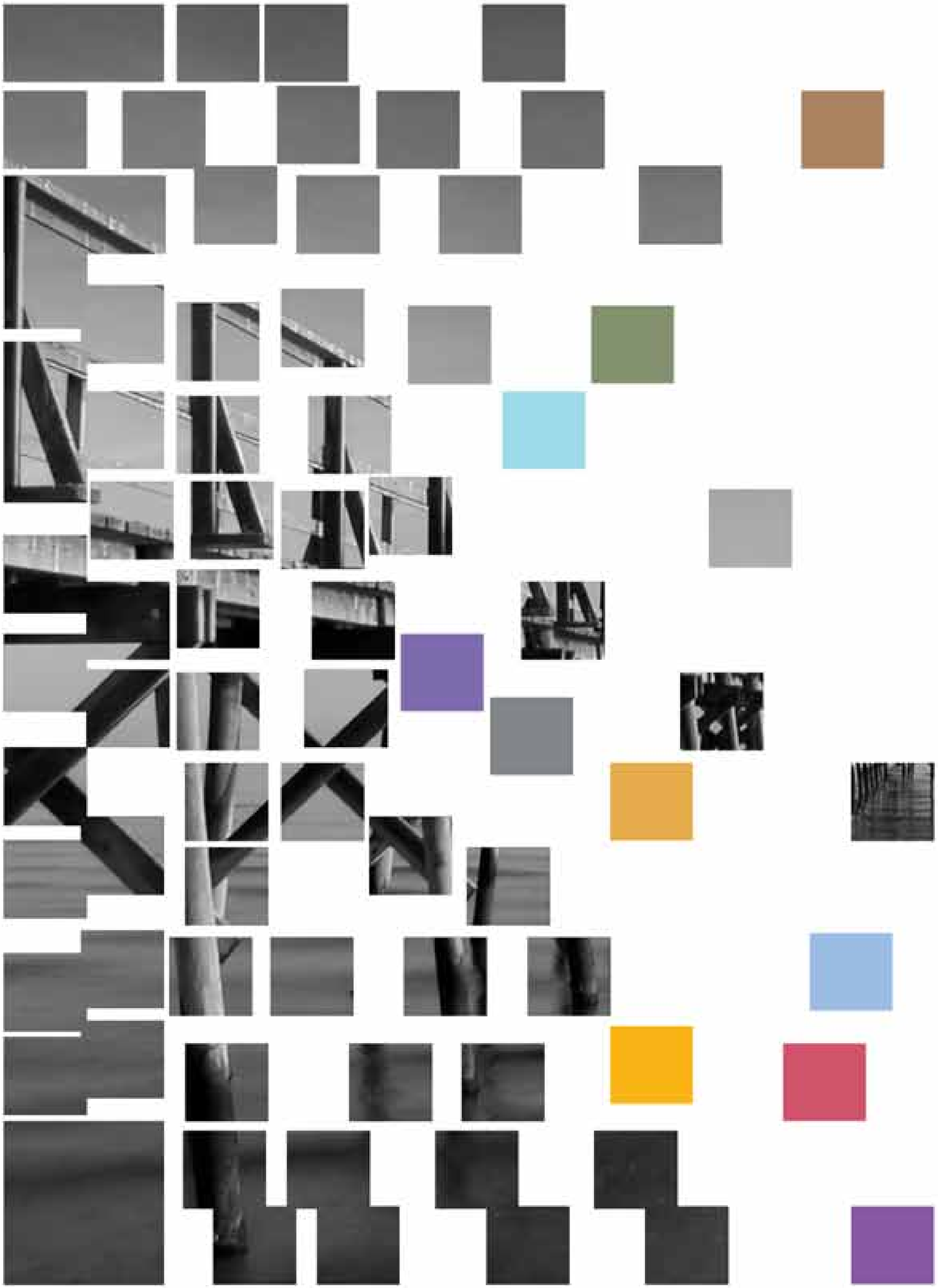

Mississippi Gulf Coast Water Assessment

February, 2012

PLAN FOR OPPORTUNITY

This is a Working Document that has been approved by the Working Group and the Executive Committee. Working Documents provide information and recommendations that guide the on-going discussions and preparation of the final plan; these are not final plan documents. Once the draft final plan has been prepared, it will be brought to the public through various outreach activities and reviewed by the various planning committees before the Executive Committee votes on adopting as the Final Plan for Opportunity.

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Introduction

This work is part of the *Plan for Opportunity*, being created under the auspices of the Consortium for a Sustainable Gulf Coast. It is funded in part by a grant from the U.S. Department of Housing and Urban Development, Office of Sustainable Housing and Communities. The Constituency for a Sustainable Coast is dedicated to uniting the region's elected officials, planning professionals and the public with a common vision for a sustainable coast through the *Plan for Opportunity*.

The *Plan for Opportunity* will bring the three coastal counties and 11 municipalities together in a comprehensive regional planning process that aims to:

• Lower transportation and housing costs by creating better connections between where people live and work.

• Develop in ways that value the natural environment, understanding that regional prosperity is dependent on our many environmental assets.

• Improve air quality by making buildings more energy efficient and reducing vehicle miles traveled.

• Create a broad range of employment and business opportunities by coordinating land-use, transportation and infrastructure planning.

• Improve regional health by ensuring that all communities have access to fresh food, safe recreation, open space, medical care and clean air and water.

The planning process will be a broad-based effort, understanding that the success of the final plan rests on the extent of stakeholder input and decision making. The P*lan for Opportunity* is the key to strengthening the regional economy, improving quality of life for residents and creating a more sustainable regional future.

As part of the planning process, the Constituency is actively preparing for a sustainable future for the region's waters. This water assessment is the first stage in the Consortium's efforts to envision more sustainable water resources for the Mississippi Gulf Coast. The Consortium has undertaken this study to better understand the complicated uses of the region's waters. The use of the region's waters is complex and it is affected by a wide variety of factors, such as energy prices, trade policies, climate and development patterns. This water assessment focuses on human uses, the water dependent economy, natural resource extraction, water quality, ecology and coastal vulnerability.

This water assessment includes the three coastal Mississippi counties as well as the waters 200-miles off the coast. This includes Mississippi's state waters, the US territorial boundaries and the US Exclusive Economic Zone. In addition, consideration is given to the water basins as they extend north beyond the coastal counties. All together these water resources support the economic, social and environmental health of the region.

Mississippi Gulf Coast Water Assessment

History of Water on the Mississippi Gulf Coast

The history of the Gulf Coast of Mississippi dates back millions of years to its geologic formation. While several theories abound as to the reasons behind the formation of the water in the Gulf of Mexico and, more directly, the Mississippi Sound, its shape began as early as the break up of the supercontinent, Pangaea.[1] The earliest humans, who arrived in North America more than 10,000 years ago, saw dynamic changes to the coast and water due to the continental shift, and many of these changes continue to occur in modern times.[2] The Prehistoric Period in Mississippi began about 10,000 to 11,000 years ago. Large numbers of aboriginal people inhabited Mississippi during this time before the first Europeans began to settle in the region prior to the close of the 17th Century.[3] It was not until the turn of the 19th Century that the water began to develop in the ways that it is most commonly thought of in a current historical context. It was during this time that the water gained its most notable cultural uses: the lumber industry, the seafood industry, shipbuilding, tourism, and gambling. The history of water use continued to evolve in the 20th and 21st Centuries, despite economic and natural disaster setbacks like Hurricane Katrina and the BP Deepwater Horizon Oil Spill.

Early Human Settlement (10,000 years ago -1699)

The first inhabitants to establish a history on the waters of the Mississippi Gulf Coast were aboriginal people who traveled across the exposed land bridge in the Bering Strait during the Ice Ages. The first aboriginals to cross this bridge, the Paleo Indians, were nomads following migrating animals. Little is known about them because they did not keep a written history and the traces of their lives have been erased by the changing land formations. It is well within reason to believe that they lived a life of subsistence, surviving by living off the rivers and Sound. About 10,000 years ago, the first Native Americans began to arrive on the Mississippi Gulf Coast near the mouths of some of the major rivers, although an exact date is hard to determine because of changing sea levels since the time of first arrival.[4] Most archeological history from the time period is currently underwater, as sea levels have risen with the melting of the glaciers.

Archaeological remains dating back 10,000 years to the start of the Archaic Period (8,000 B.C. to 500 B.C.) indicate that Native American lifestyles and culture became increasingly sedentary and more complex.[5] The Archaic Natives in the area used fire to heat tools into better shapes for hunting and fishing, and they also developed spears that would travel much further than their predecessors. This tool-making trend continued through the next period, the Woodland Period (500 B.C. to 1000 A.D.). During the Archaic and Woodland periods, mound building became a part of the social and religious culture, as is evidenced in southern Mississippi. The first significant occupation along the Gulf Coast of Mississippi by Native Americans is estimated to have begun around 3,000 to 2,000 B.C., likely at the mouth of the Pearl River.[6] Mounds dating from 4500-3000 B.C. were located in downtown Pascagoula, although they were demolished around the turn of the 20th century.[7] Trade was important to the Native Americans—there is archeological evidence that different tribes and groups traveled hundreds of miles to exchange goods and

tools. Native Americans began trading along the Pearl River and coastal waterways as early as 3,000 years ago. The primary trade was for exotic stone from other parts of North America that was used to make tools and ornaments.[8] The Native Americans who settled on the banks of the Pearl River used their location as a resource for living and a base for trading in other regions. Most of the trading was centered on rivers and water systems because they provided faster means of travel than the dense forests and rolling terrain.

The Mississippi Period began about 1000 A.D., following the Woodland Period, but it preceded the arrival of Europeans around 1700 A.D. During the Mississippi Period, trading expanded and centered on flood plain horticulture. Trade routes ran from the Mississippi Gulf Coast to Mobile, up the Tombigbee River, and to the east.[9] Beads, pottery, weapons, and rocks for making tools and weapons were bartered along or on the Mississippi coastal streams. Also during the Mississippi Period, pottery became a very important cultural aspect. In a process called shell tempering, the Native Americans would add crushed shell to the soft clay before molding and firing it to create their ceramic vessels. This process was unique to Gulf Coast pottery.[10] Before the start of the 18th Century, the Biloxi, Pascagoula, Acolapissa, and Capinan Native Americans were living on the Gulf of Mississippi along the Pearl and Pascagoula Rivers. They were known for making canoes from trees and mud and then traveling along the rivers and Sound to hunt and gather oysters, shrimp, and fish. The Mississippi Period lasted until the arrival of Europeans on the Gulf Coast in 1699.

Early European Settlement (1699-1763)

In February 1699, the French, including Frenchman Pierre LeMoyne, Sieur d'Iberville, landed at Ship Island with the intent of creating a French foothold to protect their rights to the Mississippi River valley, which had previously been claimed by Robert LaSalle. Because the Spanish held claim to the lands to the east and west, the harbor of Ship Island was the most logical place to create a settlement. The shallowness of the Mississippi Sound prevented any other location from being more suitable. The first European community was established at the site of the modern city of Ocean Springs, Mississippi, on the east side of Biloxi Bay. Fort Maurepas, built on this site, was the first capital of the Louisiana Territory. It would be the foothold that the French used to explore the Mississippi River and the bays and rivers along the Gulf Coast, including the Pearl and Pascagoula rivers. The early colonies located at Fort Maurepas, and later Mobile, suffered great hardships and developed slowly during the French colonial era. Bousillage, a mixture of clay, Spanish moss, and oyster shell applied to heavy timber, was used to construct well-built residences inside of which early settlers could survive. Such commodities as bricks molded from the better-quality clay originating on the banks of waterways and the Biloxi Bay were transported by schooner to New Orleans and traded for necessities that the French settlers could not generate themselves.[11] When the French lost control of the area in 1763 after losing the French and Indian War to the British, there were 6,000 people living in French Mississippi along the Gulf Coast.[12] During this period, the Pascagoula and Biloxi tribes were living along the Pascagoula River.[13]

Changing Sovereignty (1763-1815)

During the next fifty years, the Mississippi Gulf Coast changed hands multiple times, from the French, to the British, to the Spanish, to the independent Republic of West-Florida, and, finally, to the United States. These years can best be described as having slow growth, with few new people coming to settle among the French colonies around Biloxi. The British understood the potential of the Gulf Coast as Ship Island had the only deep water harbor near Mississippi, but their lack of provisions and soldiers made them give up on building a fort to protect it. In 1772, the British built their first ship on the Pascagoula River to transport corn and deerskins.[14] Many smaller boats, including flat barges to make it up and down the rivers, were also built in this time period to accommodate the inhabitants, as it was the best mode of transportation for moving people and goods.

The region's waters were of strategic importance during this era. For a time, the British kept sixteen ships of war near the Sound to protect their regional interests. Later, Bernardo Galvez, the Spanish governor of New Orleans, organized Spanish-American troops at Ship Island and attacked Mobile and Pensacola.[15] After the signing of the Treaty of Paris in 1783 officially ended the American Revolution, the Mississippi coastal waters fell into the hands of the Spanish. The people of West Florida, as it was called during the time, revolted and formed their own republic in 1810 before being annexed into the United States in 1811. The largest naval engagement ever fought in the Mississippi Sound occurred at the end of the War of 1812 in December of 1814. The Mississippi Sound was occupied by what has been called the largest amphibious invasion force ever to enter American waters. Dozens of British warships occupied the Sound and thousands of British soldiers encamped on Ship Island in preparation for an attack on New Orleans.[16] When they left for New Orleans, a squadron of small American gunboats attacked the larger British fleet—an attack later to be known as the Battle of Pass Christian. While the Americans suffered heavy losses, they succeeded in delaying the British. This gave time for future President Andrew Jackson to organize his defenses and save the city of New Orleans in January of 1815.

Antebellum Period (1815-1861)

Mississippi became a state in 1817. During its early days as a state, the region became a summer destination for people from New Orleans. The wealthy would travel by sailboat and steamboat to their second homes on the Mississippi Gulf Coast. The region was also an escape from the yellow fever that plagued New Orleans to often epidemic proportions. Towns like Shieldsboro (now Bay St. Louis) and Pass Christian developed as coastal resort towns. In 1842, Shieldsboro extended its wharf 80 feet to accommodate more tourists at their hotels.[17] The early history of areas in present day Hancock and Harrison Counties consists of men and women strolling to the beaches to sunbathe in the salty waters of the Mississippi Sound. Sailing races in the muddy waters were also tremendously popular in this time period.

