also a dominant force in the local economy, both in number of businesses and employees. Service employment can be further subdivided into the categories of Restaurant and Accommodation (8.7%); Health Care (11.1%) and Other Services (13.5%).[14] Each of these areas has a distinct topography and will be affected differently by changing water levels. In 2010, the City adopted the Ocean Springs Blueprint and Bienville Boulevard Design Handbook to shape these opportunities for growth, from mature neighborhoods to less developed areas within the city limits. Employment and new growth in these sectors are expected to concentrate in three primary locations:

1. The Central Business District
2. The Bienville Road/Highway 90 Corridor
3. East Ocean Springs (including the Ocean Springs Hospital)

Each of these areas has a distinct geographic character and may be affected differently by changes in sea levels. Ocean Springs' Central Business District is now a regional entertainment destination. This historic area was originally built to the scale and design standards encouraged by the Master Plan today. Growth in this area will primarily be through the reuse of vacant

[13] ESRI, 2012.
[14] ESRI, 2012

properties, or the replacement of low-rise structures with larger buildings of two to four stories. At the axis of Washington Avenue and Government Street, a new two-story commercial structure anchors this growth in downtown dining and shopping options. A new hotel is soon projected for construction on Government Street. The master plan and zoning regulations for this area will guide the location and design features of the streetscape and any new development. Most of the area is built on high ground but lower areas at the fringe experience problems with storm drainage, which would be aggravated by sea level rise.

The City developed and adopted Design Guidelines for Bienville Boulevard/ Highway 90 in 2009. This corridor is the city's main highway and the spine of its auto-oriented commercial district. The Mississippi Department of Transportation is planning to expand this road from four lanes to six through Ocean Springs. The current boulevard is a four-lane highway divided by a landscaped median and is drained on either side by grassy swales, which form a significant component of the City's drainage management infrastructure. The predominant building type is strip-center retail interspersed with big-box general merchandisers like Wal-Mart. With few exceptions, these structures are set back from the highway behind parking lots. Based on growth projections, the City anticipates the largest volume of future growth within its current boundaries to occur along the east end of Highway 90 in the Gateway East and Ocean Springs Boulevard areas. With planned road expansions, and additional big box and strip center development projected, the drainage system along Bienville Boulevard will bear a heavier load from the runoff generated by new paved surfaces.[15]

The Northeastern Growth area of Ocean Springs is bounded by Ocean Springs Road to the city limits and Highway 90 to the south. It has the largest area of undeveloped land that remains appropriate for growth. Ocean Springs Hospital is the largest employer in the Singing River Hospital System with 24-hour emergency services, cardiac care, a birthing center, a neurosciences program, behavioral health center and hospice. The hospital's medical staff approaches 600 employees, and it is licensed for 124 beds. Medical offices and related services centered around the hospital at the corner of Bienville Boulevard and Ocean Springs Road are a growth industry for the City.[16] Subdivisions developed in the area prior to annexation were not required to meet the same drainage and infrastructure standards required in the City today, and residents report intermittent flooding of their streets and occasionally, homes.

3.2 Geographic Setting

Ocean Springs is located in the east Gulf Coast Plain Region in southwest Jackson County,. The area is mostly low hills, covered with pine forest. Elevations rarely reach higher than 20 feet. Topographic relief in the City of Ocean Springs is moderate, with most slopes reaching less than 5 percent. Only a few areas have slopes of 5 to 12 percent.[17]

[15] *City of Ocean Springs Comprehensive Plan*, Planning Works. 2010.
[16] Planning Works, LLC. City of Ocean Springs Comprehensive Plan. 2009.
[17] National Geodetic Vertical Datum (NGVD

The Mississippi Sound, which forms Ocean Springs' southern boundary, is a shallow body of water with average depths of 2.97 meters and is separated from the Gulf of Mexico by a series of barrier islands including Dauphin, Petit Bois, Deer, Horn, Ship and Cat Islands. The islands provide the mainland protection from storm surge associated with tropical storms and hurricanes. Actions to strengthen and stabilize Deer Island on the part of the U.S. Army Corps of Engineers are anticipated to further improve the island's ability to protect Ocean Springs' mainland. The northern boundary of the planning area is Fort Bayou, a major drainage basin for Ocean Springs and Jackson County. Other major drainage ways in the area include Stark and Heron Bayous which both terminate into Davis Bayou.

3.3 Natural Setting

3.3.1 Inland and Near-Shore Ecological Resources

The Mississippi Sound and Fort, Davis and Heron Bayous provide critical habitat for a number of plant and animal species and include freshwater and brackish water habitats. Identified ecological resources include land-based natural features such as the following:

- Watersheds
- Forest Habitats – Eastern Gulf Coast Flatwoods
- Wetlands
- National Wildlife Refuges
- Gulf Ecological Management Sites

Maps depicting these features and their geographical context within the coastal region are included in **Appendix A: Maps and Figures**.

3.3.2 Watersheds

Ocean Springs lies within the Coastal Streams Basin, which is further divided into smaller watersheds identified with a lower order stream or river.[18] All basins and watersheds in the coastal region drain either directly or indirectly to the Gulf of Mexico via connected bays and inlets. Basins and watersheds are natural features and problems associated with their management are not subject to political and administrative boundaries. **Table 3.4** provides an overview of the basins and watersheds associated with Ocean Springs, as well as their HUC number and associated water feature.

Table 3.4 Coastal Basins and Watersheds[19]

Basin **/** Watershed Name	**HUC Code**	**HUC Name**
Coastal Streams Basin	03170009	Mississippi Coastal Streams
Biloxi River	03170009-140	Coastal Streams
Old Fort Bayou	03170009-160	Coastal Streams

[18] Data on the Coastal Streams Watershed is tracked by the USGS using an 8-Digit Hydrologic Unit Code (HUC), and a 12-Digit HUC for the lower order streams.

[19] Mississippi Automated Resource Information System; www.maris.state.ms.us

3.3.3 Wetlands

Wetlands serve a protective function for coastal and bayou-front property in Ocean Springs. Coastal wetlands including seagrass beds and sandy beaches are most common on the land abutting the Biloxi Bay, Front Beach and East Beach. Tidally influenced brackish and freshwater marsh border Davis and Fort Bayous. Examples of all of the coastal wetland types present in the area are seagrass beds, mud flats, sandy beaches, freshwater marshes, wet savannahs and bogs. Gulf seafood species, including shrimp, oysters, blue crabs, flounder and redfish rely on wetlands and shallow coastal waters as nursery areas, where shrimp larvae and young fish feed and grow before moving offshore. Coastal wetlands and their associated habitats, ranging from seagrass meadows and oyster reefs to salt marshes and coastal pine savannahs, form a belt comprising about 800 square miles including the Ocean Springs planning area. [20]

3.3.4 Geology

Ocean Springs' three major geologic formations are the Biloxi Formation, the Prairie Formation and the Gulfport Formation. The Biloxi Formation is deposited in marine and brackish water both near and offshore and is made up of clay, fine sand and sandy clay. The formation is as deep as 120 feet thick in Jackson County. The Prairie Geologic Formation encompasses most of Ocean Springs and it is composed primarily of sands and muddy sands with fossil tree trunks, leaves and occasionally pine cones. It ranges from 15 to 40 feet thick and forms the wide, flat coastal plain immediately north of the coastal marshes and beaches on the Mississippi Sound. The Gulfport Formation is the most prominent geologic formation along the coast and the source of all of the sand on the mainland beaches. Gradual warming and rising sea levels also eroded and leveled a postglacial landscape as the prehistoric river valleys were filled and became swamps and marshes.

The Jackson County Soil Survey has grouped soils in the area into three associations.[21] The most wide-spread is the Harleston-Escambia-Bayou association found primarily on terraces landforms, next is the Handsboro-Axis-Maurepas association found in coastal marshes and floodplains, and finally, the Eustis-Wadley-Benndale association characteristically found along ridges. Soil phases within the City range from fine sandy loam to loam and are outlined in **Appendix B: Major Soil Characteristics**. Hydric soil phases, Smithton loam, Harleston fine sandy loam (on 0-2 percent slopes), and Handboro mucky silt loam (in frequently flooded areas) are often found in wetland or frequently flooded areas where conditions are favorable for the formation of wetland, soils. Because wetland areas are federally protected, these areas are not well-suited for development. The wetlands and marshes of the area play a crucial role in water quality protection because they naturally filter pollutants and sediment. Soils best suited for development include the Eustis series, Benndale series, and the Harleston and Escambia series found on higher slopes.[22]

---

[20] Planning Works. *Ocean Springs Blueprint: Comprehensive Plan.* 2010.

[21] The NRCS Jackson County Soil Survey uses *soil associations* to group soil series based on similar repeating characteristics. A *soil series* contains soils with similar profiles. A soil series can be divided into *soil phases* by characteristics like surface layer, slope, stoniness, salinity, and degree of erosion.

[22] United States Department of Agriculture. Soil Survey of Jackson County, Mississippi. 2006.

3.3.5 Gulf Ecological Management Sites (GEMS)

The Gulf Ecological Management Sites (GEMS) program is a partnership between the Department of Marine Resources (DMR), EPA and the Gulf of Mexico Program to study ecologically important areas of the Gulf region. The State of Mississippi has 22 GEM sites, which have been included in the Mississippi Coastal Preserves. For each of the sites listed below, the following information is provided on the Mississippi GEMS website: 1) Site Information and Points of Contact; 2) Geographic Information including: Narrative Description of the Site, Location, and Area of Influence; 3) Ecological/Cultural Characteristics including: Habitat Type and Uniqueness of Natural Community; 4) Current and Potential Use of Site, 5) Management Status; 6) Site Viability; and 7) Links for Additional Information. The GEMS sites n the Ocean Springs area are located within tidal zones and are as follows:

TABLE 3.5 GULF ECOLOGICAL MANAGEMENT SITES IN OCEAN SPRINGS

• Sandhill Crane Refuge	• Davis Bayou
• Bellefontaine Marsh	• Old Fort Bayou
• Deer Island	

4.0 Analysis of Potential Sea Level Rise Risks

Any sea level rise observed on the bays, beaches and bayous of Ocean Springs is tied to the larger trends in ocean levels. Evidence indicates global sea levels have risen at a consistent rate of approximately 0.04 to 0.5 inches per year since 1900.[23] Today, methods of sea level rise detection are increasingly sophisticated. Satellite technology now indicates a rise of 3 millimeters or about .12 inches per year (NOAA Science on a Sphere). There are generally two separate mechanics involved in sea level rise on a global level:

1. Global temperature increases warm the oceans' waters and cause them to expand.
2. Melting of ice over land, which adds water to the oceans.

In addition to these two processes, changes in sea level may be exacerbated on the local level by erosion and subsidence. Subsidence is the lowering of the land surface due to several possible natural or manmade factors including: soil compaction, earth movements, added loading on the surface, changes in groundwater levels, or removal or underlying support materials.

The Mississippi Department of Marine Resources conducted a sea level rise assessment and plan in 2011, authored in cooperation with Eco-Systems. A survey of the different models and scientific efforts to predict sea level rise over the next 100 years was prepared as a part of that analysis, and a full review of the literature can be found in the *Sea Level Rise Plan for Coastal Mississippi (MDMR, 2010).* While a number of different models are used to predict the international effects of changing sea levels, most relate to the data and predictions of the International Panel on Climate Change (IPCC) which meets every four years to track trends and refine its scholarship. To summarize the findings of Mississippi's *Sea Level Rise Plan*, estimates of global sea level rise range from 1.34 to 2.99 feet by 2100. This translates into a mean linear increase of .18 to .40 inches per year. The data presented within the context of global sea level rise also represents a potential worst-case scenario equal to approximately 6.25 feet of sea level rise by the year 2100 or approximately .83 inches per year. Based on this scenario of rising waters without taking into account erosion and loss of coastal vegetation, the Mississippi Gulf Coast could experience sea level increases of 4.15 inches in five years, 8.3 inches in ten years, 16.6 inches in twenty years, 41.5 inches in fifty years, and 74.7 inches by the year 2100.[24]

4.1 Mississippi Region Research and Data

While much of the current research on sea level rise in the Gulf of Mexico has focused on areas such as the Mississippi River Delta, the Florida Keys, and the Texas Gulf Coast, a growing body of data is available for Mississippi's Gulf Coast. To account for the lack of empirical data providing sea level rise projections for Mississippi, this plan considers historical data from nearby tide monitoring stations in Dauphin Island, Alabama and Pensacola, Florida along with the more recent data available for Mississippi.