The region's rivers were crucial in bringing goods to the coast for export. Shipping was also important to communities like Pass Christian, which exported lumber, tar, and charcoal made from kilns in the pine forest. The sawmill industry started out slowly in the 1830s and 1840s, with only a few tiny mills were built in proximity to the mouths of the Pearl, Escatawpa, and Pascagoula Rivers and the banks of Bayou Bernard.[18] The virgin forests in the Pine Hills region were harvested for lumber. Logs would be cut upstream and floated down the Pearl and

Pascagoula Rivers with log men riding them the entire way to the saw mills. In 1840, Pascagoula began to develop into a great port for the Mississippi coast when Captain John Grant of Baltimore dredged a channel into the East Pascagoula River and the Sound to Mobile.[19] Much of the lumber that was produced on the Escatawpa and Pascagoula Rivers was loaded up and shipped to Europe, making the Mississippi coastal towns world famous. The port at Pascagoula also benefited from farmers in the interior. Between 1830 and 1860, the number of cotton bales being shipped down the Pascagoula River increased from 65,000 bales to almost one million. In 1859, the U.S. Army Corps of Engineers began construction of a fort on Ship Island in order to guard ocean transportation routes and the naturally deep-water harbor at Ship Island.[20] Brick, lumber, and other materials had to be floated across the Sound to the island. The fort, later named Fort Massachusetts after the Union ship that would seize control of the unfinished fort from Rebels, would play a role in the Civil War.

Civil War (1861-1865)

The War Between the States caused an abrupt end to normal life and economics in the waters of coastal Mississippi, which was the second state to secede from the United States. Fort Massachusetts became the base of operation for future attacks on Confederate strongholds and, once the Confederates seized it, to blockade the Rebels from exporting or importing goods to and from foreign countries in Europe or Cuba. During the early war years, ships began bringing supplies and Federal troops to Ship Island to prepare for the attack and capture of New Orleans in 1862 and Mobile in 1864. At one time, between 12,000 and 15,000 soldiers occupied the barrier island. Ships were constantly traveling in and out of the harbor and Mississippi Sound during the Civil War. Late in the war, prisoners—possibly as many as 3,000 at one time—were ferried out to the island and interred there.

The Union Navy blockade around the Sound, which caused a loss of trade, forced many Mississippians along the coast to struggle. In Biloxi and many other shoreline communities, people could not get enough salt for their diets, so they set up seawater stills to make salt to barter with inland farmers. Mullet and other fish from the Biloxi Back Bay and the Mississippi Sound provided a steady diet during the war years, when no other foods could be obtained from outside the region.[21] They were lean years, and people lived off of the backwaters, rivers, and the Sound, which they depended on to provide fish, shrimp, and oysters to eat. Blockade runners did occasionally make it out of the Sound and to Cuba for supplies. The logs that once came down the Pearl and Pascagoula Rivers quit coming, the saw mills closed, and steamboats no longer brought tourists, but times would change quickly with the closing of war and a return to peace.

The Gilded Age of Industry (1866-1914)

With both its unique geography and industries that were distinct from much of the rest of the state of Mississippi, the Gulf Coast was little phased by Reconstruction. Lumbering, fishing/shrimping, trade, shipbuilding, and tourism began to grow like never before in the region's history. Technological innovations such as railroads replacing the rivers as the primary way to move goods led to increases in productivity. While logs no longer had to be floated down rivers, it was still a common practice. Saw mills cut the logs into lumber in places like Biloxi and Pass Christian, where it was either put on schooners or barged out to Ship Island. There it would be reloaded on oceangoing ships and transported to ports in Europe. Railroads and better mechanization in the saw mills resulted in more and larger sawmills being built along all of the coastal waterways. Many of the saw mills were built along the waterways to make faster exports and to provide steam for the dry kilns. In the late 1800s, hundreds of millions of board feet of lumber were produced each year across the region. However, economic development pushed the natural environment to its limits during these years. Many natural resources, like the virgin forest and the oyster reefs, were severely depleted to the point that they are still recovering almost 100 years later.

The timber industry and its byproducts spurred towns like Pascagoula, Moss Point, and, later, Gulfport into becoming some of the most active ports on the Mississippi Gulf Coast. However, square lumber was not the only product being shipped; turpentine, naval stores, and paper were also exported. A rich

oil tycoon named Captain Joseph T. Jones built a railroad along the 4,500-foot wharf and paid nearly $1 million of his own money to dredge a 300-foot-wide, 23-foot-deep channel, making Gulfport a man-made deep water port.[22]

While millions of cut boards were being shipped in the 1890s, the lumber industry also contributed to the growth of a large shipbuilding industry in places like Pascagoula. A variety of boats were built for overseas shipping, fishing, and for the US Navy during multiple wars. These shipyards would in time convert from wood to metal shipbuilding. In the thirteen-year period from 1893 to 1906, the number of shipyards in Pascagoula tripled.[23] In nearby Biloxi, shipbuilding became so dominant and important to the city that an entire type of ship was named after the city, the Biloxi Schooner; it was created after an 1893 hurricane destroyed the old schooner fleet on the Gulf Coast causing the need for a new fleet to be designed.[24] With newer and better vessels, the seafood industry continued its steady climb in the Mississippi Sound's waters.

The seafood industry thrived because the estuarine and shallow environment was perfect for shrimp and oysters. One of the largest, nearly continuous oyster reefs in the world lies off of Pass Christian.[25] There were also oyster reefs between the two Pascagoula Rivers, which helped Pascagoula have an important seafood industry as well. When ice began to be manufactured along the Gulf, fishermen could stay out even longer to catch a bigger crop, to the point where they would return with their decks at the water's edge. Ice also made it possible to store and export the surplus of seafood that was being harvested from the Mississippi waters. Five major seafood companies became the heart of the economy around Biloxi, Mississippi.[26] The seafood industry was so vital to the city that it was dubbed the "Seafood Capital of the World" in 1904, seizing the title from Baltimore, Maryland. In 1890, Biloxi's canneries reported a yearly processing of two million pounds of oysters and 614,000 pounds of shrimp.[27] By 1902, those numbers had exploded, with twelve canneries accounting for a combined catch of 5,988,788 pounds of oysters and 4,424,000 pounds of shrimp. Seafood is big business in the history of the waters of the Mississippi Sound, and shrimp canneries and fishing were critically important during this age.

Two World Wars and Prohibition (1914-1945)

World War I, World War II, and the interlude in between had an enormous impact on the history of the Mississippi waters. The seafood industry that had been producing at an all-time high ten years before the start of the Great War had to take a back seat to the war cause and shipbuilding. In the Biloxi Back Bay, the shipyards converted from making Biloxi Schooners for shrimping and fishing to making ocean-going ships to combat German U-boats.[28] Other waters along the coast, including those in Pascagoula, picked up on this trend of building boats for the US Navy—there were as many as 20-40 warships built and launched into the waters at Pascagoula during the United States' short entry in World War I. When the US entered World War II at the end of 1941, there was a great need for wartime goods to be shipped and new boats to be built. The City of Gulfport became a valuable port for the US military and ship building was prominent in Biloxi and Pascagoula. Ingalls Shipbuilding, a shipyard in Pascagoula, built over 80 co3 all-purpose ships during the war.[29] Additionally, the United States Coast Guard and Navy used the Barrier Islands to deter German U-boats from approaching the Mississippi Coast, where they were sinking many merchant ships. The military also used the islands for other purposes. Cat Island was used to train dogs to attack Japanese soldiers by their scent and Horn Island was used as a chemical weapons testing site.[30 31] Neither effort proved very successful, and both were dismantled soon after the war ended.

One of the biggest impacts on the Mississippi Gulf Coast during this period was the passage of Prohibition by Congress in 1919. Even though the State of Mississippi had been a dry state for many years, bootlegging became big business after this. Many of the boats previously used for the seafood catch were now carrying a new cargo across the Mississippi Sound and up the coastal rivers: illegal alcohol. Alcohol that was not distilled on the backwaters was imported from the Caribbean Antilles to different barrier islands, where the goods were transferred to smaller, faster, armed power boats for delivery to locations along the bays, rivers, and bayous in Mississippi. Once the illegal liquor reached shore, it was distributed to secretive clubs and casinos or hauled as far north as Chicago. Ports such as Pass Christian and Biloxi, which had been crowded with shrimpers, were now replaced with bootleggers. Bootlegging became so popular on the barrier islands that a couple of Mississippians built the Isle of Capri, a gambling resort, on Dog Keys in 1926.[32] The island had a natural artesian well and the Sound was dredged to accommodate the new marine traffic that would be landing on the thousand-foot pier. It was a popular tourist destination until 1932, when erosion resulting from human disturbance and tropical storms sucked the resort and the island into the waters of the Mississippi Sound.

Other developments changed the Mississippi Sound's waters in the 1920s and 1930s. A seawall was built along the coast in Harrison County and parts of Hancock County. The Harrison County seawall would later lead to the creation of the longest man-made beach in the world. Tourism declined in the 1930s because of the Great Depression. Gulfport began to import bananas from Central and South America in 1920, which marked a change in the use of the port from wood exporting to banana importing.[33]

The Atomic and Space Ages (1946-2011)

The end of World War II ushered in a new age, creating an economic recovery for the region supported by the Keesler Air Force Base and Ingalls Shipbuilding. Many of the waterborne industries that had flourished before the Depression thrived again. World War II was transformative in creating jobs that required a larger workforce, which resulted in a population boom. Shrimping, tourism and illegal gaming, shipbuilding, and, later, legalized gambling were all part of a more industrialized economy. The population boom also began, increasing the need for infrastructure further from the water because of more suburban and retail development inland. For example, waterways were trenched to provide boat access to new residential developments on the north side of Saint Louis Bay in the latter half of the 20th Century.[34] Many homes were built on pilings along natural and manmade water inlets along the Jourdan River. In addition, seafood packing plants were

prominent during the 1960s.

The Port of Gulfport continued to increase in size and the shipping channels increased in depth during the 1950s and 1960s. After 1959, it became a State port, as the city could no longer financially support its continuing expansion. By 1973, it would become the largest banana port in the United States.[35] In the late 1980s, cruise ships began to use Gulfport as a dock to set off for the Gulf of Mexico and the Caribbean, but this practice was later discontinued when New Orleans became the principal dock for cruise ships. Ingalls Shipbuilding in Pascagoula continued to mass produce ships for the US Navy in the second half of the 20th Century. Many nuclear ballistic missile submarines and guided missile destroyers were built at the shipyard. Ingalls Shipyard also built many cargo and container ships and cruise liners, in addition to Navy frigates and amphibious craft. The deep water port at Pascagoula also played a historic role in commerce and was expanded in the 1950s. In Hancock County in the 1960s, the National Aeronautics and Space Administration (NASA) built a rocket testing facility along the Pearl River. Today, it is called the Stennis Space Center and Testing Facility and, along with the Port Bienville Industrial Park, it brings large ocean-going ships into the Pearl River to use the manmade Port Bienville canal.[36]

Marinas and yacht clubs are active members of the marine community and a vital part of tourism in the area. There are hundreds of marinas dotting the coastline and small boat harbors of every town. Many of the coastal rivers, like the Pearl, Jourdan, Wolf, Tchoutacabouffa, Biloxi and Pascagoula Rivers are popular destinations for sailing, canoeing, and recreational fishing. The coastal streams between the Pearl and Pascagoula rivers are often shallow and lead to less populated, undeveloped grounds and parks for camping. In 1971, the Gulf Islands National Seashore was created. The National Park Service now controls tourist and visitor activity on the Barrier Islands from Ocean Springs. About fifteen years ago, there were an estimated 60,000 recreational fishermen, 1,800 commercial fisherman, and 27,000 boat owners and operators using the region's natural resources.[37] The struggle between recreational and commercial fishers has strained the marine economics during different periods. This strain was more pronounced during the recessions of the 1970s and 1980s. The catch per unit of effort has been in decline for decades due to over fishing. Hurricane Camille in 1969 also had devastating impacts on the history of the Mississippi coastal waters. It was the worst hurricane to hit the coast before Hurricane Katrina in 2005. The destruction of Hurricane Camille provided a window of revitalization, preservation, and expansion to recover from the damages.

In response to a severe depression in Mississippi in the 1980s, the State passed a law allowing legalized dockside gambling in 1990.[38] Any county touching the Mississippi River or the Mississippi Sound—including Hancock, Harrison, and Jackson counties—was eligible to open a casino upon voter approval. Jackson County did not pass gambling, but the other two counties did. The gaming industry had one of the biggest impacts on the region in nearly a hundred years or more. Casinos were not allowed to be docked where beaches existed because of a ruling by the Mississippi Secretary of State. For this reason, casinos were placed in many of the ports and harbors, creating increased congestion. The earliest dockside casinos were built on small, self-propelled craft that could be moved in and out of the harbor during hurricanes. When the potential wealth that could be made from gaming was realized, barge casinos were built. Essentially, these were multi-story buildings constructed on flat barges that were tied and docked near where the seafood industry was located along the Gulf Coast. The existing waterfronts in Biloxi transitioned to make room for waterfront hotels and casinos, and similar transitions took place in Gulfport and other Gulf communities in Harrison and Hancock Counties. "Casino Row," as the end of Biloxi peninsula came to be known, became the biggest casino strip between Las Vegas and Atlantic City.[39] The benefit of the casinos has been noted with increases in tourism and revenue, but there have been a wide range of new environmental and social impacts. There is fear that the Sound and access points will become more polluted from runoff on impervious surfaces surrounding casinos, hotels, and parking garages. Following Hurricane Katrina, the casinos moved to land near the shore.

The 21st Century was to offer a new history of the water: casinos mixed in with the seafood, trade and shipbuilding industries, tourism, and recreational fishing. Over the last decade, several events have changed or altered this progress. In 2005, 125-mile-per-hour winds and heavy flooding brought by the Category 3 hurricane Katrina destroyed much of the Gulf's infrastructure and buildings. In 2010,the Deepwater Horizon oil spill occurred in the Gulf of Mexico off the coast of Mississippi. The oil spill continued over a period of six months, resulting in oil washing onto the barrier islands and mainland. Efforts were immediately made to begin cleaning up the toxic residue. Many fishers aided in the removal of the oil from the Gulf. Others have cleaned beaches, wetlands, and flora and fauna in order to restore the Mississippi coastal water to glory. The water's edge is home to many research institutes and laboratories, where citizens and scientists have done their best to begin efforts to monitor the effects that the spill might have on the water in the future. The Gulf Coast Research Laboratory of Ocean Springs was established in 1947, and many similar labs (Stennis Space Center, the Mississippi-Alabama Sea Grant Consortium, the National Oceanic and Atmospheric Association, the Gulf of Mexico Alliance, and the Northern Gulf Institute to name a few) are dotted across the Sound in cities such as Pascagoula, Ocean Springs, Waveland, Gulfport, Moss Point, and Bay Saint Louis. Research and education is a strong, collaborated coordination driving the area to greater prospects of sustainability. The labs are leaders in monitoring sea level rises, studying environmental health, and predicting future hurricanes and tropical storms. The coming ages of the water on the Mississippi Gulf Coast have been safeguarded well by a civic-minded constituency. Mississippi's strong connection to its water resources has led to its rich history and enduring impact.

Figure 1

Mississippi Gulf Coast's Water History

First American Era | Early European Settlement | Changing Sovereignty | Antebellum Period | Civil War | Gilded Age | Prohibition and World War | Atomic and Space Ages

10,000 years ago

First humans/ Native Americans arrive at Gulf Coast.

3,000 B.C - 2,000 B.C

First significant settlement of humans/ Native Americans on Gulf Coast.

1,000 B.C

Trade of exotic stones occurs on the Pearl River.

1699 A.D

French establish settlement at present day Ocean Springs, MS

1763

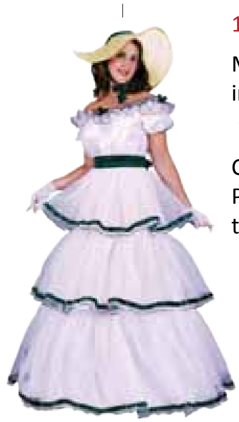
6,000 French living along Mississippi coast when British gain control of area.

1772

First ship is built in the region by the British.

1814

Largest naval engagement ever fought in the Mississippi Sound occurs between Americans and British.



1817

Mississippi becomes the 20th state in the Union.

1840

Channels are dredged in East Pascagoula River and the Sound to Mobile.

1860s

Fort Massachusetts is used by Union to attack New Orleans and Mobile.

1890s

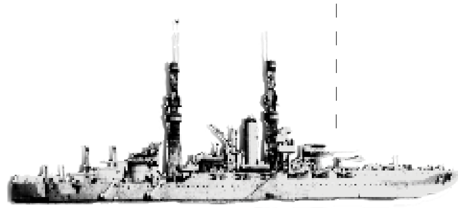
Major growth in lumbering, shipping, ship building, and the seafood industry.

1902

Mississippi Oyster Commission established.

1904

Biloxi becomes the "Seafood Capital of the World."



1926-32

Isle of Capri on Dog Keys signifies high point of Prohibition in Mississippi.

1940s

Ingalis Shipbuilding in Pascagoula builds over 80 ships for WWII.

1959

The Port of Gulfport becomes a State port.

1960s

Stennis Space Center and Testing Facility opens in Hancock County.

1969

Hurricane Camille destroys much of the Gulf Coast.

1973

Gulfport becomes largest banana port in U.S.

1990

Offshore gambling is legalized in Harrison and Hancock Counties.

2000s

Hurricane Katrina and BP Deepwater Horizon oil spill.

Environmental Conditions

The coast of Mississippi is a unique environment that formed through several geological ages. It includes extensive coastal underground aquifers, diverse coastal ecosystems, and the Mississippi Sound and its barrier islands. Including coastal indentations and the barrier islands, the Mississippi coastline is 369 miles in length.[40] The fresh water that flows into the Mississippi Sound is provided by three river basins: the Lower Pearl River, the Coastal Streams Basin, and the Pascagoula River.

The Lower Pearl River occupies 24 counties in east-central and southwestern Mississippi as well as several parishes in eastern Louisiana. The Pearl River is approximately 490 miles long and drains an area of 8,760 square miles into the Mississippi Sound and Lake Borgne in Louisiana. The lower 61 miles of the Pearl River run along the western edge of Hancock County and serve as part of the boundary between the States of Mississippi and Louisiana.[41] The Lower Pearl River Basin covers approximately the western one fourth of Hancock County.

The Coastal Streams Basin begins in Lamar County and extends south to the coastline of most of Hancock County, all of Harrison County, and part of Jackson County. The Coastal Streams Basin includes Deer Island, the Mississippi Sound, and Cat, Ship, Horn, Round, and Petit Bois barrier islands. The Lower Pearl River Basin is the western boundary of the Coastal Streams Basin. The basin is interrupted by the exit of the Pascagoula River Basin on its eastern side, but it extends beyond to the Alabama state line. The Coastal Streams Basin drains an area of approximately 1,545 square miles and differs from the other two basins in that it consists of several smaller independent watersheds. It is common for the rivers to each flow separately into the Sound or one of the bays, such as Saint Louis Bay or Biloxi Bay. For example, the Wolf and Jourdan Rivers and Bayou la Croix empty into the shallow Saint Louis Bay, which was part of an ancient river valley or delta when the coastline extended further into the Gulf of Mexico during a glaciation. The primary streams draining into the Back Bay and the Biloxi Bay include Tuxachanie Creek and the Biloxi, Little Biloxi, and Tchoutacabouffa Rivers. Most of the streams in the Coastal Streams Basin have clear water and are relatively shallow.[42 43]

The Pascagoula River Basin is the second largest basin in the State of Mississippi, and the Pascagoula River is the last unimpeded large river system in the lower 48 states. The basin occupies 22 counties in southeastern Mississippi and parts of Alabama. It drains an area of approximately 9,600 square miles into the Mississippi Sound at its exit in Jackson County.[44]

Formation of the Coast

The original Gulf of Mexico was likely formed when the continents broke apart and began moving to their present locations on the globe. The Gulf was then a body of water separating the North and South American continents. Later, during a more unstable time in Earth's history, volcanic islands formed on the ocean floor, eventually becoming a mountain range and the isthmus that separates the resulting Gulf from the current Pacific Ocean.[45] There are two theories as to why the basin floor of the Gulf of Mexico collapsed about 300 million years ago and formed a deeper sea. The first theory is that the basin floor sank under the weight of sediments being deposited by rivers during millions of years. The second theory is that the collapsed was caused by subduction of the tectonic plates. It is possible that elements from both theories had a role.[46] For the millions of years that followed, these same processes continued to form and shape the Gulf of Mexico. Even today, the basin is greatly influenced by residues of soil, rocks, and organic material being deposited by the Mississippi and other smaller river systems.

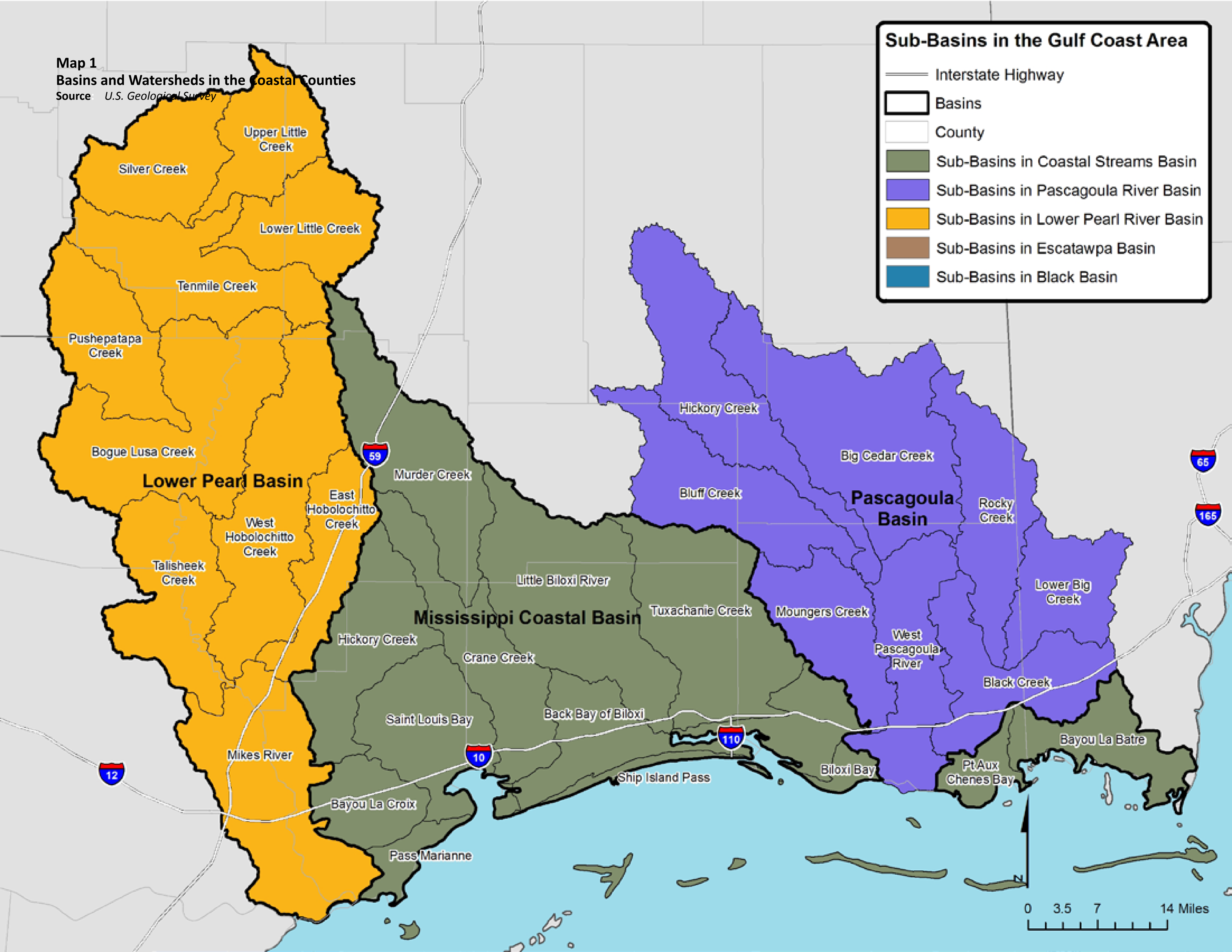
At the same time, marine organisms living in the coastal waters provided much of the organic sediments that exist today, including limestone and oil deposits. Subsurface and emergent topographic features on the continental slope of the Gulf Coast, such as the Pinnacles region off shore of the Mississippi/Alabama coast, are created from salt deposits.[47] The Pinnacles are a "broad band of 'drowned reefs' or 'fossil reefs' found about 230 to 400 feet below the water's surface".[48] The Pinnacles, a vital underwater region, are hypothesized to have formed due to lower sea levels during the last Ice Age 10,000 to 18,000 years ago. It is an important spawning habitat for many commercial fish and a valuable area for oil and natural gas production.

The formation of the coastal counties of Mississippi spans four geological epochs. Geological formations dating back to the Miocene Epoch (23 to 5.3 million years ago) can be found in the northern parts of the coastal counties. However, the majority of the area was formed during the late Pliocene (5.3 to 2.58 million years ago) and Pleistocene Epochs (2.58 million to 11,700 years ago), and the formation continues in the Holocene Epoch (11,700 years to present day). The Ice Ages that characterized the Pleistocene Epoch, with its repeated cycle of warm interglacial periods and cooler glacial periods, were critical in the formation of the coast.[49] [50] During each glacial period, glaciers formed in the Arctic regions, draining the oceans and moving the seashore further out. Rivers draining into the newly exposed seashore formed new deltas as they spread out to reach the Gulf's more southern coastline. The opposite happened during interglacial periods, when the glaciers would melt and deposit large amounts of sediment along the coast and in the Gulf. It is estimated that more than six million cubic miles of sediments have been deposited since the Mesozoic era, about 200 million years ago. Also, as the glacial waters filled the oceans, salt water filled the valleys cut earlier by the rivers, drowning out the old coastline and deltas. Many of the bays along the Mississippi Gulf Coast were created in this manner when the Wisconsinan glaciers melted between 8,000 and 10,000 years ago. These bays include Saint Louis Bay, Biloxi Bay along with its backwater area, and the Pascagoula River's outlet into the Mississippi Sound. [51]

The Mississippi Sound was also probably created through this process, but what separates the Sound from the rest of the Gulf of Mexico are its barrier islands. The barrier islands could have been formed by modern or ancient river deltas or sand being swept by waves off the shore.[52] Sand is usually first trapped on an underwater ridge, where it accrues over time from waves and wind deposition until it eventually reaches the surface. At this point, plants can begin to grow from seeds brought by the wind, water, or animals. The vegetation helps stabilize the barrier islands somewhat, but barrier islands are particularly fluid in their development and history, often changing location and size. The plants also help form dunes that protect the islands from constant weathering. After many years, forests and freshwater marshes can also appear. Large storms, such as hurricanes, have the capability to completely destroy an island or cut it into pieces. Today, impacts are also caused by human actions, such as the dredging of the Sound.