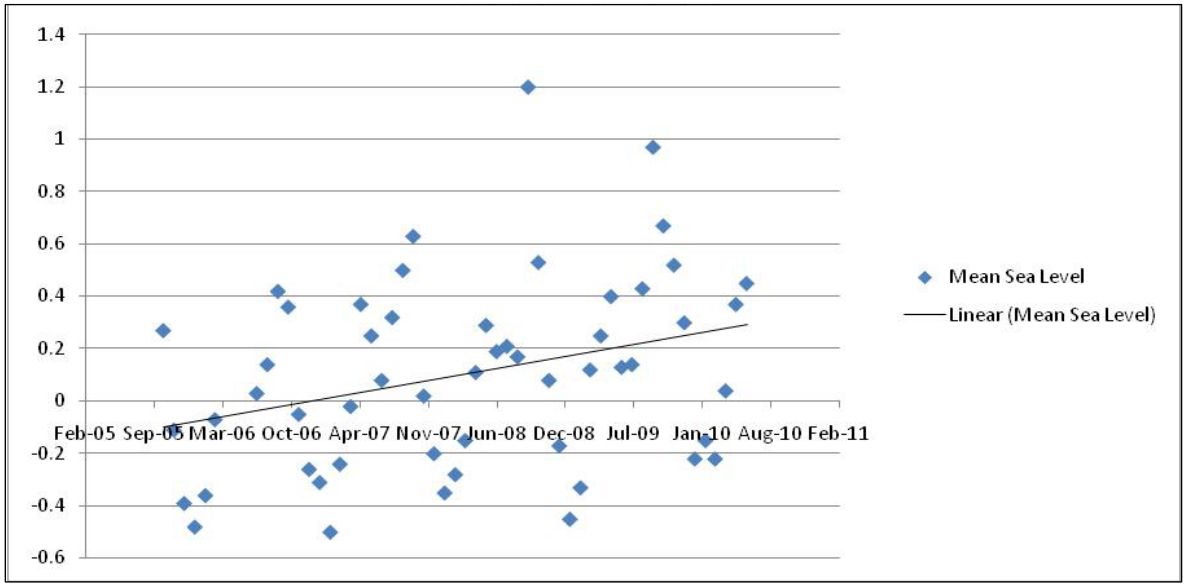
[23] NOAA Science on a Sphere: http://sos.noaa.gov/datasets/Ocean/sea_level.html
[24] Eco-Systems, Inc. for Mississippi Department of Marine Resources. *Sea Level Rise Plan for Coastal Mississippi*. 2011.

4.1.1 Mississippi-Specific Sea Level Trends

NOAA tide gauging stations provide the most specific local and regional data about any changes in sea levels on the Gulf Coast. Although Mississippi's three tide gauging stations were placed in the Sound relatively recently, an analysis of short-term data from Mississippi compared to long-term stations reporting from Alabama and Florida indicates a strong correlation and consistency in the data. The *Sea Level Rise Plan for Coastal Mississippi* compared the data below from the three Mississippi NOAA gauges to data from the long-term data sets available from tide stations at Dauphin Island, Alabama and Pensacola, Florida.

The methodology used to determine linear projections of sea level rise for the Mississippi coast included an analysis of both short and long-term data for the Dauphin Island and Pensacola Tide Stations and a comparison of data from those stations to the short-term data available for Mississippi Tide Stations including stations located at the Pascagoula NOAA Lab, the Gulfport Harbor, and the Bay-Waveland Yacht Club. Comparing the short term Mississippi data with these longer term trends in the region provides the ability to conceptually project sea level into the future to help provide a context for planning considerations in Ocean Springs. Data for each of the three Mississippi gauging stations is graphed as a scatter plot in the figures below. The trend line through the graph represents sea level change over time. To attest to the consistency of these conclusions, the final figure in this series charts the trends in Pensacola, Dauphin Island and the Mississippi tidal stations.

Figure 4.1 Station 8741533 – Pascagoula NOAA Lab 5-Year Sea Level Trend[25]



[25] NOAA Tides and Currents

Figure 4.2 Station 8745557 – Gulfport Harbor 5-Year Sea Level Trend[26]

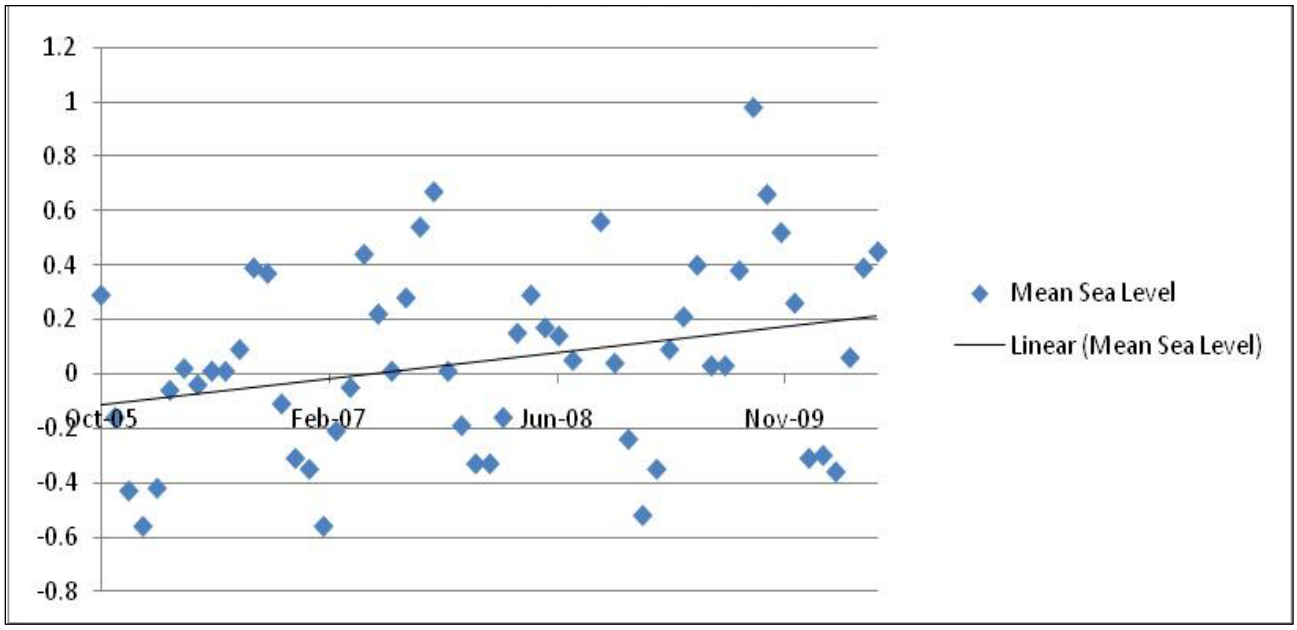
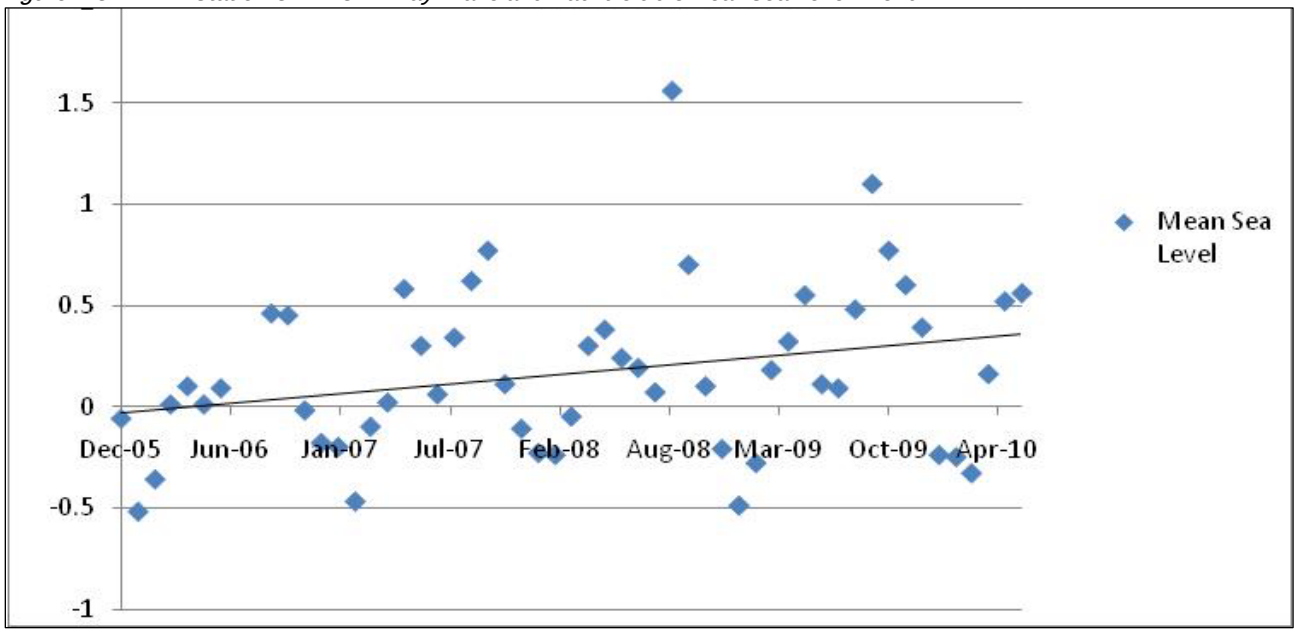
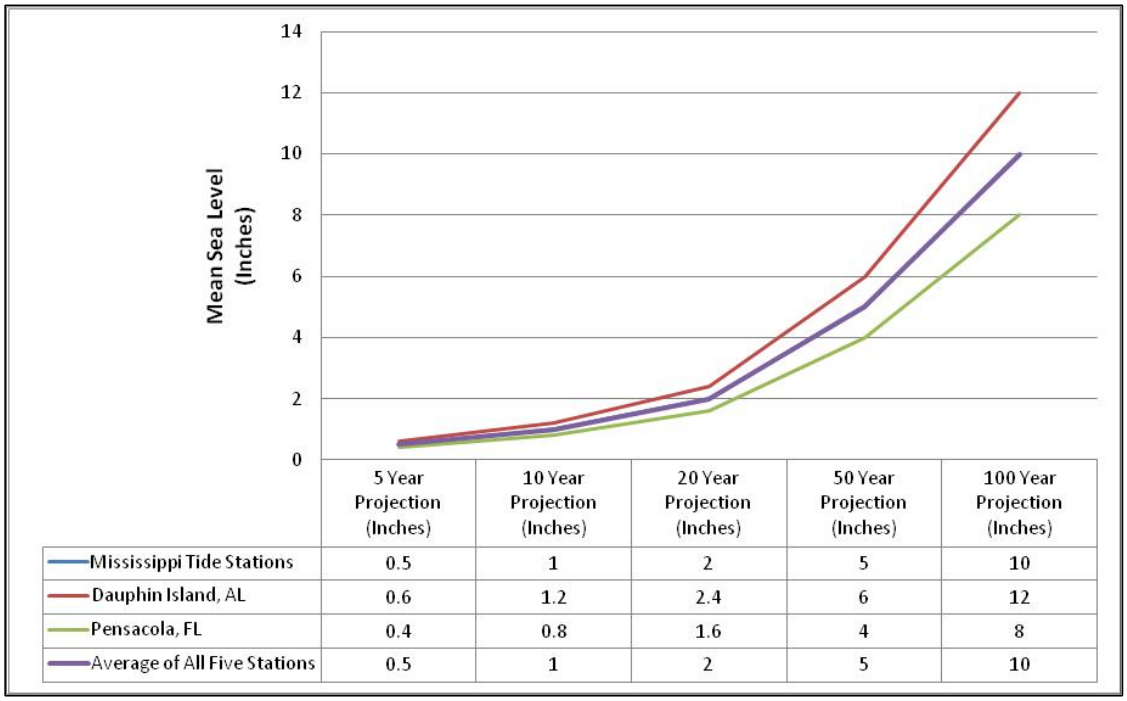


Figure 4.3 Station 8747437 – Bay Waveland Yacht Club 5-Year Sea Level Trend[27]



[26] NOAA Tides and Currents
[27] NOAA Tides and Currents

Figure 4.4 Summary of Local and Regional Sea Level Rise Projections



	5 Year Projection (Inches)	10 Year Projection (Inches)	20 Year Projection (Inches)	50 Year Projection (Inches)	100 Year Projection (Inches)
Mississippi Tide Stations	0.5	1	2	5	10
Dauphin Island, AL	0.6	1.2	2.4	6	12
Pensacola, FL	0.4	0.8	1.6	4	8
Average of All Five Stations	0.5	1	2	5	10

4.1.2 Summary of Local Sea Level Rise Data

As illustrated in **Figure 4.4**, the trend for the Mississippi Tide Stations is consistent with the trend illustrated for the Dauphin Island, Alabama and Pensacola, Florida Tide Stations. The Mississippi trend is equivalent to the average of the three states' data. Comparing the five-year trends of the Mississippi tide gauging stations to those in Alabama and Florida provide confidence that historic trends for sea levels could continue throughout the region in a similar fashion, that is, approximately 0.1 inch per year. As a result, the mean projected linear sea level rise trend for Mississippi was determined to be an average of .10 inches per year, yielding projections of .5 inches in five years; 1 inch in ten years, 2 inches in twenty years; 5 inches in fifty years, and 10 inches in 100 years.