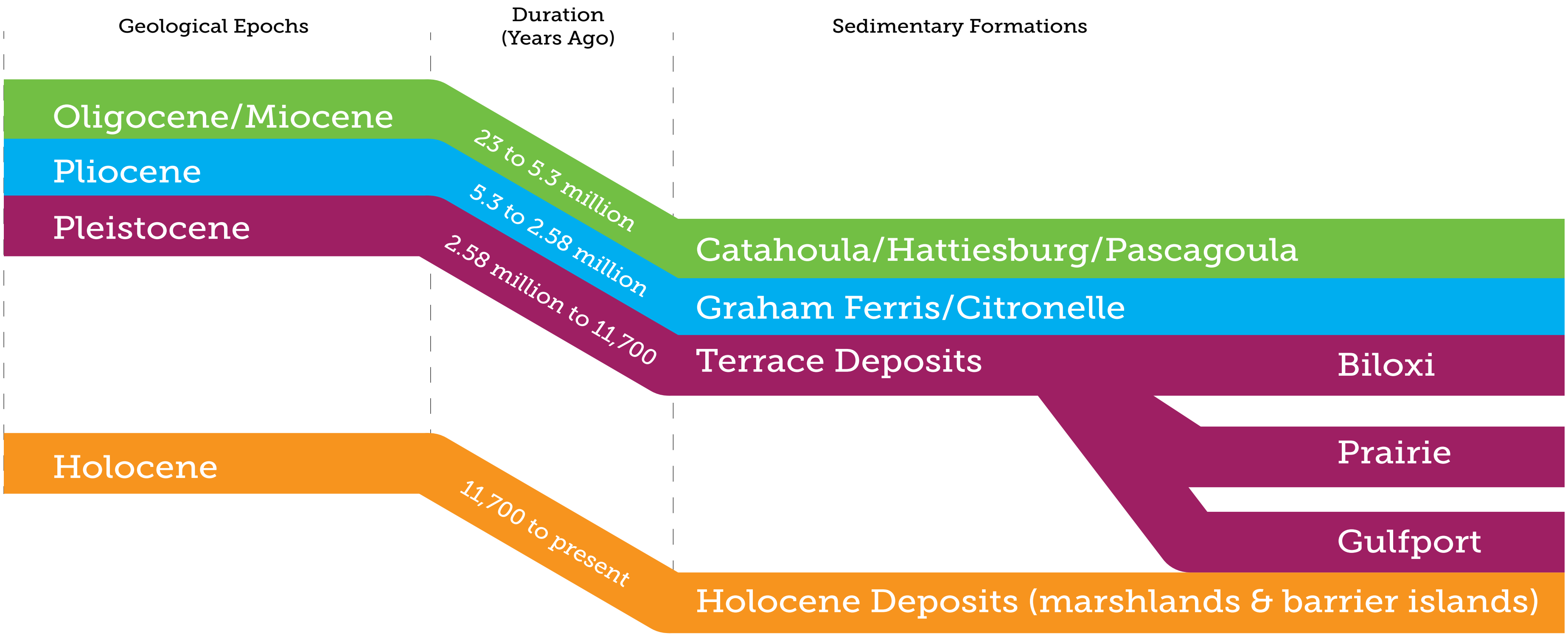
The geology of the Mississippi Gulf Coast is characterized by sedimentary formations of estuarine and deltaic origin ranging in age from the late Oligocene to the Holocene epochs. The formations dating to the late Oligocene and Miocene include, in ascending order, the Catahoula, Hattiesburg and Pascagoula Formations. The Catahoula and Hattiesburg formations are not exposed to the surface in the three coastal counties, but they are very important as they contain freshwater at pressures conducive to artesian wells.[53] Together, the Miocene formations range in thickness from 1600 feet to 5,000 feet.[54]

The formations dating to the Pliocene are, in ascending order, the Graham Ferry and the Citronelle formations. The Graham Ferry Formation, overlaying the Pascagoula Formation, is the most exposed formation in the three counties and ranges in depth from 113 feet in eastern Jackson County to 975 feet in



Map 1
Basins and Watersheds in the Coastal Counties
Source *U.S. Geological Survey*

Figure 2
Chronology of the Formation of the Coastal Geology



Gulfport. It is comprised of clay, silt and sandy deposits. The basal sands and gravels in this formation are good reservoirs of fresh water, providing more than half of the artesian wells in the coast. Overlaying the Graham Ferry is the Citronelle Formation, also described in the literature as the High Terrace Deposits. The Citronelle Formation consists primarily of red sands and clay at the surface, with a minor amount of gravel. This formation is also exposed but is less predominant than the Graham Ferry Formation in the three coastal counties and is found mainly on the higher altitudes on the northern portions of the counties. It ranges in thickness from a thin mantle, sometimes worked into the Graham Ferry, to about 100 feet and up to 160 feet in the ridge crests. The Citronelle Formation is perennially saturated with water in the lower few feet and has good transmissibility, which makes it a good source of water for small volume wells. [55]

During the Pleistocene, additional fluvial and marine sediments were deposited in coastal terraces and stream terraces. The coastal terraces have been further divided and describe as the Gulfport and Biloxi Formations, and the stream terrace has been described as the Prairie Formations. The Biloxi Formation is the oldest and the Gulfport Formation the youngest. The Biloxi Formation, which consists of clay, fine sand, and sandy clay, is rich in fossils. It was mainly deposited on the near shore of the Gulf and in bays and lagoons. The Prairie Formation, which was formed during the warm interglacial Sangamon Period of the Pleistocene Epoch, is a blanket of alluvial deposits 14.7 to 39 feet thick that wedges out landward against older formations and interlocks with the Biloxi Formation. At several landward locations, Prairie sediments directly overlie the Biloxi Formation.[56] The Gulfport Formation consists of fine and medium sands, which formed a wide shoreline during the Sangamon Age. Today, the Gulfport

Formation is a sand unit that is dredged from the Mississippi Sound to replenish the manmade beaches between Pass Christian and Biloxi. These coastal and stream terrace deposits make up the beaches and barrier islands as well as the bottom deposits of the Mississippi Sound, the various bays and estuaries, and the continental shelf.[57 58]

In the last Ice Age, 20,000 years ago, the coast of Mississippi was more than 60 miles southeast of Biloxi.[59] During the Holocene Epoch, the sea-level continued to rise from the very low levels of 20,000 years ago. During this time, deposition of sediments and organic material continued on the coast, providing for the formation of Holocene deposits and physiography. The Holocene deposits are mostly sandy, fine-grained silts and clays rich in organic matter. These sediments filled the coastal estuaries, and their high organic matter content gave rise to the marshlands. The current beaches and dunes are coastal deposits resulting from the erosion of sandy materials in the Prairie and Gulfport Formations.

The barriers islands are less than 5,000 years old and are the result of sand carried by waves from Northwest Florida and Alabama. The islands shift westward by erosion on their east ends and accretion on their west ends. For example, construction of Fort Massachusetts started in 1859 approximately 500 feet from Ship Island's extreme western end, which is now about a mile from the western tip and is close to being in the Mississippi Sound.[60 61] The marshlands in the western part of the Mississippi Coast are also experiencing higher subsidence rates than the marshlands in the eastern end of the Sound.[62] The fine-grained, highly saturated deposits that sustain the marshlands are also rich in organic matter. As this organic matter is decomposed and mineralized by microorganisms, the deposits will lose volume and get compacted, resulting in subsidence of the coast and encroachment by sea water.[63] On the other hand, the coastal deposits on the eastern side have been less prone to subsidence and are relatively stable. Any loss of coast line in the eastern side will be more influenced by erosion than by subsidence.[64] Barrier islands create a critical natural barrier between the open sea and the mainland, absorbing wind and wave energy produced by hurricanes and storms. The islands also provide a unique habitat for plants, wildlife, and migrating birds due to the distinct ecologies resulting from the geological origins of the islands.

Topography and Soils

The three Mississippi coastal counties are characterized by two major physiographic provinces: the Coastal Flatwoods and the Coastal Plain Uplands. The Coastal Flatwoods comprise about 45 percent of the coastal counties and extend as an irregularly shaped band approximately five miles in width along the coast, as well as extending inward about two miles north of the Back Bay of Biloxi. The soils are mainly level to gently sloping and their elevations range from zero to 50 feet above sea level in some inward areas. The Coastal Flatwoods is underlain by sands, gravels, clays, and silts from Holocene and Pleistocene origins. These soils range from poorly drained to wet. At the eastern and western ends of the coast, the Coastal Flatwoods give way to a smaller physiographical region, the Tidal Marsh. The Tidal Marsh makes up about 6 percent of the region and is mostly found in the extreme southeastern and southwestern portions of the Mississippi Coast. Tidal marsh soils are nearly level, with very poor drainage, and they are flooded daily with seawater.[65 66 67]

The Coastal Plain Uplands occupy the northern 45 percent of the coastal counties. The soils are older and more weathered. The Coastal Plain Uplands are underlain primarily by sands and clays of Miocene and Pliocene ages and gravels, sands, and clays of Pleistocene age. Natural erosion processes created deeper valleys and a more uneven surface. Slopes range from nearly level to moderately steep. Elevation in the uplands can range from 65 to 200 feet above sea level in northeastern areas around Jackson County. Although the elevations have a wide range, locally the distinction in elevation between the Coastal Flatlands and the Coastal Plain Uplands is difficult to observe.[68]

At the western side of the Mississippi Coast, the Coastal Plain Uplands and Coastal Flatwoods are interrupted by another small physiographic province known as the Low Lying Terraces and Floodplain of the Pearl River. This distinct physiography covers about four percent of Hancock County and is mainly restricted to the Lower Pearl River area. These are older, more weathered soils ranging from nearly level to moderately steep. These soils are somewhat poorly drained to poorly drained and prone to frequent flooding.[69]

Most of the soils in the coastal region formed in unconsolidated beds of fine- to coarse-textured Coastal Plain sediments. Some soils formed from alluvium deposits washed from upland soils. These are found mainly along the larger streams and have a mostly sandy texture. The younger Holocene soils formed in deposits of highly decomposed plant material in areas adjacent to saltwater or brackish water that are periodically flooded during high tides. These soils continue to form today, as newly deposited grassy vegetation decomposes. In addition, other soils formed in hummocks from sand blown from the beaches of the offshore islands. Beaches were deposited by the action of the tides, waves, and currents of the sea or by hydraulic dredges. The bright-colored soils found throughout the region formed through the influence of water percolating down through material above the water table (e.g., the grayish soils formed in low, flat areas where the water table is high and drainage is poor).[70 71 72]

The Mississippi Sound's bottom is covered by layers of sandy clay-mud that was deposited by the coastal rivers prior to and after the Sound's formation. It is estimated that the bottom of the Mississippi Sound consists of five percent sand, 80 percent clay-mud, and 15 percent silt or sandy silt.[73] Before the advent of dredging, it was difficult to reach the coast from the islands without using smaller boats. The Mississippi Sound is naturally most deep between the barrier islands and the midline of the Mississippi Sound.[74] Because of the quantity, freshness, and looseness of the mud, the Sound's water is extremely turbid.

Aquifers

With 16 major aquifers and numerous minor aquifers distributed throughout the state, groundwater resources provide over 90% of Mississippi's drinking water supply.[75] In the coastal counties, water is provided primarily by the Grand Gulf Aquifer System and minor amounts from the Terrace Deposits aquifers. The Grand Gulf Aquifer System is alternatively referred to as the Oligocene-Miocene-Pliocene Aquifer System in reference to the three geological epochs during which it was formed. The name Miocene Aquifer is used in some documents, but that usage has fallen out of favor. The Office of Land and Water Resources MDEQ adopted the use of the name Grand Gulf Aquifer System to simplify the nomenclature and clarify what aquifer intervals were included within this system. This system is comprised by the following aquifers, in ascending order: the Catahoula, Hattiesburg, Pascagoula and Graham Ferry.[76] The limestones and clays of the Vicksburg and Jackson groups underlie the base of the Grand Gulf Aquifer System and provide a confining layer separating it from the older sediments below.

The Grand Gulf Aquifer System consists of alternating sands and clays and covers approximately the southern one-third of the state. It formed from deposits in a subsiding basin centered in the southern part of the Mississippi Embayment Aquifer. The thickness of the deposits generally increases from northeast to southwest and the sand percentage increases from east to west.[77] The aquifers were formed by deposition in a deltaic or marine environment, and these deposits contained saltwater at the time of deposition. As the sea levels dropped, saltwater was flushed out by freshwater, which also pushed saltwater downdip. As a result of their marine origin, the downdip part of the aquifers have higher salinity, where it is observed as a saltwater diffusion section.[78] The depth of the freshwater section changes in gradient being thinner towards the east. The base of freshwater (saltwater-freshwater contact), defined as 1,000 PPM total dissolved solids, can be found at approximately 1,000 feet below mean sea level (bmsl) in the Pascagoula area, about 2,000 feet bmsl on the southeast of Harrison County in the Ocean Springs area, 2,400 feet bmsl in southwest Harrison County and about 3,000 feet bmsl in southwest Hancock County.[79, 80] In the barrier islands, the base of freshwater is approximately 1,500 bmsl at Horn Island and 2,900 feet bmsl south of Ship Island.The Graham Ferry and Pascagoula are the main aquifers used along the coast. The Hattiesburgh aquifer is also used but to a lower extent.[81] Many of the aquifer within this system remains untapped except for the upper several hundred feet.[82]

The Terrace Deposits (stream terraces, coastal terraces, and high terraces) overlie the Grand Gulf Aquifer System in the coastal counties, but they are not continuous across the entire area.[83] The underlying Graham Ferry and Pascagoula intervals are exposed in those areas where the terraces are not present. These aquifers contain freshwater across the entire area of study; however in some areas near the coast they might have more contact with surface water from the Gulf of Mexico or estuarine water and become brackish. In addition, these aquifers tend to be high in iron and manganese.[84, 85]

The danger of saltwater intrusion into coastal aquifers is an important concern for all coastal areas. In Mississippi, several studies have been conducted to monitor natural salinity and effect of groundwater withdrawal since the 1940's.[86] In 2002, MDEQ published a study of historical data from monitoring wells on the coast. The study corroborated that the chloride (salt) concentrations in the area are naturally higher, but these concentrations have not increased in such a pattern as to provide evidence of saltwater intrusion. The study also concluded that is very unlikely that saltwater intrusion will occur due to extraction of groundwater in the deeper confined aquifers.[87]

Water Column Features

The Mississippi Sound is a predominately estuarine environment, with an average salinity of 22 parts per thousand.[88] The Gulf of Mexico, which is as salty as the world's oceans (30 to 50 parts per thousand), mixes with the freshwater of the Mississippi coastal river systems in the Sound. This heterogeneous mixture creates brackish water that is typically about half as salty as the water in the Gulf. The brackish water is very important to numerous marine organisms that can only survive in this environment. There are times when the mixture of river fresh water and Gulf sea water becomes imbalanced. During flood conditions, the Mississippi Sound can become almost all fresh water as the rivers overflow the region and push out the saline sea water. On the other hand, during a drought, when there is very little to no fresh water draining into the Sound, it can become as saline as the rest of the Gulf of Mexico.[89] In addition, the salinity level in the Sound is impacted when fresh water from the Mississippi River is diverted to the Bonnet Carre Spillway. The Spillway diverts to Lake Pontchartrain and Lake Borgne and then into the Mississippi Sound. Salinity levels can remain depressed for months in the western two-thirds of the Sound after a spillway diversion.[90]

The Mississippi Sound waters are much shallower than those in the Gulf of Mexico. The average depth of the Mississippi Sound is 13.1 feet, with portions reaching a depth of 20 feet.[91] The US Army Corps of Engineers manages the Gulf Intracoastal Waterway, which has a depth of 12 feet and is used for marine traffic.[92] In addition, dredged ship channels run north and south to connect the Port of Gulfport and Port of Pascagoula to the Gulf of Mexico between the barrier islands.

The circulation of water in the Mississippi Sound is primarily influenced by tides, which are influenced by the bathymetry and geometry of the Sound, river outflow, and winds.[93] The mean tidal range across the coast is less than two feet, with a mean tide level under one foot.[94] The Mississippi Sound's tides are primarily diurnal and vary from 1.7 feet at Horn Island Pass to 1.5 feet at Pascagoula to 1.6 feet at St. Louis Bay.[95]

The effects of winds generally overwhelm the effects of tides and play a significant role in the local water depth and surface level.[96] The prevailing winds in the summer come from the south and southeast, and in the winter they come from the northeast.[97] Sustained south and southeast winds push water into the Sound, piling it against the mainland. North winds have the opposite effect, driving the water out. The average wind speed is 6.5 miles per hour.[98] The currents are variable across the coast, averaging 1.2 knots at Pascagoula.[99 100]

Prevailing winds blowing from the southeast move Caribbean water between the Yucatan Peninsula and western Cuba to form the Gulf Loop Current. This current moves north towards the Mississippi and Alabama coast lines, then curves south along the west coast of Florida and exits the Gulf between the Florida Keys and the north shore of Cuba.[101] The Gulf Loop Current forms a ring that is separate from the main flow of water. The ring drifts westward and eventually dissipates. Smaller tidal and wind-driven currents are present in the nearshore environment.[102]

As water moves from the Gulf of Mexico into the Mississippi Sound, tidal waves turn into shallow waves.[103] The temperature varies as water moves from the rivers into the Sound and Gulf. For example, in the winter the average water surface temperature is 59 degrees in the Mississippi Sound, but it rises to 70 degrees out

in the Gulf of Mexico. In the summer time, the temperatures in the bays are in the upper seventies while the temperatures of the water in the Sound and Gulf are in the eighties.[104] Within the bays, temperatures can vary more. For example, Biloxi Bay has had a low temperature of 44 degrees and a high of 93 degrees.[105]

Sediment Transport

Sediment originates in rivers and dunes, where the force from the fluid velocity of water and wind erodes the soil surface and eventually transports it to coastal areas. The texture of each sediment (e.g., fine clay or coarse sand) will depend on the type of soil from which it originated from and how it is affected by abrasion during transport. The extent of the abrasion effect is influenced by the length of transport and the media—water or wind—transporting the sediment. The type and amounts of sediments deposited can give form to sandy beaches, marshes, dunes, sand bars, and other soil formations, thus determining the coastal topography and ecology. Sediments are eventually lost from the immediate coast. In the Gulf region, offshore coastal canyons are the major sediment sink. Under natural conditions, the amount of sediments deposited equals the amount lost. However, activities such as river stream diversions, dams, dredging, and beach re-nourishment can significantly alter this balance.[106]

Sediments in the Mississippi Coast are mostly unconsolidated Holocene deposits from predominately fluvial and deltaic sources. Sediments with silt and clay textures are more prevalent than sandy sediments, which are found concentrated in areas associated with the underlying Gulfport Formation, while clay-muddy sediments are associated with the Biloxi Formation. Generally, a sediment's texture gradient changes from sand in the nearshore to fine-muddy off shore. The thickness of the Holocene sediment layer can range from two to 15 feet along the west-east direction, with the clay-muddy sediments typically thicker than the sandy sediments.[107] [108]

Sediment quality can be affected by major storm events, which introduce sediment contaminants, change salinity, and dissolved oxygen, all things that can stress benthic organisms.[109] In a study between 2000 and 2004, sediment analysis indicated that samples contained arsenic (53 percent of sediment samples), chromium (10 percent of samples) and cadmium (6 percent of samples). However, none of the levels exceeded environmental standards.[110] Previous studies have found that the contaminants in river-borne sediments disperse when they reach the Mississippi Sound and Gulf of Mexico, therefore posing minimal risk. Organic carbon, nitrogen, phenols, and hydrocarbons were concentrated in the Pascagoula River due to industrial development.[111] Sediment samples from the Mississippi Sound were collected two months after Hurricane Katrina to monitor the effect of the storm surge on concentrations of organic contaminants and trace elements. The results, which were compared to samples collected before the storm, showed that concentration levels of organic contaminants and trace elements in the Sound sediments remained similar to the concentration levels before the storm.[112] Another study conducted from September 2005 to October 2006 monitored the concentration levels of trace elements at four sandy beaches, four boat ramps, and a marina. Although some trace elements were detected at concentrations above recommended levels at a few sampling locations, in general no trends of long-term distribution or persistence were observed following Hurricane Katrina. The concentration levels were consistent with previous post-hurricane studies conducted in the Gulf, which found that concentration levels return to normal within a few months of a storm.[113] The Deep Water Horizon oil spill also raised concerns about contaminants entering the Gulf of Mexico and Mississippi Sound. Studies focusing on the spill are currently ongoing.[114]

In the Mississippi Sound, sediments are predominately carried by currents and waves in a westward direction. The action of the currents and waves not only transports sediments from the bottom of the Sound, it can also change the contour of the nearshore and shoreline itself. Nearshore sand bars can be observed to change in location over time. In Harrison County, the 26-mile man-made beach is periodically eroded, requiring renourishment with sands from other locations. The beach was renourished in 1953, 1964, 1973, 1988, 2001, and 2010. The shoreline erodes an average of 3.3 feet per year, but some segments erode at a rate of six to ten feet per year.[115] In Hancock County, there is a beach that runs between Bay St. Louis and Waveland. This beach was renourished in 1941, 1967, 1972, 1994, and 2006, with the most important dates being 1967 and 1994, when 200-foot-wide beaches were created.[116] Renourishment was done using Gulfport sands from a borrow pit located offshore across the beach. Monitoring studies conducted by the Mississippi Department of Environmental Quality (MDEQ) noted that erosion occurs most quickly at each end of the beach and near the borrow pit.[117] At a different scale, easterly wave approaches to Horn Island result in a westward migration of the barrier island.

There are many benefits to beach nourishment, including improved beach landscapes, flood mitigation, erosion prevention, and buffers from waves and high water.[118] However, a drawback is the large amount of sand and natural material required, which can cause environmental damage at the site of extraction, specifically in the Sound. Other drawbacks include high energy costs for transportation of materials and difficulties in finding suitable sand.[119] The criteria for acceptable extraction material is very strict in order to match the current environmental conditions and limit impacts, although nourishment can still bury and destroy natural beach ecology even when using appropriate materials. Renourishment material for the Gulf Coast area typically comes from areas offshore in the Mississippi Sound, although some renourishments were completed with sand extracted from nearshore areas.[120]

MDEQ studied the movement of the sand at a renourished beach in Hancock County and found that the shore sand is mainly deposited in the nearshore. Over time this has raised the nearshore, making it shallower and serving as an erosion control by preventing most sand from being transported offshore and lost. The heightened nearshore forms a nearly closed system that should require less sand in future renourishements. It was also observed that the offshore side of the pits left in the nearshore when sand was extracted for renourishement were susceptible to erosion. Although the manmade beaches seem to be stabilizing, the sand source location for future renourishements must be carefully selected to avoid promoting erosion of the nearshore next to the almost-stabilized beach.[121]

Culverts that exit and extend to the nearshore are also a factor in sediment transport, as they might act as barriers. Westward movement of currents and waves builds up sand sediments on the

Source: *Angel Arroyo-Rodriguez*

Culverts help drain stormwater, but can contribute to erosion of beach sand.

eastern side of the culverts, making the eastern side shallower. The western side of the culverts stays deeper and causes the current flow to accelerate, compounding the erosion effect. The design of the culverts impacts sediment collection. The larger the diameter of the culvert, the stronger the groin effect will be. Also, culverts with smoother surfaces tend to allow sediments to flow over.[122]

In Jackson County, erosion has been occurring since before the 1850s as a result of the separation of the Escatawpa and Pascagoula Rivers and the change in barrier island configuration since the 1700s.[123] [124] In the 1700s, Petit Bois Island separated from Dauphin Island and the mainland lost its protection, resulting in significant erosion of Grande Batture Islands and Point aux Chenes.[125] The Grand Bay Marsh, in the southeast corner of the county, is also experiencing erosion as a result of wave action and relative sea-level rise. From 1993 to 1999, marshland loss caused by wave erosion was estimated at an average of 13.3 acres per year. The southwestern shoreline of South Rigolets Island is the most vulnerable to erosion, with an observed rate of 27 feet per year during the same period.[126]

In Western Hancock County, marshland is also eroding. Erosion has been occurring for thousands of years, since the Mississippi River abandoned the Saint Bernard delta lobe.[127] In addition, the erosion is a result of relative sea-level rise, wave attack, and upland conversion to development.[128] Erosion is most significant for the shorelines exposed to the prevailing southeasterly winds in the summer and northeasterly winds in the winter. For example, the shoreline from Three Oaks Bayou to Lighthouse Point represents an area of significant erosion. Erosion is also significantly occurring within Heron Bay. The marshlands in Hancock County are protected by offshore marshes in Louisiana, limiting erosion.[129]

The Mississippi Office of Geology estimates that 4,000 acres of coastal Mississippi were lost between 1850 and 1999. Of this, 5,600 acres are natural change, while manmade changes resulted in a gain of 1,700 acres. Approximately 15 percent of the total marshland south of Interstate Highway 10 has been lost. Of this, 2,700 acres are now under water and 3,500 acres has been converted to development.[130] While loss of coastal habitat continues at rates similar to the historic trends, increases in sea level rise will heighten coastal loss.[131]

Shoreline Protection and Floodplain Management

Shoreline management involves implementing management practices to protect coastal areas regardless of their location in or out of the floodplain. The National Oceanic and Atmospheric Administration (NOAA) classifies shoreline management practices into four main categories: hard/structural stabilization, soft/non-structural stabilization, hybrid stabilization, and policy and planning techniques.[132] Hard/structural stabilization uses hardened structures, such as bulkheads, concrete sea walls, riprap, jetties, breakwaters, or stone reinforcement, to armor and stabilize the shoreline from further erosion.[133] While it can slow erosion landward of the structure, hard stabilization often exacerbates erosion seaward and alters shoreline and water dynamics.9[134] Soft/non-structural stabilization uses plants or organic matter to restore, protect, or enhance the natural shoreline through the implementation of vegetation plantings, coir fiber logs or other natural materials, or beach renourishment.[135] While these methods have many benefits for erosion protection and habitat preservation, they often require constant maintenance and are not suitable for high-energy environments, or environments where the energy and turbulence of waves prevents sediment from settling.[136]

Hybrid stabilization is therefore a combination of hard/structural and soft/non-structural stabilization methods, actualized as combinations of rock, rubble, oyster reefs, or wood structures with soft stabilization techniques; beach renourishment, segmented sills, and marsh plantings; or beach renourishment with living breakwater.[137] A common form of hybrid stabilization is known as a living shoreline, or a shoreline reconstruction using living plant material, oyster shells, earthen material, or a combination of natural structures with riprap or offshore breakwaters.[138] It is especially beneficial because it maintains natural coastal processes, preserves habitats, and improves water quality while being economical and preventing erosion.[139] Recent focus on living shorelines by the Mississippi-Alabama Sea Grant Consortium (MASGC) has led to workshops on creating living shorelines and projects such as Pelican Landing at Moss Point.

Alternatives to shoreline management often involve regulating human use near or on the shoreline in place of physical alterations. These policy and planning techniques are often used to avoid the need for physical stabilization or when stabilization would be costly or ineffective.[140] Some techniques that are commonly used are construction set-backs, land-use planning, buybacks and managed retreat, or relocation of structures and utilities.[141]

Legal Framework

Federal and state laws provide a framework for managing the effective use of a region's water resources. These laws and the governmental agencies that enforce them can be broadly categorized as those that protect natural resources and those that regulate their extraction. State agencies must follow federal laws and agency rules, but states also exercise a large degree of freedom in implementing their own regulations related to resource protection and extraction.

The State of Mississippi has jurisdiction for three nautical miles from the mean low water mark, or approximately 3.45 statute miles, based on the authority of the Outer Continental Shelf Lands Act.[145] The federal government has jurisdiction in its territorial waters for 12 nautical miles from the mean low water mark. Beyond 12 nautical miles, the federal government exercises sovereign rights on all resources within a 200-nautical-mile Exclusive Economic Zone (EEZ). [146] The federal government uses the EEZ for the exploration and use of marine resources, such as oil and gas. The Law of the Sea Convention provides the framework for the use of the ocean in the EEZ.

Federal Laws Affecting the Protection of Natural Resources

In 1890, Congress passed the River and Harbor Act, one of the oldest environmental laws in the country. The Act requires the U.S. Army Corp of Engineers to approve any obstruction or alteration of any navigable water in the United States.[147] The General Dam Act of 1906 gave the federal government power to enforce dam construction without just compensation.[148] The River and Harbor Act was followed by the Fish and Wildlife Coordination Act of 1934, which has been amended as recently as 1995. The Act requires that the impacts on wildlife "be considered equally with all other features in the development of water resource projects," [149] and it charges the Secretary of the Interior with the responsibility of coordinating with federal, state, and other public and private organizations to develop and protect wildlife species and their habitats. This designation of authority to the Department of the Interior sets the standard for many of its current duties.

The 1948 passage of the Federal Water Pollution Control Act marked the beginning of the expansion of federal laws and agency rules to regulate the protection of natural resources in federal and state waters.[150] In 1972, 1977, and 1988, the Federal Water Pollution Control Act was amended, and it is commonly referred to as the Clean Water Act. This far-reaching program "establishes water use categories and delineates acceptable water quality standards for those categories."[151] The other prong of the Clean Water Act created the National Pollution Discharge Elimination System, which allows individual states to establish standards for point-source pollution. States must receive authorization from the federal EPA to run this program, or else the federal agency itself can administer the program in a state. in Mississippi, those that wish to perform regulated activities that require the disposal of chemicals into waterways must first secure permits from the Office of Pollution Control, a state office within the Mississippi Department of Environmental Quality.[152] The State of Mississippi issues discharge permits in state waters, while the EPA issues them in federal waters. These permits can be issued for mariculture facilities, deepwater ports, offshore oil and gas exploration and production, and offshore seafood processing.[153] The Safe Water Drinking Act of 1974, 1986, and 1996 requires the protection of drinking water and its sources including rivers, lakes, reservoirs, springs and ground water wells. The Act aims to strengthen public health protection from contaminants in drinking water.

The National Historic Preservation Act of 1966 requires that historical and cultural resources that may be present in or near water be treated similarly to land based historic resources.

The National Environmental Policy Act of 1970 requires federal agencies to consider environmental impacts of the uses and activities within coastal environments. Environmental impact statements and environmental assessments allow agencies to explain and document the degree to which governmental action and user conflict will affect critical ecosystem functions and services.[154] Additionally, the Supreme Court of the United States has held that federal agencies engaged in multiple projects in the same region must complete a single comprehensive analysis whenever multiple projects will have a cumulative impact on that region; this requirement has had a significant effect on agencies like the U.S. Army Corps of Engineers.[155]

The Coastal Zone Management Act of 1972 and its 1990 reauthorization require NOAA's Office of Ocean and Coastal Resource Management to balance ecological, cultural, historic, and aesthetic values alongside economic development. The Act mandates that federal actions that have "reasonable foreseeable effects on any coast use or resource" be consistent with NOAA-approved state coastal management programs.[156] Coastal management programs administered by a state may provide additional resources to preserve public recreational access, prioritize coastal-dependent uses, and manage coastal development.