At a minimum, Mississippi can expect a sea level rise of approximately ten inches by the year 2100. However, data gaps, including the lack of long-term historical sea level trends, does impact the accuracy of data presented here. Actual sea level rise levels in the future are also dependent on a number of risk factors that are difficult to predict. These factors include erosion, accretion, and subsidence as local contributing factors. Accretion is the vertical soil rise through sedimentation, while subsidence is the lowering of the soil surface due to a variety of natural and manmade causes. Other factors such as glacial melt and climate change are more global in nature but still have potential to impact future sea levels on the Mississippi coast. Because of these uncertainties, additional methods to assess the risk associated with Ocean Springs' natural environment are examined in the vulnerability assessment below.

4.2 Ocean Springs/Jackson County Vulnerability Assessment

Historic sea levels on a global and regional basis are helpful for predicting future changes in sea level, but they only provide part of the picture. There are other risk factors that are also a reliable predictor of sea level rise, as identified by the United States Geological Service (USGS). These factors also represent important planning considerations for coastal management. The results are presented in a Coastal Vulnerability Index (CVI), which considers a coastal system's susceptibility to change and its natural ability to adapt to constantly changing environmental conditions.

The six physical variables that the USGS recommends using to assess coastal vulnerability to sea level rise include:

- Geomorphology (land form),
- Coastal slope (percent),
- Rate of relative sea-level rise (inches/year),
- Shoreline erosion and accretion rates (inches/year),
- Mean tidal range (feet), and
- Mean wave height (feet). [28]

The vulnerability of Ocean Springs to sea level rise includes a compilation of the CVI, social vulnerabilities, vulnerabilities of natural systems, and vulnerabilities of manmade systems.[29]

Each of these physical variables is assigned a risk relative to the size of its contribution to potential physical changes as sea levels rise. **Table 4.5** provides the risk values associated with each of the six physical variables used in the CVI. The resulting CVI describes how vulnerable the region is to the effects of sea level rise but does not provide an indicator of future sea level increases or decreases. The formula for calculating the CVI is included in the footnote below. [30] This method is primarily concerned with establishing how much risk the Jackson County coastline is exposed to because of its location and the environmental features it considers. Just because an area is highly vulnerable, however, does not mean that it is likely, or probable, that the risk will be realized. For this reason, we are considering factors from increased vulnerability, to historical sea levels to knowledge of the Ocean Springs environment most accurately estimate potential sea levels for the Mississippi Gulf Coast.

[28] U.S. Department of the Interior, U.S. Geological Survey: *National Assessment of Coastal Vulnerability to Sea Level Rise: Preliminary Results for the U.S. Gulf of Mexico Coast*; U.S. Geological Survey Open-File Report 00-179, E.Robert Thieler and Erika S. Hammar-Klose; Woods Hole, Massachusetts. http://pubs.usgs.gov/of/2000/of00-179/pages/data.html Last modified: 01:11:24 Fri 11 Jan 2013.

[29] USGS, *National Assessment of Coastal Vulnerability to Sea Level Rise*.

[30] The Coastal Vulnerability index uses the variables in Table 5.0 applied to the formula as follows: CVI=√((a*b*c*d*e*f)/6), where: a = geomorphology; b = coastal slope; c = relative sea-level rise rate; d = shoreline erosion/accretion rate; e = mean tide range; f = mean wave height

Table 4.5 USGS Method for Determining Coastal Vulnerability Index (CVI)

Ranking of Coastal Vulnerability Index[31]					
Variable	**Very Low 1**	**Low 2**	**Moderate 3**	**High 4**	**Very High 5**
Geomorphology	Rocky, cliffed coasts, fiords	Medium cliffs, indented coasts	Low cliffs, Glacial drift, Alluvial Plains	Cobble beaches, Estuary, Lagoon	Barrier beaches, sand beaches, Salt marshes, Mud flats, Deltas, Mangrove, Coral reefs
Coastal Slope (%)	>11.5	11.5 to 5.5	5.5 to 3.5	3.5 to 2.2	<2.2
Sea Level Rise (in/yr)	<.07	.07 to .098	.098 to .12	.12 to .134	>.134
Shoreline Erosion/Accretion (ft/yr)	>6.56	3.28 to 6.56	-3.28 to +3.28	-3.61 to -6.56	>-6.56
Mean Tide Range (ft)	19.69	13.45 to 19.69	6.56 to 13.12	3.28 to 6.23	<3.28
Mean Wave Height (ft)	1.81	1.81 to 2.79	2.79 to 3.44	3.44 to 4.10	>4.10

Certain variables may have a higher impact on an area's vulnerability than others. The following sections provide data specific to Ocean Springs' and the Mississippi Gulf Coast's vulnerability. **Table 4.6** provides generalized rankings for Jackson County and a coast-wide average using the NOAA CVI. CVI values below 8.7 are considered low risk for sea level rise vulnerability. Values from 8.7 to 15.6 are considered moderate risk. Values from 15.6 to 20.0 are considered high risk, and values greater than 20.0 are considered very high risk.[32]

Table 4.6 Jackson County & Mississippi Gulf Coast CVI Ranking

Variable	Jackson County Value	Jackson County Rank	Coast Wide Value	Coast Wide Rank
Geomorphology		5		5
Coastal Slope (%)[33]	6.53%	2	4.85%	3
Relative Sea Level Rise Rate (inches/year)[34]	0.1	3	0.1	3
Shoreline Erosion/Accretion Rate (feet/year)[35]	-7.54	5	-7.54	5
Mean Tide Range (feet)[36]	1.429	5	1.561	5
Mean Wave Height (feet)[37]	1.41	1	1.41	1
CVI	**11.18**		**13.69**	

[31] USGS National Assessment of Coastal Vulnerability to Sea Level Rise.
[32] USGS National Assessment of Coastal Vulnerability to Sea Level Rise.
[33] MARIS
[34] NOAA Tides and Currents
[35] Morton, Robert A., Miller, Tara L., Moore, Laura J., National Assessment of Shoreline Change: Part 1 Historical Shoreline Changes and Associated Coastal Land Loss Along the U.S. Gulf of Mexico; USGS Open File Report 2004-1043
[36] NOAA Tides and Currents
[37] NOAA National Data Buoy System

The low flat coastal plain landform, (or geomorphology), relatively high erosion rates and wide tidal range combine to increase the likelihood Ocean Springs will be moderately vulnerable to sea level rise. All three Gulf Coast counties are considered at moderate risk of impacts from sea level rise, although among the three coastal counties, Jackson County evidenced a slightly lower risk than the Mississippi Gulf Coast as a whole.

Comparing the five-year trends of the Mississippi tide gauging stations to those in Alabama and Florida provide confidence that historic trends for sea levels could continue throughout the region in a similar fashion, that is, approximately 0.1 inch per year. As a result, the mean projected linear sea level rise trend for Mississippi was determined to be an average of .10 inches per year, yielding projections of .5 inches in five years; 1 inch in ten years, 2 inches in twenty years; 5 inches in fifty years, and 10 inches in 100 years. However, because this trend represents a best-case scenario for the Mississippi Gulf Coast and does not take into account other risks to the natural coastal eco-system, like the loss of marshland or damage to the barrier islands and heightened storm surge, we provide a range of predictions from the a best-case scenario of one foot over 100 years with the worst-case scenario equal to the approximately 0.83 inches per year occurring globally to provide a range of predictions for future sea levels on the Mississippi Coast. For this reason, the maps provided in **Appendix C**: **Sea Level Rise Simulation** are designed to anticipate sea level rise more closely resembling global levels of one-foot and two-feet of sea level rise in the coming decades.[38]

[38] USGS; Sea Level Rise Visualization for Alabama and Mississippi; http://gom.usgs.gov/slr/slr.html

5.0 Analysis of Potential Sea Level Rise Impacts

5.1 Vulnerability of Natural Systems

Marshland, sand beaches and the Mississippi Sound's string of barrier islands provide Ocean Springs with natural protection against coastal storms, erosion and wetland fill. Damage to any of these systems makes the City more vulnerable to sea level rise. Natural features like hydric soils limit development potential in some areas. Vulnerability to flooding and storm surge make many lots near the coastline and Fort Bayou less appropriate for development.

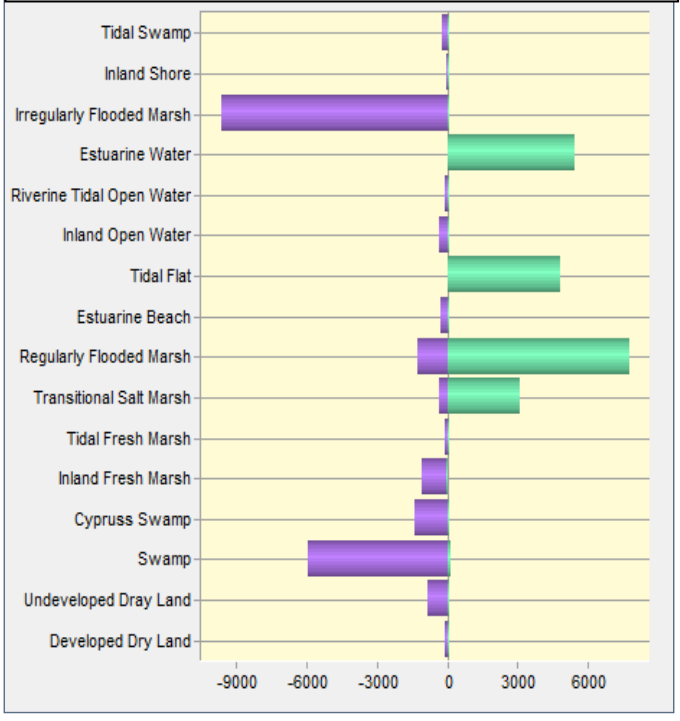
5.1.1 Sand Beaches

Prior to the 1940s, the shoreline of the Mississippi Sound was still in its natural state and was primarily defined by natural outcroppings of trees and marshy areas. Sand beaches were created in the early 1950s by pumping dredged sand materials onto the shoreline.[39] From 1850 through 1950, the Mississippi Gulf Coast experienced a net loss of approximately 1,224 acres mostly through natural processes. In contrast, from 1950 through 1986, the Mississippi Gulf Coast experienced a net gain of 9 acres, primarily due to the development of the sand beach, reclamation of wetlands and other man-made processes.[40]

5.1.2 Marshland

Although the reclamation of land on the shoreline through beach renourishment provides an additional buffer for Ocean Springs and its neighbors, during the time period from 1850 to 1986, the Mississippi Gulf Coast lost approximately 8,500 acres of marshland with approximately 2,300 acres of this loss attributed to water gain or sea level rise and approximately 3,500 acres lost due to human activities. The loss of marsh lands since the 1950s averages to approximately 172 acres per year. Jackson County alone experienced a net loss of 446 acres, despite beach construction and fill activities for development in Gulf Park estates and other wetland areas. According to historic maps of land losses, Ocean Springs experienced substantial erosion along Front Beach and East Beach.[41] The

Figure 5.1 MS Marsh Gains & Losses between 2009 & 2100



Source: The Nature Conservancy. *Gulfwide Conservation Analysis, 2012*

[39] Justia.com; United States of America v. Harrison County; http://cases.justia.com/us-court-of-appeals/F2/445/276/16352/

[40] Coastal Change in Mississippi: A Review of 1850 to 1999 Data; March 15, 2001; Keil Schmid; MDEQ – Office of Geology

[41] MDEQ – Office of Geology, 2001

Nature Conservancy prepared a Sea Level Rise Affecting Marshes Model to determine how sea level rise on the Gulf Coast might change the character of coastal environments. They projected that over the next 100 years, waters in the Mississippi marshes in the nearby Grand Bay National Estuarine Reserve (NERR) could rise as much as one meter. Marshes are likely to migrate inland. The number of tidal flats is expected to increase and areas that are only intermittently flooded today would become regularly flooded marsh. As much as 30% of the population in the Census block groups to the west of the NERR could be affected.[42] Given the similar environments of marshland occurring on Front and East Beach, near the Gulf Islands National Seashore and on the city's western peninsula, Ocean Springs residents are also likely to feel the effects of a migrating coastline through the loss of residential properties, developable coastal land. Recreational areas would also be likely to diminish in acreage, and trails, pedestrian and play areas might experience more intermittent flooding that affects the number of days they are available to the public.