The Ports and Waterways Safety Act of 1972 allows the U.S. Coast Guard to take the necessary measures to protect the safety and security of maritime activities. The Coast Guard is responsible for navigable waters seaward out to 12 nautical miles and for offshore oil platforms and other structures in the EEZ. [157]

The Marine Protection, Research, and Sanctuaries Act of 1972, also known as the Ocean Placement Act or the Ocean Dumping Act, requires a permit from the U.S. Army Corp of Engineers to transport dredged materials and place them in the Mississippi Sound or Gulf of Mexico. The EPA designates the sites appropriate for placement of materials. Prior to issuing a permit, appropriate state agencies, such as Mississippi's Department of Environmental Quality, must certify compliance with state water standards.[158]

The Marine Plastic Research and Control Act accompanied the Clean Water Act in 1988. The Act allows the EPA to fine those who dispose of plastics at sea. To aid in the proper disposal of plastics and other refuse, the U.S. Department of Transportation is required to provide proper trash and refuse receptacles at all ports. [159]

The Oil Pollution Control Act of 1990 phased in the use of double-hulled vessels that could better withstand external breaches that could cause leakages.

State Laws Affecting the Protection of Natural Resources

The Mississippi Public Trust Tidelands Act of 1972 set forward that all tidelands, defined as "those lands which are daily covered and uncovered by water by the action of the tides, up to the mean line of the ordinary high tides," are to be held in trust by the state for public enjoyment, use, and conservation.[160] The Mississippi Secretary of State has authority to lease submerged lands in state waters, based on this Act. The Coastal Wetlands Protection Act protects the boundary between the tidelands and other lands, including areas that have been altered by human efforts. The Mississippi Secretary of State is charged with administering leases for these tidelands. Revenue resulting from these leases is mostly redirected to local agencies and municipalities.[161]

The Mississippi Marine Litter Act of 1990 followed the general structure of the federal Marine Plastic Research and Control Act by making the improper disposal of synthetic ropes, fishing nets, and other plastics into state waters illegal.[162]

More recently, the Coastal Wetlands Protection Act of 2003 protects "the economic, environmental, scenic, historical, and archaeological resources of the coastal area to serve the best interests of the citizens of Mississippi, to preserve the natural state of the state's coastal wetlands and their ecosystems, to hold them in public trust, and to prevent their destruction."[163] All activities that cause some form of material harm to wetlands require a permit. Activities related to conservation, repletion, and research by the Commission on Marine Resources, the Mississippi Gulf Coast Research Laboratory, the Commission on Wildlife, Fisheries, and Parks, and the Mississippi/Alabama Sea Grant Consortium are not subject to these permit requirements.

Federal Laws Affecting the Protection of Plants and Animals

There are federal laws that regulate the movement of plant and animal life, and a number of them specifically protect endangered animals and their habitats in the Gulf Coast. The Lacey Act of 1900 restricts the importing, exporting, transporting, sale, acquisition, and purchase of fish, wildlife, and plants in the United States.[164] Similarly, the Migratory Bird Treaty Act of 1918 makes statutory a previous agreement between Great Britain and the United States that prohibited the taking of migratory birds, including the bird, nest, and egg. [165] Enacted by Congress in 1966, the National Wildlife Refuge System Administration Act created the National Wildlife Refuge System, a network of ecosystems and habitats that include the Mississippi Sandhill Crane National Wildlife Refuge and the Grand Bay National Wildlife Refuge.[166] The Marine Mammal Protection Act of 1972 prohibits the taking of marine mammals.[167] Additionally, the Magnuson-Stevens Fishery Conservation and Management Act of 1976 created eight Regional Fishery Management Councils across the nation that were charged with developing fishery management plans and management measures, to be approved by NOAA, for the fisheries within their respective EEZs.

Ultimately, the Endangered Species Act of 1973 provides for the conservation of species that are threatened or endangered. The U.S. Fish and Wildlife Service and the National Marine Fisheries Service ensure that federal action does not jeopardize the existence of a protected species or result in an adverse modification or destruction of critical habitat. This Act also prohibits the taking, harassing, hunting, wounding, trapping, or capture of threatened species.[168]

Many federal laws require agencies to collaborate on plans for the protection of natural resources. For example, the National Aquaculture Act of 1980 calls for the preparation of a National Aquaculture Development Plan. This plan is regularly created through a partnership of the NOAA, the U.S. Department of Agriculture, and the Department of the Interior. These departments provide advice, education, and technical assistance to support the implementation of the plan.[169]

The Coastal Barrier Resources Act of 1982 created the John H. Chaffee Coastal Barrier Resources System, and it encourages the conservation of hurricane-prone, biologically rich coastal barriers by restricting federal expenditures that encourages development on or in the vicinity of the barrier islands.[170]

In 1988, Congress amended the National Fishing Enhancement Act of 1984 by adding to it the National Artificial Reef Plan. This Plan allows old oil and gas drilling platforms located in federal and state waters to be used in part or in whole in the construction and management of artificial reefs.[171]Specific U.S. Army Corps of Engineers permits are needed to sink these platforms.

Additionally, fishery resources in federal waters are regulated under the Magnuson-Stevens Act, which was reauthorized in 2006. The Act created eight regional councils, of which the Gulf of Mexico Fishery Management Council is one, that create plans for the management of fish and other species in their respective EEZs. These plans are subject to approval by the U.S. Secretary of Commerce. The Act seeks to prevent overfishing, to rebuild overfished stocks, and to achieve an optimum yield from fisheries. The Secretary of Commerce prepares a fishery management plan that addresses highly migratory species, such as tuna, marlin, swordfish, and sharks.[172] Regional Fishery Management Councils, such as the Gulf of Mexico Fishery Management Council, are charged with developing plans for commercial and recreational fishing stocks to minimize the risk of overfishing.[173] The Magnuson-Stevens Act also regulates foreign fishing in the EEZ under international fishing agreements, and it issues vessel fishing permits. Under the Act, National Marine Fisheries Service and the U.S. Coast Guard are responsible for enforcing the councils' approved fishery management plans in order to maintain sustainable commercial and recreational fishery stocks.[174]

Just as animals are protected by federal law, so too is flora. The National Invasive Species Act of 1996 authorizes the Secretary of Homeland Security and the U.S. Coast Guard to promulgate regulations preventing the introduction and spread of aquatic nuisance species, specifically through ballast water. The Act requires the study of water ecosystems to develop methods for controlling aquatic invasive species. It also mandates that the Coast Guard and Department of Defense administer a ballast water management program for their vessels.[175]

Federal Laws Affecting the Extraction and Development of Natural Resources

The system of laws that protects water resources has a sister system designed to regulate and encourage the safe development, extraction, and use of those resources. This alternate system has the division of coastal territory regulation, as established by the Submerged Lands Act of 1953, as its foundation. The Submerged Lands Act grants coastal states the rights to natural resources within three miles of their coastal lines.[176] The Outer Continental Shelf Lands Act, also of 1953, allows the Secretary of the Interior to grant leases for mineral exploration of oil, gas, and sources of renewable energy in federal waters. The Secretary operates the Outer Continental Shelf Leasing Program, which establishes a five-year schedule of oil and lease sales based on the location, timing, and size of leases based on the national energy needs in a specific period.[177] This leasing arrangement aims to balance energy needs with environmental considerations.

The federal Minerals Management Service (MMS), which was established in 1982 under the U.S. Department of the Interior, was responsible for administering the provisions of the Outer Continental Shelf Lands Act before Hurricane Katrina. Congressional review of the BP Oil Spill and the events leading up to it raised concerns that systemic weaknesses within the organization of MMS prevented it from adequately exercising its regulatory duties.[178]

In response, Secretary of the Interior Kenneth Salazar reorganized MMS and divided its duties between three new units in May 2010. The Bureau of Ocean Energy Management now exercises regulatory control over development of oil, gas, and renewable energy; the Bureau of Safety and Environmental Enforcement now enforces safety and environmental laws and regulations; and the Office of Natural Resources Revenue manages royalty and revenue functions for onshore and offshore activities.35 Despite the creation of the new organizations, MMS's previous regulations and operations remain largely intact. The Department is required to create five-year plans for the leasing, development, and production of offshore oil and gas drilling. All steps of the exploration and drilling processes, including preliminary work, exploration, development, production, operation, and expansion, are subject to approval by the three new bureaus. "[R]egulations generally require that a company with leasing obligations demonstrate that proposed oil and gas activity conforms to federal laws and regulations, is safe, prevents waste, does not unreasonably interfere with other uses of the [Outer Continental Shelf], and does not cause impermissible harm or damage to the human, marine, or coastal environments."[180]

Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) is the primary permitting agency that reviews applications for leases, easements, and use of right of way. After BOEMRE approval, the Federal Energy Regulatory Commission (FERC) issues a license for the siting of hydrokinetic facilities, which generate power from waves, tides, and ocean currents.[181] For example, FERC issued permits for projects on the Mississippi River because that is a state-regulated waterway. [182]

While the Ocean Thermal Energy Conversion Research, Development, and Demonstration Act of 1980 provides authority for pilot and demonstration projects, the Ocean Thermal Energy Conversion Act of that same year additionally requires permits from NOAA for the construction and operation of ocean thermal energy conversion facilities. NOAA, the Department of Energy, and the U.S. Navy are currently working together on pilot projects. [183]

The National Methane Hydrate Research and Development Act of 2000 authorizes the Department of Energy and NOAA to determine and realize the energy supply potential of methane hydrate through the creation of research centers, including the University of Mississippi's Gulf of Mexico Hydrates Research Consortium. This includes addressing questions of sea-floor stability, drilling safety, and environmental protection.[184]

In order to minimize the adverse impacts of development on marine environments beyond U.S. territorial seas, the Deepwater Port Act of 1974 creates a licensing and permitting system under the U.S. Department of Transportation for the construction, operation, and decommissioning of deepwater port structures.[185] The law's effects are primarily felt by offshore Liquified Natural Gas (LNG) facilities that are licensed by US Department of Transportation, Marine Administration (MARAD). The Governor has the right to veto an offshore LNG facility.[186] There are no such permits off the Mississippi coast in state waters due to state restrictions, although applications have been approved off of the Louisiana coast and an application for a permit has been made off the Alabama coast.[187] The Natural Gas Act of 1938, which regulates the routing, construction, and operation of interstate gas pipelines that originate onshore or offshore, is responsible for gas import and export facilities and Liquified Natural Gas terminals that are not subject to the Deepwater Port Act.[188]

In the aftermath of the Exxon Valdez oil spill disaster in Prince William Sound, Congress enacted the Oil Pollution Act of 1990, which provides federal oversight of maritime oil transportation in order to increase the safety of oil and toxic chemical transportation. It also establishes a trust fund to pay for response costs and claims for damages resulting from oil spills.[189] The Oil Pollution Act built on the efforts of the Federal Water Pollution Control Act and the Comprehensive Environmental Response, Compensation, and Liability Act, both of 1988. These two Acts regulate the discharge of oil and other hazardous chemicals into U.S. waters. Under the current set of laws, those deemed responsible for any spills must prove that no harmful chemicals were released, contain and prevent the spread of the spill, or face serious criminal charges for willful negligence. Furthermore, the Oil Pollution Act allows states to "impose unlimited liability under state law, and […] construct their own regimes regarding financial responsibility requirements, response and compensation funds, taxing authority to finance those funds, civil and criminal penalties, and regulatory authority over safety, operation, and maintenance of facilities and, to some extent, vessels."[190]

In addition to the trio of oil spill laws, the 1990 National Oil and Hazardous Substances Polluting Contingency Plan was implemented to realize the goals and authorize the agents of the aforementioned legislation. The national plan enumerates federal, state, and local responsibilities, and it identifies available resources and response personnel.[191] The Mississippi Department of Environmental Quality Office of Pollution Control is the state agency that coordinates with the national plan on issues related to oil spills. Furthermore, each EPA region also has a regional plan that helps states work with its counties and municipalities to develop specifically tailored contingency plans. [192] Mississippi, a member of EPA Region IV, which has its headquarters in Atlanta, Georgia, has worked with coastal communities to make sure that each local plan addresses oil spills and other natural disasters. The state has published a comprehensive plan titled A Contingency Guide to the Protection of Mississippi Coastal Environments from Spilled Oil that acts as a compendium of practices and plans for such disasters.

The Energy Independence and Security Act of 2007 expands the use of America's waterways to relieve landside congestion along coastal corridors. This Act integrates the marine highway into the surface transportation system and encourages the development of multi-jurisdictional coalitions to expand or add new services to relieve traffic congestion, improve air quality, and reduce energy consumption.[193]

Marine Transportation

The United States' has a long history of regulating coastal transportation, especially for commercial purposes. The Merchant Marine Act of 1920 contains the Jones Act, which regulates cabotage, or the carrying of goods between U.S. ports. The Act states that vessels transporting goods between U.S. ports must be owned by U.S. companies with at least 75 percent U.S. citizen ownership, operated by a crew that is composed of at least 75 percent U.S. citizens, built in the United States, and registered in the United States. As happened for two weeks after Hurricane

Katrina devastated the Gulf Coast, the Secretary of Homeland Security has the authority to waive these requirements on a case-by-case basis when issues related to national defense, such as oil and gas shortages, arise.

Federal fishing vessel regulations are outlined in the American Fisheries Act of 1998 and the Omnibus Consolidated and Emergency Supplemental Appropriations Act of 1999. These Acts designate the Maritime Administration as the federal department responsible for regulating compliance with ownership and control requirements for commercial fishing vessels that are 100 feet or longer.[194] The American Fisheries Act was particularly enacted in order to fix a loophole in the Anti-Reflagging Act of 1987, which was supposed to prohibit foreign-built ships from reflagging as U.S. ships. Certain types of trawling ships, however, were excluded from official definitions and, as such, they were not subject to the 1987 law.

The Maritime Transportation Security Act of 2002 requires that all U.S. ports organize Area Maritime Security Committee is composed of federal, local, and state agencies, industry, and the general public. These groups create plans to deter, prevent, and respond to terror threats.

The Port Development Authority Act of 2007 encourages the development of port and transportation facilities in connection with waterborne commerce. The Secretary of Transportation and Secretary of the Army work together to review port development with local communities.[195]

The Energy Independence and Security Act, also of 2007, mandates the creation of a network of marine corridors to aid in the decongestion of America's network of freeways and interstates. In August 2010, U.S. Transportation Secretary Ray LaHood began implementing the Marine Highway Program by designating 11 corridors, four connectors, and three crossings "that serve as extensions of the surface transportation system." [196] The Gulf Coast corridor connects to the Great Lakes, the St. Lawrence Bay, and the Ohio River through the Mississippi River.

Federal Flood Management Policy and Agents

Flooding along the Mississippi River, the Ohio River, and several other major U.S. rivers in the early 20th Century spurred Congress to pass the nation's first flood legislation, the Ransdell-Humphreys Flood Control Act of 1917. The 1928 River and Tributaries Act was spurred by the 1927 flood of the Mississippi River, which required the evacuation of 750,000 people. The flood inundated 27,000 square miles of land and caused $300 million in damage.[197] [198] [199]

The 1936 Flood Control Act authorized dams, levees, dikes, and other flood control measures to be undertaken by the U.S. Army Corps of Engineers and other federal agencies.[200]

According to the National Weather Service, floods account for over 60 percent of federally declared disasters, with their fiscal damages currently averaging $6 billion per year.[201] The National Flood Insurance Act of 1968 established the National Flood Insurance Program (NFIP), which was subsequently amended in 1973, 1982, and 2004.[202] The Flood Disaster Protection Act of 1973 introduced mandatory purchase provisions for flood insurance.[203] The NFIP provides flood insurance at low cost to those whose properties are located in areas with high risk of annual floods, which it defines as at least one percent. Local communities participate in the NFIP by adopting and enforcing flood prevention ordinances and by regulating development in floodplains. The National Flood Insurance Reform Act of 1994 strengthened the mandatory purchase provisions of the 1973 Flood Disaster Protection Act.[204]

Waterways will change over time as a function of climate change and topographical erosion. Our evaluation methods will need to be vigilant and comprehensive with respect to development goals along them. There is a human factor that is considered in respect to risk when land owners develop in these areas. With respect to favorable changes in flood risk a policy holder might wish to them noted on floodplain maps as a reference source used to request lower rates. It is against current FEMA policy to raise its flood insurance rates based on map revisions.[205] Statistically, flood insurance funds have been paying

Source: *Corrin Hoegen Wendell*

Ingalls shipyard in Pascagoula is in part possible by dredging funds allocated as part of the Dredging Trust Fund.

the same individuals for the same properties in high-risk zones for a very long time. Some of these tax payers have collected much more than their homes are worth over the past 20 years.[206] The average distribution will decrease as people build less often within the flood plain and take prescribed risk mitigation methods. Flood plain articles written prior to Hurricane Katrina are now less valuable as analytical sources, but they still serve to illustrate building and development practices in flood plains that are now considered too risky.

The U.S. Army Corps of Engineers also has an important role in facilitating development and flood control on the Mississippi Coast. In 1990, Congress passed the Water Resources Development Act, which includes environmental protection as a primary mission of the Corps. The Act also created an interim goal of no overall net loss of existing wetlands in America.[207] The 1994 Interagency Floodplain Management Review Committee outlined a new course for the Corps' flood control procedures that emphasizes the use of nonstructural measures.[208] This new course was later reaffirmed in a memorandum sent by the directors of the Office of Management and Budget and the Council on Environmental Quality on February 18, 1997 that advocated the purchase of conservation, reforestation, and flooding easements to preserve natural ecosystems while simultaneously discouraging construction.

The Corps' mission of preserving wetlands and using nonstructural measures to preserve floodplains, as set out in Section 404 of the Clean Water Act, is also an essential component of the Mississippi Coastal Improvements Program Comprehensive Report and the Integrated Programmatic Environmental Impact Statement from June 2009. Within the next four decades, the plan established in the Report calls for the restoration of the Mississippi barrier islands and 3,000 acres of wetlands and forest habitat, the purchasing of lands for easements, and the movement of residents who are currently in high-risk flood areas to new land.

State Enforcement Agencies

In order to enforce the laws protecting natural resources, a number of state agencies coordinate with each other and the federal government to support, protect, and develop coastal waters. Federal agencies include but are not limited to the NOAA, the U.S. Army Corp of Engineers, the National Marine Fisheries Service, the U.S. Department of the Interior, the U.S. Coast Guard, the Secretary of Homeland Security, the U.S. Department of Transportation, and the U.S. Fisheries and Wildlife Service. State agencies include the MDEQ, the Mississippi Department of Marine Resources (MDMR), the Mississippi Secretary of State, the Mississippi Department of Wildlife, Fisheries, and Parks, the Mississippi Emergency Management Agency (MEMA), the Mississippi Forestry Commission, the Public Services Commission, the Mississippi Oil and Gas Board, and the Mississippi Department of Archives and History.

Like the U.S. Congress, the Mississippi State Legislature is composed of an upper body, the State Senate, and the lower body, the House of Representatives. However, unlike its federal law-making counterpart, the Mississippi State Legislature is considered a traditional or citizens' legislature. Compensation for elected officials is low, the work is less than part-time, and the legislature has only a small staff to aid in its work.[209] The legislative session for 2011 began on January 4 and ended on April 7.[210] The next legislative session will begin on January 3, 2012, and continue until May 5, 2012.[211]

Because the compensation is low and the legislative schedule short for State Senators and Representatives, Mississippi's governor plays a very large role in the daily operations of the state. The governor is responsible for major departmental appointments. All of the following boards, agencies, and departments are heavily reliant on the governor's directives and directors.

The Department of Wildlife, Fisheries, and Parks operates as the state's environmental conservation and protection agency. The Department is charged with managing the state's freshwater resources, state parks, and the Mississippi Museum of Natural History.[212] The Department offers online systems for tracking native plants and animals, it provides hunting and boating education classes, and it is responsible for issuing hunting and boating permits and formulating regulations that apply to them.

The Department of Wildlife, Fisheries, and Parks was also formerly home to the Bureau of Marine Resources, which has subsequently been separated and made its own state agency. This new agent, the Mississippi Department of Marine Resources, is dedicated to enhancing, protecting and conserving marine interests of the state by managing all marine life, public trust wetlands, adjacent uplands and waterfront areas to provide for the optimal commercial, recreational, educational and economic uses of these resources consistent with environmental concerns and social changes.

As far as the state's mineral resources are concerned, the Mississippi Oil and Gas Board "has primary permitting authority for pipeline construction, operation, and maintenance" in the Mississippi Gulf Coast.[213] Despite this primary control, the U.S. Army Corps of Engineers and the Environmental Protection Agency must often be consulted for the issuance of permits and certification in order to comply with the Endangered Species Act.

The Mississippi Department of Environmental Quality (MDEQ) "has charge over regulation of air and water quality, resource recovery, and pollution prevention."[214] Its programs, rules and regulations work to eliminate existing pollution while collaborating with other state and federal agencies to limit new point and non-point sources of pollution. Despite the large number of state departments that participate in watershed management, MDEQ, through its Office of Pollution Control, is the primary agency charged with planning water-related activities and infrastructure. MDEQ operates a water management program called the Basin Management Approach, through which it assigns a basin coordinator to each watershed in the state to facilitate the development of local plans.[215] The Basin Management Approach encourages the pooling of financial resources in order to prioritize and address watershed concerns and provide the following benefits:

- Identifying and targeting water quality concerns in order to focus funding on efforts to solve them,
- Providing opportunities for Mississippians to be involved in developing and implementing solutions to these problems,

- Creating and identifying ways for basin stakeholders to access available technical assistance and funding resources, and
- Increasing the likelihood of quality water resources for future generations.[216]

MDEQ will create a statewide watershed plan in order to address the management and protection of Mississippi's valuable water resources, but that plan relies on the completion of local and regional plans.[217] Multiple counties, aggregated into water management districts, will formulate local watershed plans. Local plans will be analyzed and used to make regional plans, which will be collected and organized into the statewide plan for water resources.[218]

After Hurricane Katrina, the Governor's Commission on Recovery, Rebuilding, and Renewal tasked MDEQ with creating a Gulf Region Water and Wastewater Plan, which was subsequently published in 2006. The Plan identifies critical water, wastewater, and stormwater infrastructure needs in the region and prioritizes those needs within the context of an implementation plan "for long-term growth and recovery."[219]

The Governor's Commission and the Mississippi State Legislature authored Senate Bill 2945, which "authorize[s] the creation of county utility authorities for each of the affected counties of Hancock, Harrison, Jackson, Pearl River, Stone, and George."[220] These authorities are responsible for the management of water, wastewater, and stormwater systems within county jurisdictions. They are permitted "to regulate water infrastructure, enter into contracts, set utility rates for consumers, charge for services, issue revenue bonds, and borrow money for the provision of services and facilities.[221] Senate Bill 2945 also created the Gulf Region Utility Board, which guides and encourages "long-term economic development and infrastructure planning."[222] The Mississippi Public Service Commission is charged with regulating utility rates and issuing certificates for operation of water and wastewater facilities and jurisdiction.[223]

Despite the effects of Senate Bill 2945, the Mississippi Public Service Commission continues to regulate many public and private water and sewer utilities at the local level. The Mississippi Gulf Region Utility Board, which was created as part of the State's legislative response to Hurricane Katrina, coordinates with other county coastal utility boards in order to rebuild the backbone infrastructure of coastal watersheds. In addition, MEMA "has authority for emergency response and disaster relief necessitated by flooding of streams and limited waterways and is responsible for coordinating with FEMA and other federal agencies, MDOT, appropriate flood control districts and municipalities."[224]

State law restricts leasing of offshore drilling north of the barrier islands except in Mississippi Blocks 40, 41, 42, 43, 63, 64, and 66 through 98.[225] Further, surface offshore drilling operations are not allowed within one mile of Cat Island. The Mississippi Secretary of State oversees leasing of state-owned submerged lands.

Before the creation of county utility authorities, the Mississippi Department of Health monitored 185 water supply, treatment, and distribution systems within the Gulf Coast region. Many water and wastewater systems are still operated by a number of different entities, including municipalities, not-for-profit associations, and for-profit companies.[226]

Mississippi's Seawall Act allows county officials to condemn private property in order to create seawalls to protect public roads.[227] The Act only applies if county officials show that a seawall is essential for the protection of a public road.

Although casinos are now built on-shore, all responsibility and authority for regulating the gaming industry remains vested with the Mississippi Gaming Commission.[228] The Commission has divisions that regulate casino gambling, charitable gaming, rules and standards compliance, and legal proceedings.

After Hurricane Katrina, the Mississippi State Legislature authored House Bill 45,which allows Mississippi's coastal casinos to locate "within 800 feet [of] the line of both the Gulf of Mexico coastline and Biloxi's Back Bay."[229] Previously, the Mississippi Gaming Control Act of 1990 only authorized dockside gambling.[230]

Human Use of Water

The waterways of the Mississippi Gulf Coast offer residents and visitors a wide variety of activities, resources, and opportunities. Beyond its basic uses for human survival, water can provide enjoyment aesthetically and recreationally while also contributing to local economies and ecosystems. The interaction of humans with water involves a give-and-take, as water requires replenishing when its resources are depleted and the damage it can cause requires humans to sometimes clean up after its disastrous effects. Particularly in the Gulf, water is an invaluable resource in many ways.

Recreational Uses

The coast and its upland waterways provide a wide range of recreational activities, and the capacity for recreational activities is a growing market as the population of the Mississippi Gulf Coast continues to rise. In fact, from 1995 to 2008 the number of recreation facilities in the state of Mississippi as a whole increased by 40 percent.[231] While not all of these activities are dependent on water resources, fishing and recreational swimming were included in 2008's top three activities.[232] In a public opinion survey conducted in the Southern Mississippi Planning and Development District on 65 outdoor recreational activities, nine out of the 45 most popular were water related. The most popular activities include fishing, canoeing, kayaking, rafting, and tubing. Other popular water-based activities are recreational swimming, wind surfing, water skiing, jet skiing, parasailing, boating/sailing, recreational crabbing/oystering and scuba/snorkeling.[233]

Birding

The activity of birdwatching covers a wide range of activities, from identifying birds in one's own yard to traveling to watch, photograph, and identify birds. Based on these definitions, there were 46 million birdwatchers in the United States aged 16 and older in 2001—one in five people living in the US at the time.[234] Also in 2001, 18 million Americans ventured away from home to bird watch, 78 percent of whom reported observing waterfowl.[235] In the same year, two in every 11 people living in Mississippi (18 percent of the state's population) were classified as birdwatchers.[236] However, these resident birders only comprised 88 percent of the birding in the state, with the remaining 12 percent consisting of nonresidents. Birding attracts a significant number of tourists.[237]

Because of the great variety of bird species living along the Mississippi coast, the area is a favored locale of both in-state and out-of-state birdwatchers. Coastal environments are ideal for birding because they are open and allow easy viewing. Wind and waves concentrate food sources along the shorelines, which are common pathways for migratory birds.[238] Apart from the benefits of all coastal habitats, the Mississippi Gulf Coast has certain assets that make it particularly appealing to birdwatchers. The barrier islands located a few miles offshore limit the more saline Gulf waters from coming into the Mississippi Sound, while the Pascagoula, Biloxi, Pearl and other rivers bring fresh water into the bays and Sound. This mix of fresh and salt water creates optimum estuarine conditions for marine fish, shrimp, crabs, and other food sources for the shorebird population.[239] The nearby hardwood forests, swamps, pine forests, and pine savannas also

provide a rich habitat for a very diverse avian population. During spring migration, the Mississippi Gulf Coast is the first landfall for millions of migratory species en route from Central America across the Gulf, while in the fall they often congregate along the coast to wait for weather changes.[240]

The coast of Mississippi has many parks and sanctuaries that provide constant refuges for birds and birders alike. The Mississippi Sandhill Crane National Wildlife Refuge is the area's premier birding sanctuary, with trails that provide a chance to view birds in their natural habitat.[241] Other popular birding locations in the area include the Grand Bay National Wildlife Refuge, the Gulf Islands National Seashore, De Soto National Forest, and the new Audubon Birding Trail.[242]

Recreational Fishing, Boating, and Water Sports

Fishing piers and marinas with boat launches are widespread throughout the bays, bayous, rivers, and Sound.[243] There are 191 public access points to water throughout the coastal counties, as seen in Table 1 below.[244] Many of these public access points offer additional amenities, such as walking/biking paths, parks, boardwalks, picnic areas, campgrounds, fishing, hunting, and birding, although only one site offers canoe/kayak access.