If these marshlands cannot migrate inland due to barriers or maintain accretion rates (vertical soil rise through sedimentation) with the rate of sea level rise, they risk becoming an open water area, drowning existing habitats and losing great ecological diversity. In addition, the loss of the marshland vegetation will increase the potential for coastal erosion if the land stabilizing marsh vegetation is not encouraged and allowed to migrate inland.

5.1.3 Barrier Islands

The network of barrier islands has already been weakened by a series of catastrophic storms and natural erosion for a loss of a total of 2,695 acres during that time period. Restoration on Deer and Ship Islands is adding landmass back to the islands and attempting to stabilize them against future storm impacts.[43]

Long-term rates of loss for the Mississippi mainland are moderated by extensive armoring and periodic beach nourishment along the Mississippi Sound. These man-made protective measures have served to slow rates of loss for the mainland. However, long and short-term rates of erosion and land loss of the barrier islands indicate land loss rates ranging from 10.17 feet per year to approximately 19 feet per year. [44]

5.1.4 Summary of Vulnerabilities of Natural Systems

The low flat coastal plain landform (geomorphology), relatively high erosion rates and wide tidal range combine to increase the likelihood that Ocean Springs' natural systems will be especially vulnerable to sea level rise. Of particular concern are the impacts to the barrier islands, marshlands and sandy beaches. The impacts will be felt through reduced buffer

[42] The Nature Conservancy. *Gulfwide Conservation Analysis, 2012*.
[43] USGS, Robert A. Morton, Tara L. Miller, Laura J. Moore. *National Assessment of Shoreline Change: Part 1 Historical Shoreline Changes and Associated Coastal Land Loss Along the U.S. Gulf of Mexico*; USGS Open File Report 2004-1043
[44] USGS, Ibid.

protection from storms and surges, degradation of the diverse ecological system, possible negative impacts to the fishing industry, and reduced protection against erosion.

Throughout the City, the natural systems create the first barrier between the sea and the manmade systems. As a result, the natural systems will be the first impacted. If unmitigated, this impact will significantly reduce the ability of the natural systems to provide protection to the adjacent areas and the coastal residential and commercial properties will face greater storm and surge impacts. Without these barriers, the waterfront manmade systems will more regularly be the initial line of impact.

Additionally, Gulf Coast fisheries have a high dependency on wetlands, as 90% of the commercial and recreational fish species spend much of their life in the wetlands. *(citation: . J. Titus et al, "Greenhouse Effect, Sea Level Rise and Coastal Wetlands," U.S. Environmental Protection Agency, July 1988.)* If these wetlands are not allowed to migrate inland, the fish nurseries and fishing industry that depends on successful nurseries, will be negatively impacted. Natural systems are key to the long-term resiliency of the manmade systems and must be given high priority by recognizing their benefits and promoting their conservation and protection.

5.2 Vulnerability of Man-Made Systems

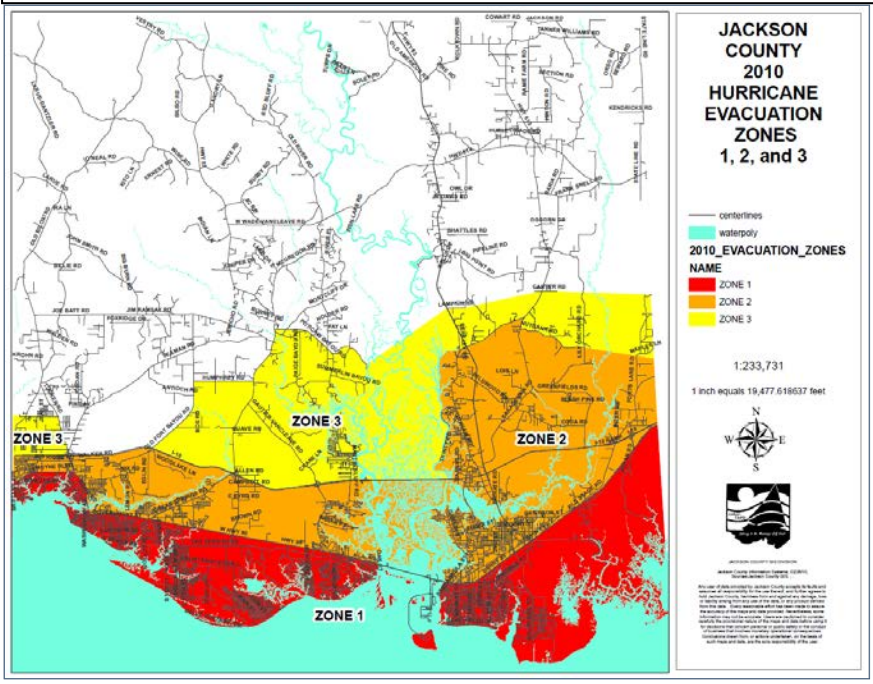
Although Ocean Springs' highest concentration of development is on higher ground away from the coastline and most structures within the city are setback from the waterways, perhaps the greatest risk associated with sea level rise is to the infrastructure serving coastal properties. Transportation in Ocean Springs and its region could be heavily affected, as 24% of Jackson County's roadways are located in the FEMA designated floodplain areas.[45] Waterfront infrastructure, including water and sewer lines, storm drainage and electrical services all border the Gulf. While the renourishment of beaches provides some protection, a moderate rise in sea level could affect all of these systems, not only on the waterfront, but also for properties to the City's interior.

5.2.1 Roads & Bridges

Roads that are located directly on Ocean Springs' coastline, including Front Beach Drive, East Beach Drive and Harbor Road are most likely to be affected by changes in sea level, as their locations are only a few feet above sea level. While changes of up to a foot in sea level might not cause most of the roadway to go underway, periodic flooding would certainly increase, particularly in times of high tides and tidal surge. Inundation of these roadways, even periodically, can result in costly maintenance, in addition to unsafe driving conditions. Road pavement will crack more easily and potholes will occur due to increase water in the soils below the surface.

[45] NOAA Coastal Services Center. Flood Exposure Snapshot: Jackson County, Mississippi. June 2012.

Figure 5.2 Jackson County Hurricane Evacuation Zones



Further inland, of greater concern is the impact on hurricane evacuation routes on Highway 609/Washington Avenue and Highway 57. All of the land area south of Highway 90/Bienville Boulevard is Hurricane Evacuation Zone 1. As the roads in the region south of Highway 90 currently flood in a tropical storm, the increase in sea level rise will further exacerbate this flooding and increase the challenges to evacuation. This concern arose during the preparation of the Hazard Mitigation Plan, as the City must already prepare for the difficult logistics of evacuating the majority of historic Ocean Springs and its Central Business District if a disaster occurs that leads to storm surge from the Mississippi Sound and damage to the railroad tracks that form the northern boundary of historic Ocean Springs. Derailments and track damage in the event of a disaster could effectively shut off evacuation north toward Bienville Boulevard for personal and emergency vehicles. The remainder of the city is also at high risk, being located in Hurricane Evacuation Zone 2. The low-lying bridges on Ocean Springs' southern boundary, including those over Kensington and Pine are susceptible to flooding, as are the bridges over Stark, Heron and Davis Bayous.

Recovery time from this roadway flooding will continue to increase as sea level rises. With rising sea waters, the bayous and marshes will also rise. The rate of gravity drainage will decrease as sea level rises, as the difference in elevation between the area being drained and the water source it is draining to will be decreased (discussed in greater detail below).

5.2.2 Sanitary Sewer Infrastructure

Sea level rise may raise the groundwater table in many coastal regions. These higher groundwater levels may cause the underground infrastructure in low-lying areas, including the sanitary sewer piping and sewer pumping stations, to be submerged. Areas not submerged from higher groundwater levels may experience periodic inundation from increased rainfall and decreased surface drainage capacity. These impacts can limit access for repairs in some areas and damage the substrate under the sewer piping, compromising the performance of the system. This creates the potential for contamination of groundwater, should a sanitary sewer pipe leak occur.[46]

[46] USGS, Sea-level Rise Hazards and Decision Support, http://wh.er.usgs.gov/slr/coastalgroundwater.html

Of particular concern are septic tanks that may be impacted by sea level rise. According to City Water Department records, there are 60 addresses within the city limits that have water accounts, but no sewer accounts, indicating utilization of private septic tanks.[47] The increasing groundwater table and increasing surface inundation, due to sea level rise and increased storms/rainfall, may cause septic tanks to fail. This failure will not only render the property's septic system unusable, but could cause contamination of groundwater.

5.2.3 Stormwater Management, Drainage and Waterway Quality

Climate change, resulting in sea level rise, is forecasted to increase the number of tropical storms and associated extreme rainfall events along the Gulf Coast. Sea level rise may also increase the groundwater levels, reducing the ability of the soil to absorb surface water. The increased rainfall and higher groundwater levels will increase stormwater runoff, both inland and coastal. Debris and sediment may block inlets, pipes and outlets, further exacerbating the length of drainage time. During extreme storm events, coastal areas may be inundated by sea and rainwater, rendering the storm sewer system ineffective until the water recedes.

Figure 5.3 Stormwater Outlet into Old Fort Bayou

Outlet into Old Fort Bayou, under current (2013) water levels. One example of many outlets expected to be impacted by sea level rise.

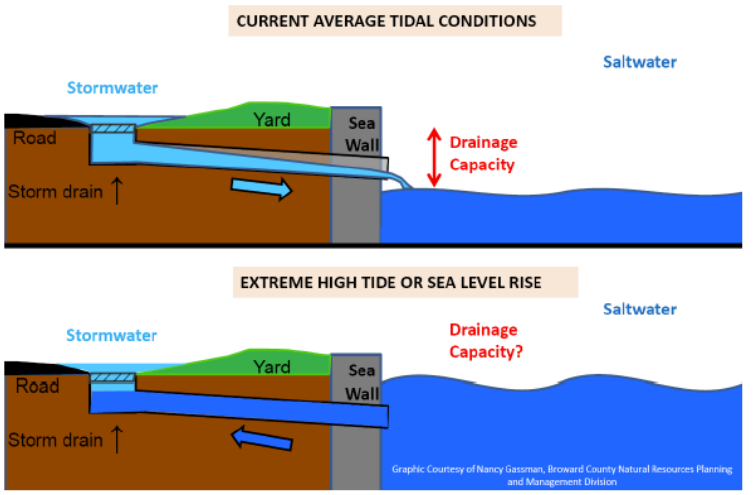
Recovery time from this flooding will continue to increase as sea level rises. As the sea, bayous and marsh waters rise, the rate of gravity drainage will decrease, as it directly correlates to the difference in elevation between the area being drained and the water source it is draining to. A greater elevation difference results in a greater slope of the "hydraulic head," which relates directly to the rate at which the water can drain.[48] This increase in elevation of the Gulf and bayou waters will decrease the hydraulic head, slowing the drainage of flooded areas. In addition, a higher water table (caused by sea level rise) reduces the ability of the soil to absorb water, increasing the likelihood of flooding. In many cases in Ocean Springs, the stormwater outlets may be under water, either due to a storm surge or sea level rise, further crippling the drainage process.

[474747] City of Ocean Springs, *City Sanitary Infrastructure Table*.

[48] Titus, James, Chin Y. Kuo, Michael J. Gibbs, Tom B. LaRoche, M. Keith Webb, and Jesse O. Waddel "Greenhouse Effect, Sea Level Rise, And Coastal Drainage Systems". ***Journal of Water Resources Planning and Management***, Vol. 113, No. 2, March 1987. http://papers.risingsea.net/downloads/sea-level-rise-coastal-drainage.pdf

The increased runoff may potentially overload the storm sewer systems and increase the amount of polluted runoff to bayous, marshes and the Gulf. As the increased rainwater runs off impervious surfaces (roadways, parking lots, rooftops), it collects sediment, pollutants and debris, which then drain to local waterways. Water quality problems (turbidity, pollutants) could worsen in the waterways around Ocean Springs due to this increase in stormwater runoff. In fact, the EPA states that increased precipitation due to climate change and resulting runoff is one of the main future challenges for estuarine water quality.[49]

Figure 5.4 Stormwater Drainage and Sea Level Rise



Source: Florida's *Post-Disaster Redevelopment Planning*, FL Dept of Economic Opportunity, FL Division of Emergency Management.

Additionally, the increase in standing water due to an increase in drainage time (discussed earlier, due to decrease in hydraulic head) to either storm sewers or waterways will increase the potential for water-borne bacteria and insect larvae, namely, mosquitoes. If this is not addressed, the potential exists for a rise in health hazards and mosquito-borne illnesses.

5.2.4 Salinization of Aquifers

An increase in sea level creates the risk of saltwater intrusion into freshwater aquifers, the source of drinking water. As population grows, the demand for freshwater increases, while at the same time, increased salinity from sea level rise decreases its availability. Ocean Springs' drinking water is sourced from groundwater aquifers, pumped through six aquifers in the City. Five of the wells source from the Graham Ferry Formation and one from the Pascagoula Formation.[50]

Saltwater has a higher mineral content than freshwater, which gives it greater density. This provides saltwater higher pressure and the ability to move freshwater. Extraction of freshwater by humans decreases the freshwater level and its pressure, reducing its ability to balance the pressures of the intruding saltwater. As a result, the saltwater intrudes the fresh drinking water. This problem is already occurring in many coastal regions, including some areas of Florida.[51]

[49] EPA. *Introduction to Common Estuarine Environmental Problems*. http://water.epa.gov/type/oceb/nep/challenges.cfm

[50] 2011 Drinking Water Quality Report, City of Ocean Springs, Public Works.

[51] Johnson, Ted (2007). "Battling Seawater Intrusion in the Central & West Coast Basins". Water Replenishment District of Southern California. http://www.wrd.org/engineering/reports/TB13_Fall07_Seawater_Barriers.pdf,

5.2.5 Potential Impact Areas

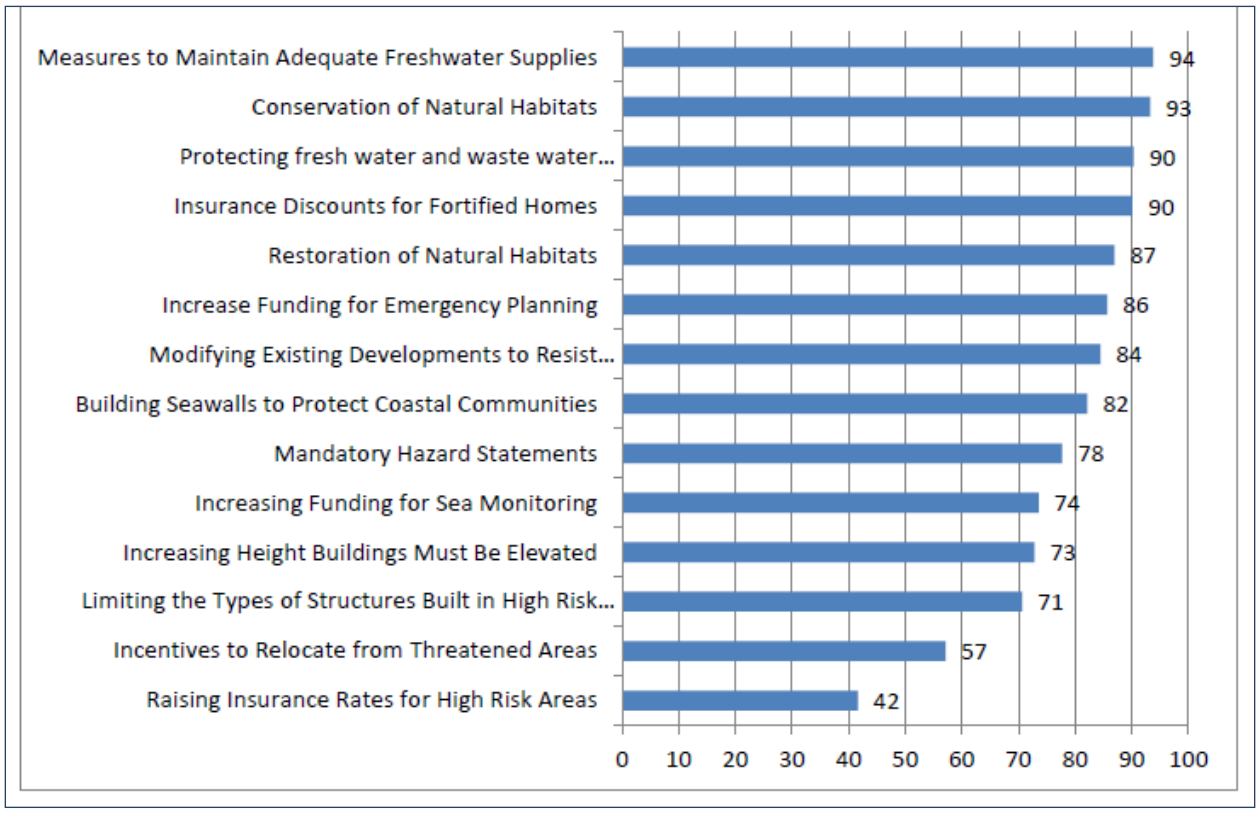
While the entire City must be diligent in its planning with an eye for sea level rise hazard mitigation, there are specific communities with elevated risk within Ocean Springs, due to their low elevations or waterfront proximity. Specific attention must be placed on the details of the future planning and development of these areas, to include:

- Lovers Lane
- Front Beach
- Gulf Coast Research Lab
- Small Craft Harbor
- East Beach
- Lower-Lying properties/infrastructure along Old Fort, Davis, Heron and Stark Bayous
- Gulf Islands National Seashore

6.0 POTENTIAL MITIGATION MEASURES FOR SEA LEVEL RISE IMPACTS

Ocean Springs is not alone in its concern about the future impacts that a changing climate might have on its citizens. In a 2012 Survey of over 3,500 Gulf Coast residents in Mississippi and the other four Gulf Coast States, residents supported a wide range of specific government actions to address climate change, as described in the table that follows: [52]

Figure 6.1 Stormwater Outlet into Old Fort Bayou



Mississippi placed an even stronger priority on freshwater supply and conservation, which both rated as desirable by over 95%. Local government measures to prevent saltwater intrusion of water supply and wastewater infrastructure received support from 92% of respondents. Natural area restoration incentives were judged as desirable by 90% of Mississippi respondents and a in slight departure from Gulf-wide results, "Modifying existing developments to resist" and "Building Seawalls" received a slightly higher measure of support. The punitive strategy of raising insurance rates for structures in high-risk areas received the lowest measure of support, at only 24.9%.[53]

[52] Sea Grant Program. *2012 Gulf Coast Climate Change Survey: Executive Summary*. Kirby Goidel, Christopher Kenny, Michael Climek, Maxwell Means, LaDon Swann, Tracie Sempier, and Melissa Schneider. page 16.
[53] IBID. page 15.

Ocean Springs identified a number of strategies that will begin to address these issues, and sea level rise specifically, in its own 2012 Hazard Mitigation Plan. Local and regional responses to sea level rise around the country generally fall into the categories of adapting, armoring or retreating. Armoring strategies are those that are intended to physically armor the shoreline against rising sea levels, like seawalls and bulkheads. Retreating strategies include "no-build" zones, deed restrictions, rolling easements, and other mechanisms designed to minimize impacts to the human and built environment. Most of the strategies Ocean Springs is practicing or has proposed in the excerpted table from the Hazard Mitigation Plan (HMP) below are adaptive in nature, including the elevation of structures and factoring changes in water level rise considerations into planning and zoning policy. **Table 6.1** represents a modified version of the table found in the HMP to show how strategies already under consideration relate to sea level rise considerations. Priority rankings shown are consistent with the table presented in the original plan.

TABLE 6.1 2012 OCEAN SPRINGS HAZARD MITIGATION PLAN FINAL MITIGATION STRATEGY RANKING AND PRIORITIZATION

Ocean Springs Adopted Mitigation Strategies		
Description	**Strategy Type**	**Priority Ranking**
Encourage the underground placement of electric, telephone and cable TV lines by developers working outside of the coastal zone to improve aesthetics, prevent disfigurement of trees and provide protection from high winds and other hazards	Infrastructure	High
Include structural design, elevation, and location standards in the Unified Development Code to mitigate effects of natural hazards.	Planning & Development Management	High
Continue to require that development exceeds FEMA's required base elevations by a measure of one foot.	Planning & Development Management	High
Use Planning and Buildings Department review and record-keeping process to ensure compliance with Flood Ordinance, determine appropriate building elevations and minimize development in the floodplain.	Planning & Development Management	High
Update the City's Hazard Mitigation and Emergency Response plan and its Hurricane Response Plan to ensure emergency service and evacuation routes are adequate, well-marked and accessible	Planning & Development Management	High
Develop a Capital Improvements Plan (CIP) for the City of Ocean Springs	Infrastructure	Medium
Inspect water wells and towers to ensure they are sufficiently strong to withstand high winds and storm surge.	Infrastructure & Drinking Water	Medium
Prepare lift stations for inundation and power outages by raising electrical equipment above the BFE in the event of storm surge and long-term power outages.	Infrastructure	Medium

Ocean Springs Adopted Mitigation Strategies		
Description	**Strategy Type**	**Priority Ranking**
Enhance Continuity Plan to ensure that emergency operations can function and that day-to-day management of the City can be back on track as soon as possible after an emergency.	Planning & Development Management	Medium
Acquire properties in V and AE zones for mitigation	Natural Systems	Medium
Improve shelter network for citizens and emergency personnel (Gay Lemon, EOC)	Planning & Development Management	Medium
Maintain the Jackson County seawall tax.	Planning & Development Management	Medium
Continue the City's efforts to upgrade drainage facilities along coastal roadways.	Infrastructure	Medium
Provide buffers between natural forest and urban development to protect against wildfire.	Planning & Development Management	Low
Mandate larger setbacks from bayous and streams	Planning & Development Management	Low
Preserve trees and vegetation on uninhabited properties to improve stormwater management /flood control	Natural Systems	Low
Preserve natural/wetlands and riparian areas through acquisition or conservation easements.	Retreat	Low
Conduct regular controlled burns to limit fuel for forest fires in wet pine savanna habitats.	Natural Systems	Low
Extend sand beach additional 100 feet to the east, and stabilize with plantings.	Adapt	Low
Request that Jackson County continue dune propagation in areas along East Beach and Front Beach	Natural Systems	Low

Although not all of the measures that would improve Ocean Springs' resilience to sea level rise are given high priority in the existing Hazard Mitigation Plan, it may be productive to revisit some of these measures, particularly those that protect the City's natural systems. Strategies such as larger setbacks from bayous and streams, marshland protection, preserving vegetation on uninhabited properties and dune propagation produce exceptional bang for the buck while capitalizing on the natural beauty that already draws people and investment to Ocean Springs.

To visualize the impacts of sea level rise on Ocean Springs, **Appendix C: Sea Level Rise Simulation** presents maps simulating a one-foot and a two-foot sea level rise. These maps of Ocean Springs and its immediate vicinity include current city boundaries, major roads and

infrastructure, and help the viewer visualize areas that might go underwater or experience increased flooding as a result of increasing sea levels in the coming decades. For planning purposes, projections of one-foot rise for 2028 and a two-foot rise in 2038 assume a worst case scenario equal to the 0.83 inch annual increase occurring globally. While this is higher than the historical trend of approximately 0.1 inch/year in this region of the Gulf Coast, accelerating global sea levels as well as marshland loss and coastal erosion in Ocean Springs are likely to produce an outcome that falls between the local and global sea level rise trends. Based on this analysis of Ocean Springs strengths and vulnerabilities, the City will be better prepared to meet any sea level rise scenario by developing a comprehensive sea level rise mitigation approach that gives particular focus to the issues discussed in detail below.

6.1 Development Management and Planning Strategies

Implementing informed policy to address sea level rise now is much less costly than reacting to sea level rise when damages occur. Land use planning and engineering designs can take into account the forecast sea level rises now at little to no costs, avoiding larger costs in the future. Ocean Springs should continue to identify areas for conservation, such as the undeveloped peninsula of Lovers' Lane and other undeveloped low-lying areas along Old Fort Bayou and Davis Bayou.

Setback requirements for structures and supporting infrastructure along all waterways in Ocean Springs should be revisited and considered during preliminary planning at the onset of any development. These setback requirements should consider flood plain locations, sea level rise, increased storm surge water levels, and any potential impacts to structures or utilities within the impact areas. During the preliminary design stages of properties adjacent to any waterways, sea level rise information and design considerations/recommendations should be discussed with property owners and/or developers to minimize future impacts.

In general, public awareness needs to be increased regarding sea level rise, particularly for property owners near water. A *Shoreline Protection Planning and Design Manual* (currently under development, sponsored by the Department of Marine Resources) will be a useful tool to provide coastline property owners with processes and best practices for sustainable and protective shoreline management. Public outreach materials should be utilized to inform residents and business owners of these available resources for sea level rise planning on their properties.

6.2 Infrastructure

While Ocean Springs is surrounded on nearly all sides by water, most of the structures within the city have been set back from the water and/or elevated. However, a significant amount of infrastructure exists in the coastal areas and should be monitored regularly and updated, moved or fortified when feasible.

To facilitate this management of infrastructure, we have prepared an initial map of critical infrastructure and GIS-based documentation of all infrastructure in Ocean Springs, presented in **Appendix C**. This initial map includes public sewer and private septic systems, water systems, stormwater systems, power utilities and communications systems. At one-foot of sea level rise, the first infrastructure to be impacted will likely be the sewer lift stations near Davis and Old Fort Bayous, East Beach Road and Lover's Lane. A full inventory of infrastructure resources in the mapped floodplain and any area at increased risk of sea level rise should be managed by the planning department and shared by all departments responsible for infrastructure and emergency response. This will aid the City in hazard mitigation for the facilities. In addition to pre-emptive planning and proper location of new facilities, continual monitoring will enable the City to react quickly when adaptation and even armoring solutions are needed. The Ocean Springs Hazard Mitigation Plan included many mitigation strategies for storm surges that also apply to sea level rise (see **Table 6.1**). In addition to these strategies, the City should also discuss these approaches:

- Improve accessibility of low bridges between 90 and Gulf during storms.
- Increase stormwater capacity in areas currently susceptible to flooding.
- Consider sewered hook-ups for susceptible locations currently with private septic systems.
- Encourage "green infrastructure," to minimize surface runoff and inundation of storm and sanitary sewer systems, including permeable pavement, constructed wetlands, and rain gardens.
- Incorporate water conservation education in City Stormwater Program to decrease load on sanitary and storm sewer.
- Armor underground piping in low-lying areas.
- Relocate impacted underground utilities to higher locations as sea level rise occurs.
- Enable sewer pump stations to be detachable in case of storm, similar to Pass Christian.
- Incorporate sea level rise into all capital infrastructure project planning and design.

6.3 Drinking Water

A readily available supply of drinking water will be imperative to the continued success of Ocean Springs. Other southeastern coastal cities (particularly in Florida) have experienced saltwater intrusion into their groundwater. It is prudent for Ocean Springs and the entire Mississippi coastal region to be proactive in monitoring and testing its drinking water supply and the location and movement of the saltwater interface, perhaps through a coastal county-wide or state-sponsored monitoring and testing program. Encouraging thoughtful use and conservation by residents and businesses will be important in mitigating the risk of saltwater intrusion through overuse of the freshwater supply.

A public education process regarding the need for thoughtful use of water is important to inform Ocean Springs residents on the risks of saltwater intrusion (caused by the combination

of sea level rise, period droughts and high water usage) and steps to eliminate excessive and unnecessary use of water. Examples of simple strategies for residents and businesses include smart yard watering, zone-appropriate and low water plantings, rain collection barrels, installation of low flow toilets and shower heads, and use of efficient washing machines. Assigning each of these water conservation approaches to a dollar amount of savings per year to the household will personalize the benefits and increase the likelihood of implementation.

6.4 Natural Systems

The natural systems, including wetlands, marshes and beaches, around Ocean Springs will be the first areas impacted by sea level rise. Natural systems that are not allowed to migrate inland or those that do not incorporate new sediment through accretion as quickly as sea level rises, will drown. Important habitat for fish and wildlife as well as storm protection may be lost in these areas. The specific implications for coastal marsh and wetlands are outlined in a Nature Conservancy study using a Sea Level Rise Affecting Marshes Model (SLAMM), and are listed in greater detail in **Figure 5.1**. They include frequent flooding of marshes, leading to a change in grasses and other plant and animal life they can support. Also projected are increases in salt marsh and the loss of swamp land, both of which are important issues to consider for private property owners and the Gulf Islands National Seashore.

Ocean Springs would benefit from a shoreline management study/program that identifies specific approaches for each region of marsh and wetland. Shorelines and coastal wetlands are continuously impacted by hardened shorelines including sea walls, riprap, groins, and other artificial stabilization methods. While shoreline erosion is a natural process, these hardening, or armoring, mechanisms have the potential to interrupt natural shoreline processes. This can lead to increased erosion down drift from the structure. A shoreline management program would identify areas of marsh should be permitted to migrate inland, as well as how to mitigate those areas with hardened shorelines than cannot migrate.

7.0 Recommendations to Mitigate the Effects of Sea Level Rise

Because of the relatively low cost and high value in terms of environmental protection, we recommend that policies to adapt to sea level rise continue to be followed whenever possible. Retreat strategies are best employed to reduce economic and ecological loss in low-lying areas with repetitive flooding and storm damage. Armoring the coastline is the most expensive strategy for adapting to sea level change. It should generally be used as a last resort. While it may protect the area immediately inland, hardened structures can cause erosion and other damage on unprotected shoreline in the immediate vicinity. As in most other communities exposed to changing sea levels, the strategies selected will need to balance costs, political feasibility and environmental benefits. A combination of approaches that adapt to, retreat from and armor the city against sea level rise will be the most sustainable pathway for Ocean Springs.[54]

Ocean Springs should continue to be proactive, cognizant and adaptable to changing conditions in its waterfront neighborhoods. A shoreline management plan could help set the tone for long-term investments in the community. Forming partnerships with institutions like the Gulf Coast Research Laboratory and Grand Bay National Estuarine Reserve will help Ocean Springs monitor environmental change and document changes in existing facilities and infrastructure. This plan presents a broad range of potential impacts from best to worst case scenario. it is very difficult to pinpoint the timing of future impacts, but diligent monitoring, early investment and keen awareness of the risks are necessary to know when to act on capital improvements. Planning for sea level rise planning should begin now.

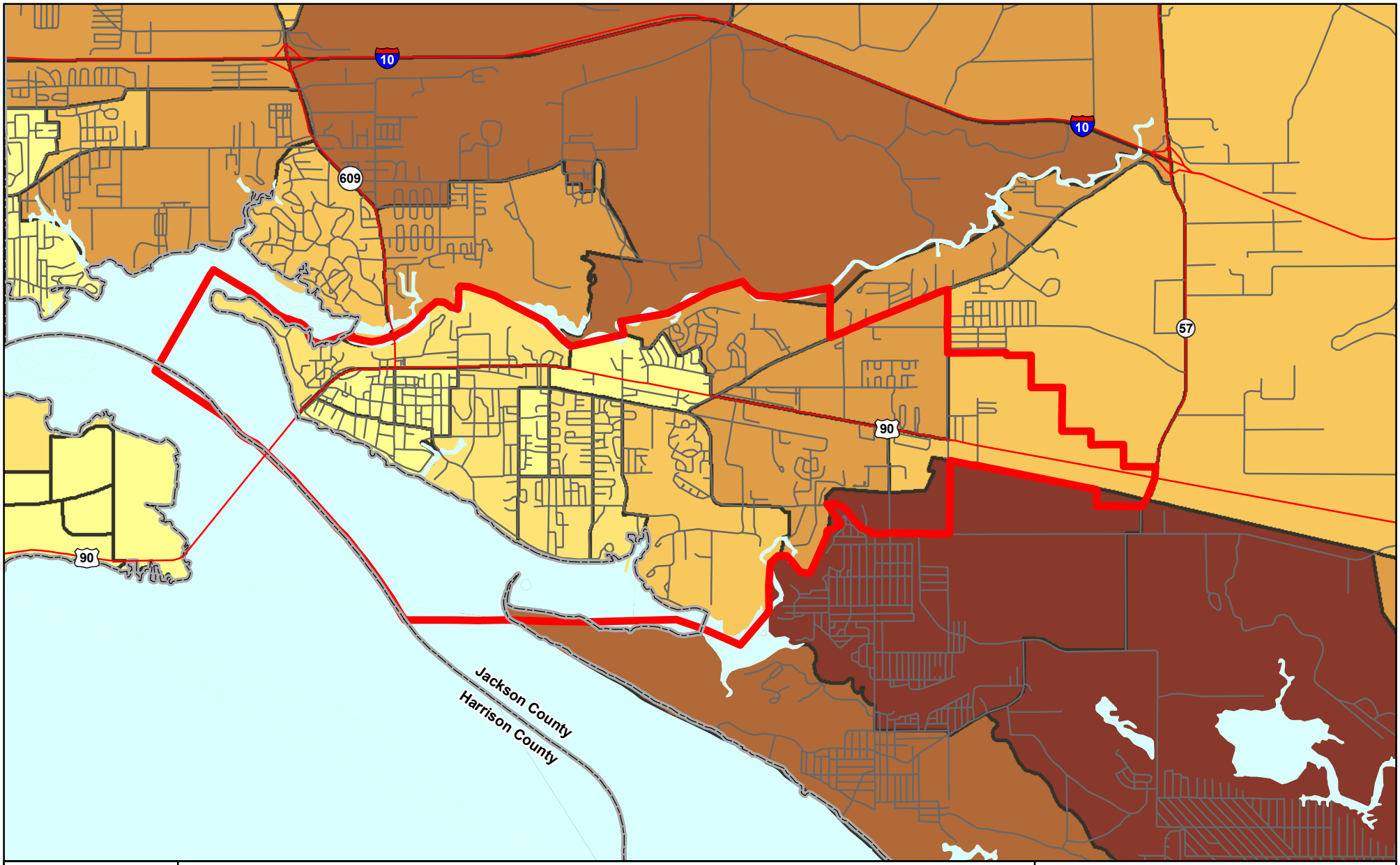
Short-term planning efforts should include a plan for where and how facilities and supporting infrastructure will be sited in this coastal region, with a focus on minimizing future impacts and costs. The City should continue its course of incorporating adaptation strategies into ongoing and future development projects to protect development from frequent coastal hazards.

Long-term strategies should focus on more cost-intensive projects on the Ocean Springs shoreline, pursuing restoration, retreat and armoring strategies where appropriate. In the long-term, as the impacts of sea level rise become visible, armoring may present the only alternative for developed areas where retreating is not feasible. Undeveloped areas should be preserved and planned to allow the sea to rise and migrate inland. In particularly vulnerable coastal areas, Ocean Springs may need to consider designation of no-build and conservation areas, or provide private property owners with incentives to relinquish property or development rights through land exchanges and trading of development rights.

Sea level rise strategies must be flexible to adjust the levels of protection necessary. Regional policies, combined with public education will prepare both current and future generations to address changes to the shape and form of Ocean Springs, so that this city may remain the jewel of the Mississippi Gulf Coast.

[54] Mississippi Department of Marine Resources. *Sea Level Rise Plan*.

Appendix A: Maps and Figures



PROJECT LOCATION

LEGEND

- City Boundaries
- Ocean Springs City Limits
- Major Interstates and Highways

Census 2010 Block Data
TOTAL

- 0 - 895
- 896 - 1326
- 1327 - 1846
- 1847 - 2613
- 2614 - 3974
- 3975 - 7131

0 3,000 6,000 Feet

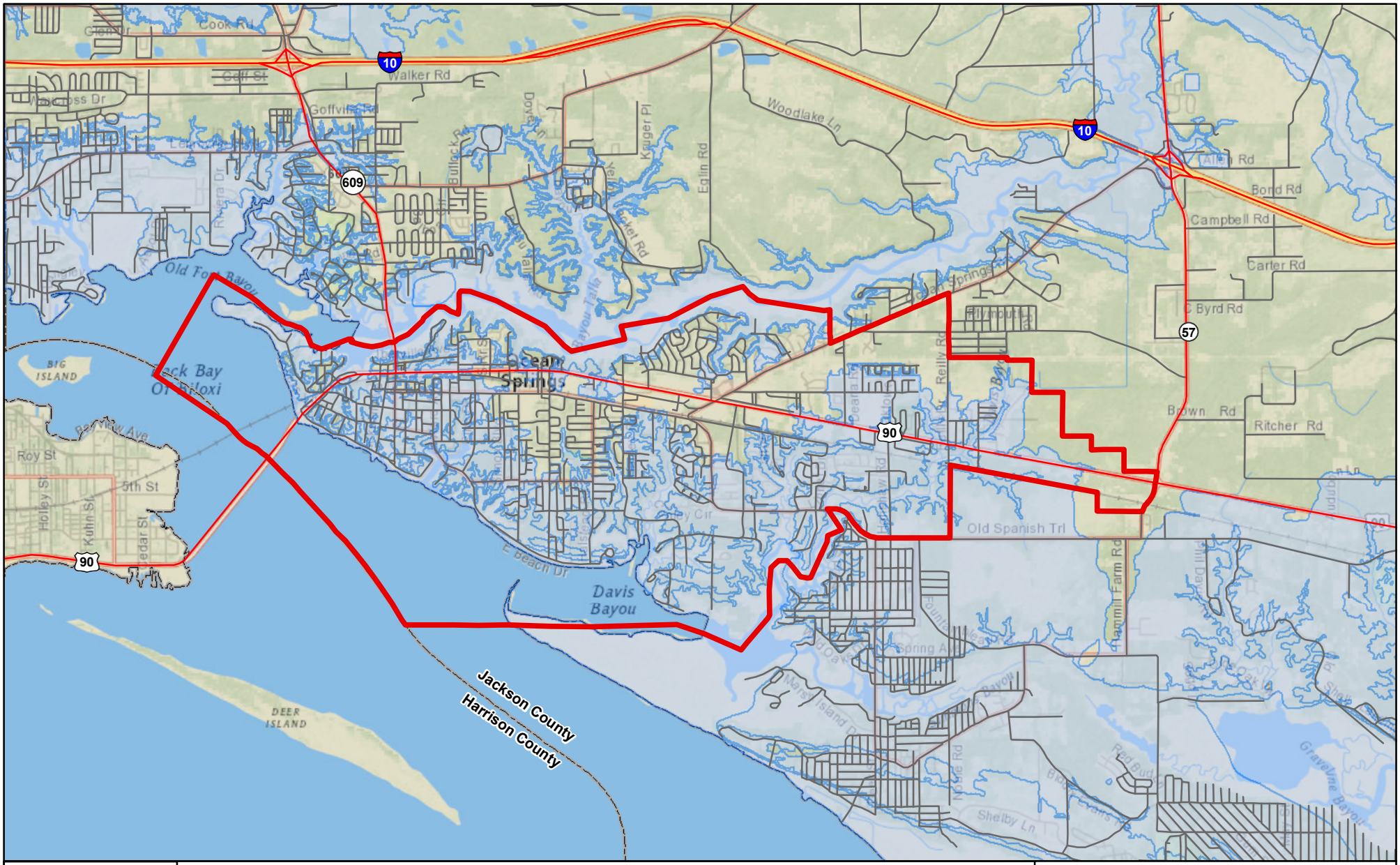
N

OCEAN SPRINGS SEA LEVEL RISE STUDY
JACKSON COUNTY, MISSISSIPPI

Eco•Systems, Inc.
Consultants, Engineers, and Scientists

SCALE: 1"=6,000'	DRAWN BY: PML	DATE: 02-01-2013
	CHKD BY: KM	DATE: 02-01-2013
PROJECT NO. 12105	FILE 12105 020113 FIG01 R00 D PD 2010 C	

POPULATION DENSITY 2010 CENSUS — FIGURE 1



PROJECT LOCATION

LEGEND

- County Boundaries
- Ocean Springs City Limits
- FEMA Flood Boundary
- Major Interstates and Highways

0 3,000 6,000 Feet

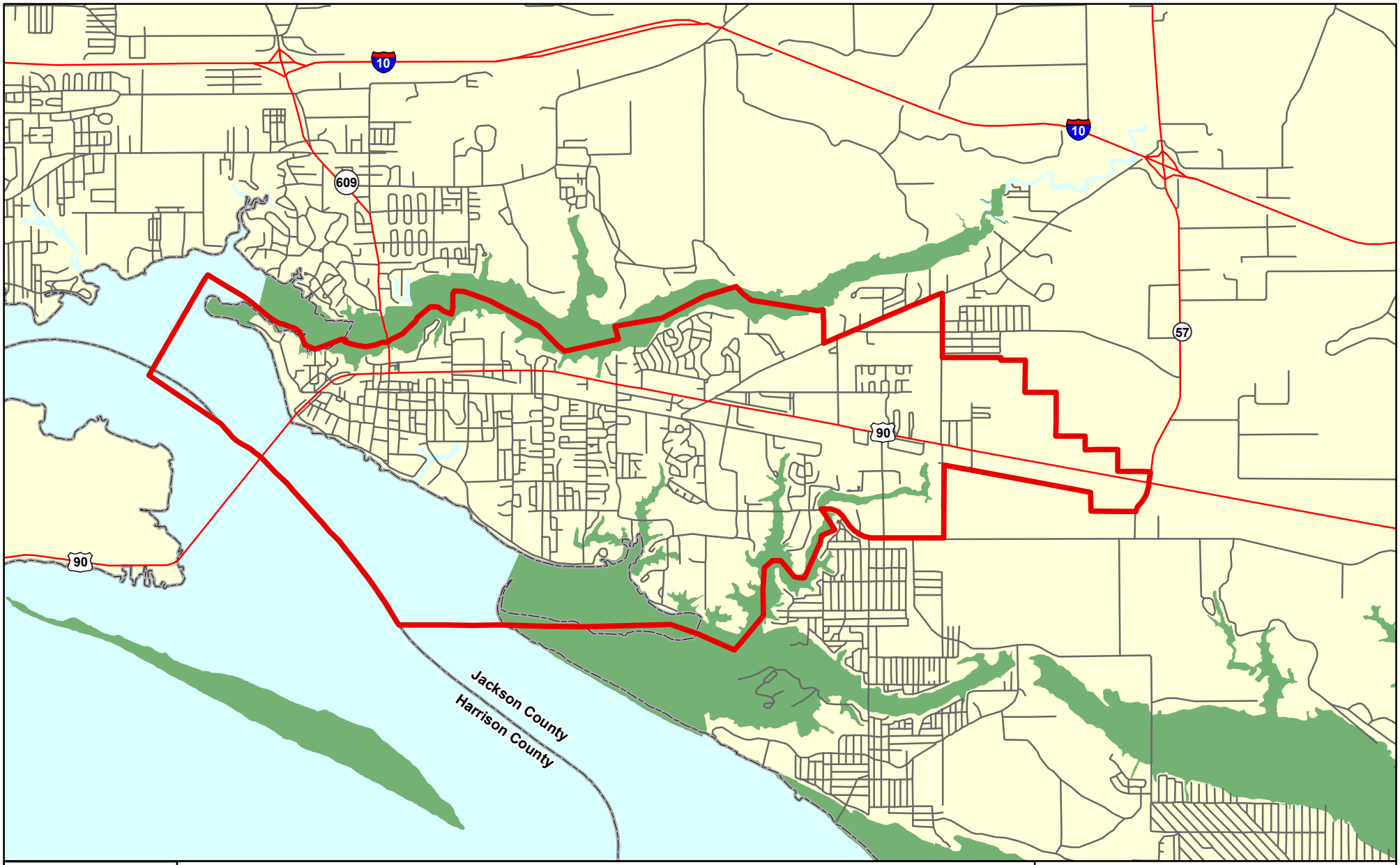
N

OCEAN SPRINGS SEA LEVEL RISE STUDY
JACKSON COUNTY, MISSISSIPPI

Eco•Systems, Inc.
Consultants, Engineers, and Scientists

SCALE: 1"=6,000'	DRAWN BY: PML	DATE: 04-09-2013
	CHKD BY: KM	DATE: 04-09-2013
PROJECT NO. 12105	FILE 12105 040913 FIG07 R00 D Infrastructure	

INFRASTRUCTURE — FIGURE 7



PROJECT LOCATION

LEGEND

- City Boundaries
- Ocean Springs City Limits
- States
- Major Interstates and Highways

Gulf Ecological Management Sites (Coastal Preserves)

- COASTAL FLATWOODS

0 3,000 6,000 Feet

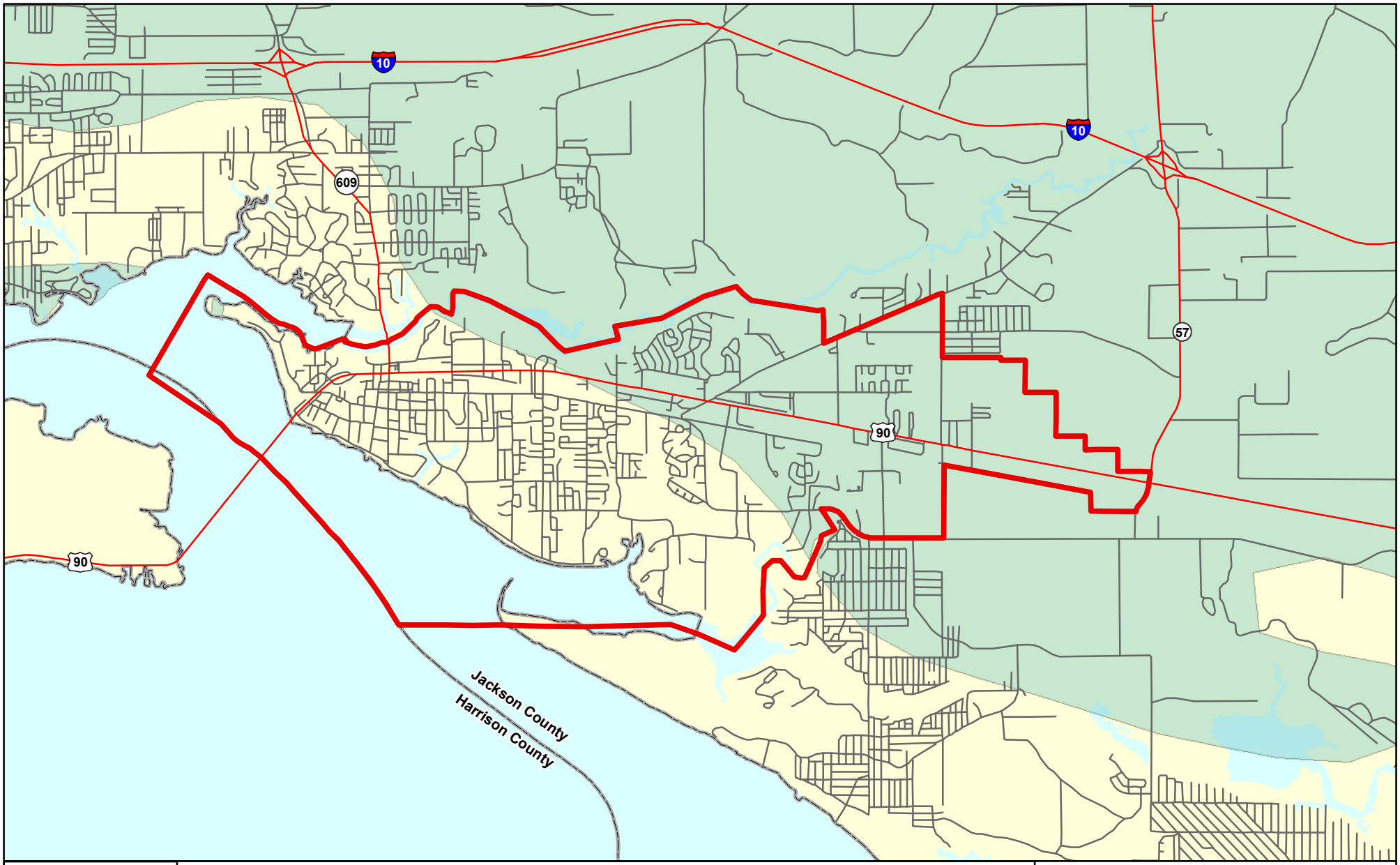
N

OCEAN SPRINGS SEA LEVEL RISE STUDY
JACKSON COUNTY, MISSISSIPPI

Eco·Systems, Inc.
Consultants, Engineers, and Scientists

SCALE: 1"=6,000'	DRAWN BY: PML	DATE: 02-01-2013
	CHKD BY: KM	DATE: 02-01-2013
PROJECT NO. 12105	FILE 12105 020113 FIG02 R00 D GEMS	

GULF ECOLOGICAL MANAGEMENT SITES (COASTAL PRESERVES) MAP — FIGURE 3



PROJECT LOCATION

LEGEND

- City Boundaries
- Ocean Springs City Limits
- States
- Major Interstates and Highways

Forest Habitat Regions

- COASTAL FLATWOODS

0 3,000 6,000 Feet

N

OCEAN SPRINGS SEA LEVEL RISE STUDY
JACKSON COUNTY, MISSISSIPPI

Eco·Systems, Inc.
Consultants, Engineers, and Scientists

SCALE: 1"=6,000'	DRAWN BY: PML	DATE: 02-01-2013
	CHKD BY: KM	DATE: 02-01-2013
PROJECT NO. 12105	FILE 12105 020113 FIG02 R00 D F H M	

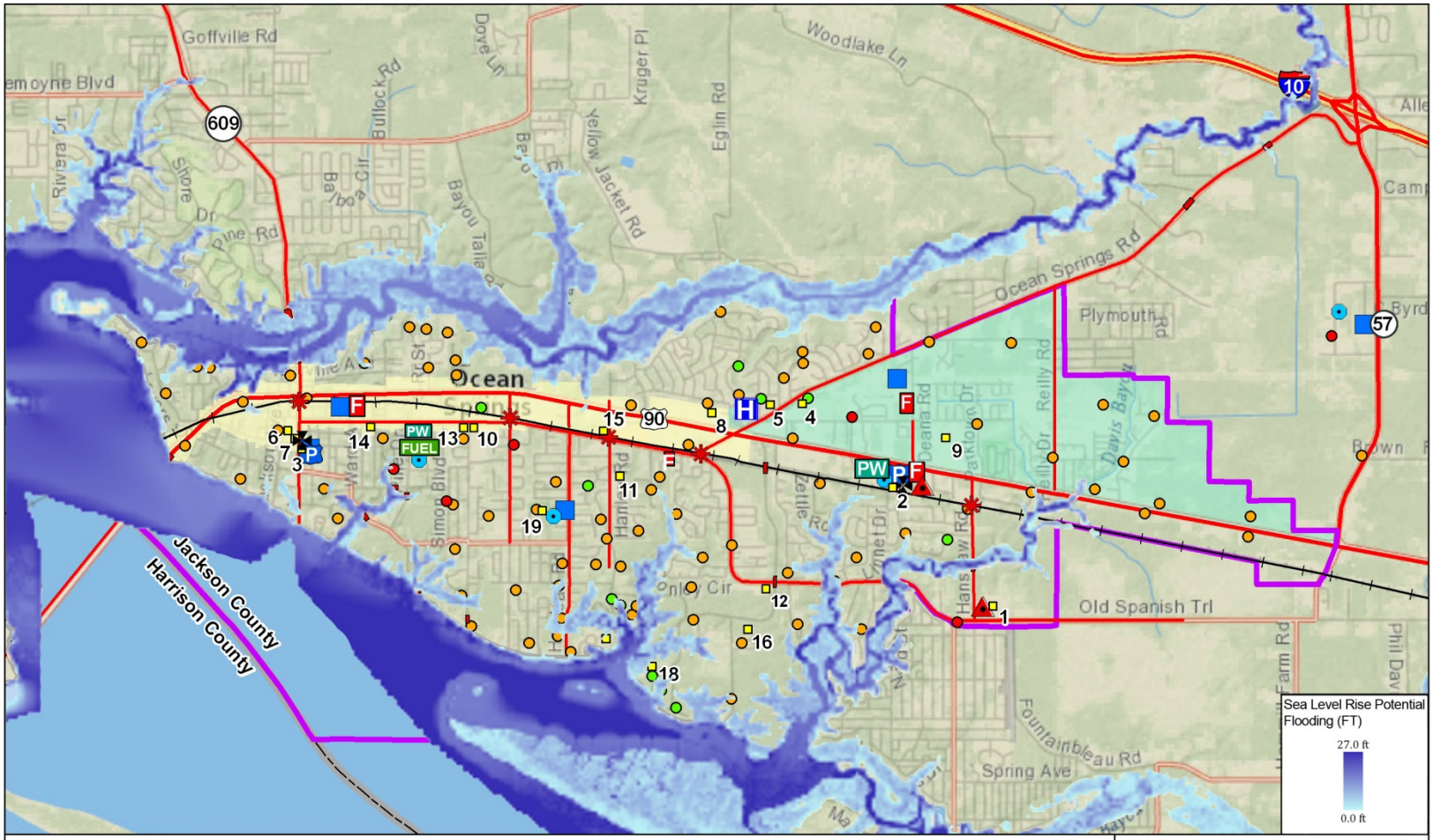
FOREST HABITATS MAP — FIGURE 2

Appendix B: Soil Types

Soil Series	Soil Type	Slope	Drainage	Current Use	Suitability to development
Eustis	loamy sand	2-5 percent	Excessively drained	Woodland and Pasture	Well suited
Bayou	sandy loam; hydric(1)	0-1 percent	Poorly drained	Woodland and wildlife habitat	Very limited
Smithton	loam; hydric	0-1 percent, Often flooded	Poorly drained and Flooding	Woodland and wildlife habitat	Very limited
Escambia	very fine sandy loam		Somewhat poorly drained	Woodland and Pasture	Suited, with some limitations
Harleston	fine sandy loam; hydric(1)	0-2 percent	Moderately well-drained	Woodland and wildlife habitat	Very limited
Harleston	fine sandy loam	2-5 percent	Moderately well-drained	Woodland and wildlife habitat	Suited
Harleston	Fine sandy loam	5-8 percent	Moderately well-drained	Woodland and wildlife habitat	Suited
Ocilla	loamy sand	0-2 percent	Somewhat poorly drained and Flooding	Woodland and wildlife habitat	Very limited
Benndale	fine sandy loam	2-5 percent	Well-drained	Cropland and pasture	Well suited
Handsboro	mucky silt loam; hydric(1)	Frequently flooded	Very poorly drained; ponding; Subsidence; Flooding	Wildlife habitat	Very limited

(1) NRCS Hydric Soils List, February 2011

Appendix C: Sea Level Rise Simulation



LEGEND

- Approximate Central Business District
- Approximate East Ocean Springs Area
- Ocean Springs City Limits
- Major Roadways - (Highway 90, Government St., Ocean Springs Rd., Old Spanish Trail, Highway 57, Riley Rd., Hanshaw Rd., Deana Rd., Hanley Rd., Halstead Rd., Bechtel Rd., Washington Ave / Hwy 609.
- Water Tower Locations
- Major Railroad Crossing Locations
- Ocean Springs Police Station Locations
- Ocean Springs Fire Station Locations
- Water Well Pump Locations
- Ocean Springs Bridges
- Emergency Operations Center
- Public Works
- Communication System (Emergency Radios)
- Public Works Fuel Pumps
- Private Sewer Lift Stations
- Sewer Lift Stations
- JCUA Sewer Lift Stations
- 1 East Emergency Operations Center - Ocean Springs Middle School
- 2 Ocean Springs Civic Center - Public Works Command Center
- 3 Ocean Springs City Hall
- 4 The Gardens
- 5 Ocean Springs Nursing Center
- 6 Samaritan House Retirement Apartments
- 7 Villa Marina Retirement Apartments
- 8 AT&T
- 9 Walmart
- 10 Ocean Springs High School
- 11 Pecan Park Elementary School
- 12 Magnolia Park Elementary School
- 13 Oak Park Elementary School
- 14 Ne Taconi Elementary School
- 15 Bus Barn
- 16 University of Southern Mississippi
- 17 University of Southern Mississippi Gulf Coast Research Laboratory
- 18 Gulf Island National Seashore
- 19 Parks

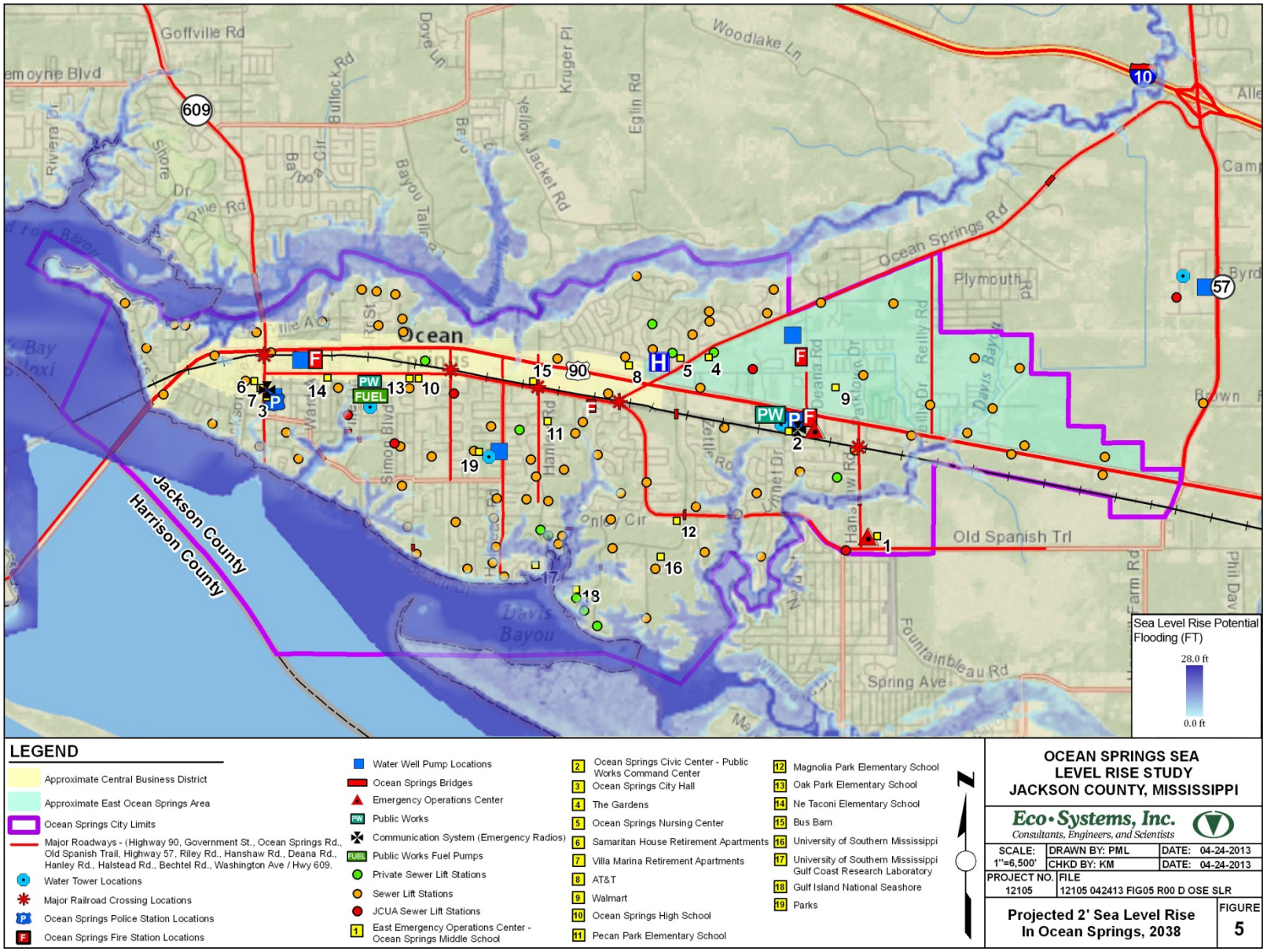
OCEAN SPRINGS SEA LEVEL RISE STUDY
JACKSON COUNTY, MISSISSIPPI

Eco•Systems, Inc.
Consultants, Engineers, and Scientists

SCALE: 1"=6,500'	DRAWN BY: PML	DATE: 06-06-2013
	CHKD BY: KM	DATE: 06-06-2013
PROJECT NO. 12105	FILE 12105 060613 FIG05 R00 D OSE SLR	

Projected 1' Sea Level Rise In Ocean Springs, 2028

FIGURE 5


Goffville Rd
Woodlake Ln
Ocean Springs Rd
Plymouth Rd
Old Spanish Trl
Spring Ave
Fountainbleau Rd
Davis Bayou
Jackson County
Harrison County
Ocean
Sea Level Rise Potential Flooding (FT)
28.0 ft
0.0 ft
LEGEND
Approximate Central Business District
Approximate East Ocean Springs Area
Ocean Springs City Limits
Major Roadways - (Highway 90, Government St., Ocean Springs Rd., Old Spanish Trail, Highway 57, Riley Rd., Hanshaw Rd., Deana Rd., Hanley Rd., Halstead Rd., Bechtel Rd., Washington Ave / Hwy 609.
Water Tower Locations
Major Railroad Crossing Locations
Ocean Springs Police Station Locations
Ocean Springs Fire Station Locations
Water Well Pump Locations
Ocean Springs Bridges
Emergency Operations Center
Public Works
Communication System (Emergency Radios)
Public Works Fuel Pumps
Private Sewer Lift Stations
Sewer Lift Stations
JCUA Sewer Lift Stations
1 East Emergency Operations Center - Ocean Springs Middle School
2 Ocean Springs Civic Center - Public Works Command Center
3 Ocean Springs City Hall
4 The Gardens
5 Ocean Springs Nursing Center
6 Samaritan House Retirement Apartments
7 Villa Marina Retirement Apartments
8 AT&T
9 Walmart
10 Ocean Springs High School
11 Pecan Park Elementary School
12 Magnolia Park Elementary School
13 Oak Park Elementary School
14 Ne Taconi Elementary School
15 Bus Barn
16 University of Southern Mississippi
17 University of Southern Mississippi Gulf Coast Research Laboratory
18 Gulf Island National Seashore
19 Parks
N
OCEAN SPRINGS SEA LEVEL RISE STUDY
JACKSON COUNTY, MISSISSIPPI
Eco • Systems, Inc.
Consultants, Engineers, and Scientists
SCALE: 1"=6,500'
DRAWN BY: PML
DATE: 04-24-2013
CHKD BY: KM
DATE: 04-24-2013
PROJECT NO. 12105
FILE 12105 042413 FIG05 R00 D OSE SLR
Projected 2' Sea Level Rise In Ocean Springs, 2038
FIGURE 5