People from all over the United States come to enjoy outdoor marine recreation in Mississippi, as can be seen in Table 2 below.[245] According to 2000 data, beach visitation is the most popular outdoor recreation among U.S. citizens in Mississippi Gulf Coast area.[246] These visitors can enjoy a wide variety of water sports through beach rentals of jet skis, aqua cycles, sail boats, paddle boats, kayaks, and stand up paddle boards.[247] While the calm waters of the Sound have prevented the area from becoming a surfing destination, local surfers can travel past the barrier islands to find larger wakes in the Gulf.[248] Local fans of surfing, kayaking, sailing, and other popular water sports are congregating into an increasing number of clubs and organizations that promote the sports, organize events, and host group outings along the Coast. The region offers a variety of cruises, including deep-sea fishing and shrimping, dolphin watching, island and marsh tours, and numerous eco-tours, while kayak and canoe tours provide a more

Table 1
Public Water Access Sites and Amenities of Mississippi Coastal Counties

Source: *Southern Mississippi Planning and Development District Post-Katrina Inventory and Assessment of Public Access Sites*

Type of Amenity	# of Sites with Amenity in Hancock County	# of Sites with Amenity in Harrison County	# of Sites with Amenity in Jackson County	# of Sites with Amenity in Coastal Counties
Boat Launch/Ramp	**15**	**22**	**44**	**81**
Marina/Harbor	**11**	**18**	**17**	**46**
Boat Slips	**3**	**11**	**10**	**24**
Fishing Pier	**16**	**34**	**36**	**86**
Fishing	**7**	**11**	**14**	**32**
Shoreline/Beach Access	**4**	**8**	**9**	**21**
Swimming In Open Water	**1**	**5**	**4**	**10**
Canoeing/Kayaking	**0**	**0**	**1**	**1**
Total Access Points	**35**	**78**	**80**	**191**

Table 2
National Survey of Recreation in the Environment, Mississippi

Source: *National Survey of Recreation in the Environment 2000*

Activity Type	Participation Rate (%)	# of Participants (millions)	# days of Participants
Visiting Beaches	**0.51**	**1.04**	**8.67**
Visiting Watersides Besides Beaches	**0.08**	**0.16**	**1.31**
Swimming	**0.27**	**0.56**	**6.73**
Fishing	**0.15**	**0.31**	**4.66**
Motorboating	**0.11**	**0.22**	**3.39**
Personal Watercraft Use	**0.08**	**0.16**	**1.31**
Viewing or Photographing Scenery	**0.11**	**0.23**	**2.38**
Bird-Watching	**0.15**	**0.31**	**7.24**
Viewing other Wildlife	**0.21**	**0.42**	**8.85**

hands-on Gulf Coast water experience.

Miles off the shore, divers can experience the wonders of the Gulf Coast through rig diving. Although the outflow of fresh water from the Mississippi River can affect the clarity of the water miles from shore, murkiness only exists in about the first 15 feet of water.[249] Whether on their own or through local trip charters, divers can achieve 80 to 100 feet of visibility and experience some of the best spearfishing and angling in the region.[250] Not only are the diving rigs home to such fish species as spadefish (Chaetodipterus faber), amberjack (Seriola quinqueradiata), snapper (Pagrus auratus), and tang (Acanthurus mata), they are also covered in corals, anemones, arrow crabs, bristle worms, and other marine life that attract divers to the area.[251]

The healthy habitat of the Gulf makes it home to many high-demand aquatic species, including those with seasonal closures or quotas, such as red snapper (Lutjanus campechanus), gag (Mycteroperca microlepis), red grouper (Epinephelus morio), tilefishes (Lopholatilus chamaeleonticeps), greater amberjack (Seriola dumerili), gray triggerfish (Balistes capriscus), and other shallow-water and deepwater grouper.[252] [253] Several programs are in place to stimulate research, coordinate interjurisdictional effors, and help Mississippi fisheries, as a part of Gulf of Mexico national fisheries, recover. The Emergency Disaster Recovery Program is an assistance program funded by Congress in 2006 to aid in the rehabilitation and recovery of marine fisheries in the Gulf of Mexico after Hurricanes Katrina, Rita, and Wilma in 2005. The efforts of the program will extend through the year 2012. Mississippi is one of the partners in the Fisheries Economic Data Program, which monitors the economic performance of the fisheries in the Gulf of Mexico. The Law Enforcement Committee of the Gulf States Marine Fisheries Commission (GSMFC) provides enforcement representation to the Interjurisdictional Fisheries Program Fishery Management Plan process as well as commenting on and making recommendations to the GSMFC on a variety of enforcement issues. The Fisheries Information Network collects, manages, and disseminates statistical data and information on the commercial and recreational fisheries of the Region. It is comprised of two distinct programs: Commercial Fisheries Information Network and Recreational Fisheries Information

Network in the Southeastern United States. The Habitat Program addresses habitat issues in both State and Federal waters in the Gulf of Mexico. The Interjurisdictional Fisheries Program promotes fishery management among Gulf States for transboundary stocks that migrate freely through state and federal jurisdictions through the cooperative development of fishery management plans (FMPs). "The Southeast Area Monitoring and Assessment Program is a state/federal/university program for the collection, management and dissemination of fishery-independent data and information in the southeastern United States."[254] The Sport Fish Restoration Administrative Program coordinates the recreational fisheries programs in the five Gulf States, with a primary focus pertaining to artificial reefs and the establishment of regional policies and planning documents, including a regional database on all permitted artificial reef sites in the Gulf of Mexico.[255]

The National Marine Fisheries Service (NMFS) lists four species of fish in the Gulf of Mexico that are subject to overfishing or are currently being overfished: gag, gray trigger fish, greater amberjack, and red snapper (red snapper is one of the top ten recreational fishing species).[256] [257] Overfishing means that the rate of removal from a stock is too high, while overfished means that the population is below a prescribed threshold.[258] In order to reduce overfishing, annual catch limits and other measures have been implemented in the Gulf of Mexico. In 2010, a limit was placed on stone crab.[259] The Mississippi Department of Marine Resources lists current recreational and commercial fishing limits on several species of aquaculture, assigning minimum/maximum length in inches and number of fishes or maximum weight. Cobia, flounder, red drum, spotted seatrout, king mackerel, spanish mackerel, tripletail, red snapper, and other fish species have catch limits imposed for both recreational and commercial fishermen.[260] The top ten marine recreational fishing species caught in Mississippi fluctuate, as shown in Figure 3.[261]

One of the means to monitor fish movement patterns and growth rates is the Marine Sport Fish Tag and Release Program, which is a cooperative effort of the Gulf Coast Research Laboratory (GCRL) , a unit of the University of Southern Mississippi (USM)[262] and anglers. Thousands of volunteer anglers help GCRL monitor important fishery species, namely cobia, tripletail, and spotted sea trout. Only with the assistance of the fishing community is the Marine Sport Fish Tag and Release Program able to tag fish and report recaptures in order to determine movement patterns and growth rates. The involvement of anglers in these activities is crucial to provide information that would be difficult to obtain by other means. [263]

Based on U.S. Department of Commerce data, most of the saltwater recreational anglers in Mississippi are coastal residents, while out-of-state tourists generally outnumber non-coastal residents of Mississippi (see Figure 4).[264] Most of the recreational fishing trips on the Mississippi Gulf Coast are taken on a private or rental boat, followed by shore-based fishing. The total number of fishing trips increased by 12 percent from 2000 to 2010, while shore fishing trips increased by 17 percent and private boat trips by 12 percent (see Figure 5). In the same period, for-hire fishing trips declined by 85 percent.[265]

Tourism

Some tourists choose to visit the State Welcome Centers, which are located in Jackson and Hancock counties. Based on the number of visitors to the Welcome Centers, tourism declined between 2008 and 2010, due in part to the economic recession. In 2010, more than 275,000 people visited the Jackson County Welcome Center, while more than 320,000 visited the Hancock County Welcome Center, down 15 and 25 percent respectively compared to 2008, as seen in Table 3.[266] [267]

The tourists visiting these Centers come primarily from Florida, Louisiana, Alabama, Texas, Georgia, and Mississippi.[268] Visitors from these six states composed 47.05 percent of the total number of 2010 registrants at the Jackson County Welcome Center and 63.75 percent of total visitors of Hancock Welcome Center.[269] [270] In 2010, most international visitors came from Canada.[271] [272]

The Bureau of Labor Statistics explains that "leisure and hospitality services include a wide variety of activities that attract tourists such as resorts, recreational parks, sporting events, concerts, restaurants and hotel lodgings."[273] The leisure and hospitality industry provides a large share of employment in the coastal counties of Mississippi. It represents 24 percent of

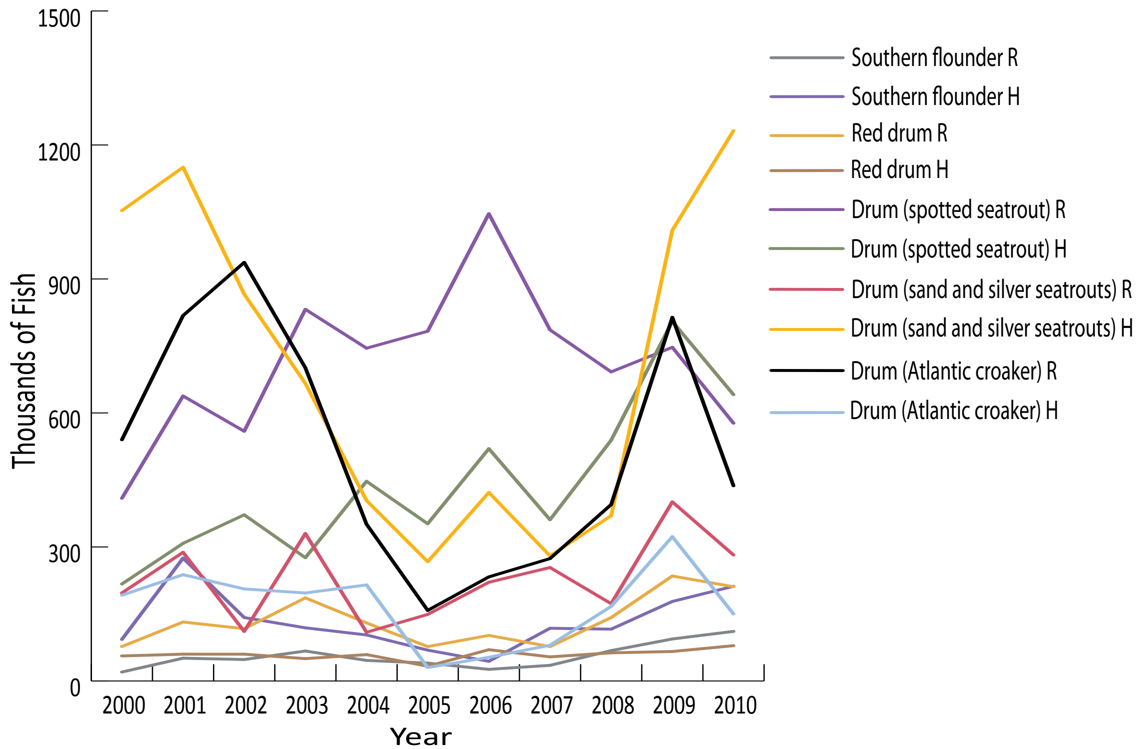


Figure 3 (Top Left)
Harvest (H) and Release (R) of Five Key Species/Species Groups (thousands of fish)

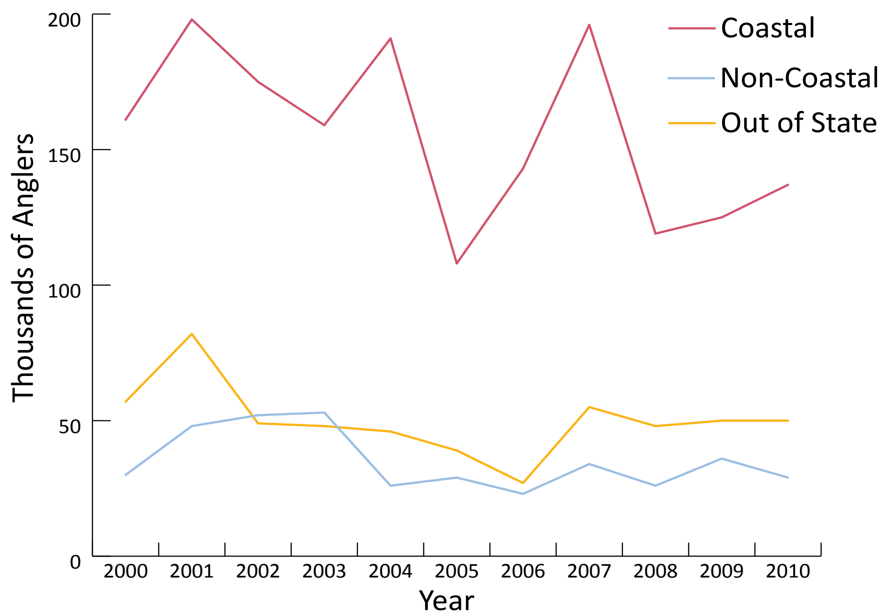
Source: *U.S. Department of Commerce, National Ocean and Atmospheric Administration, National Marine Fisheries Service*

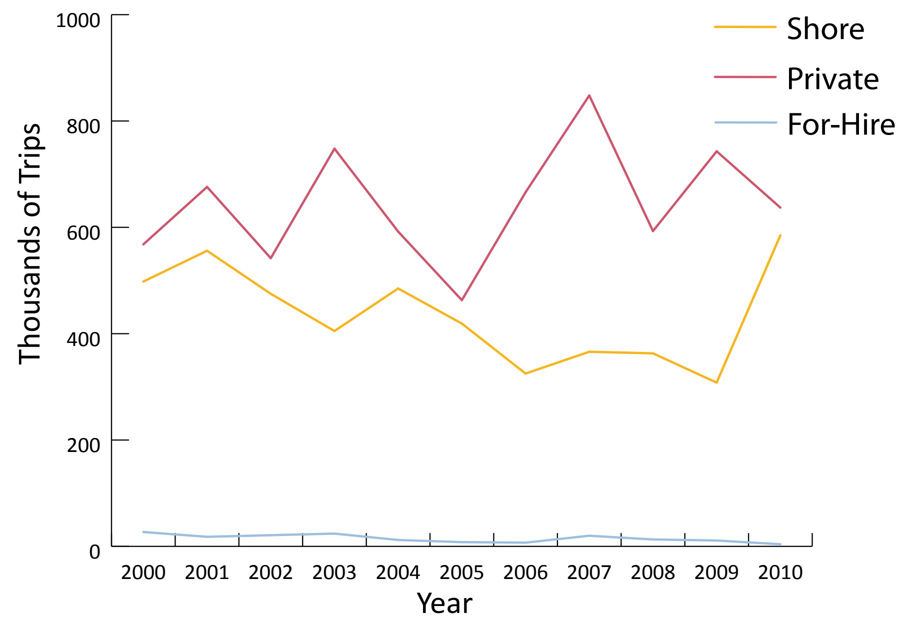
Figure 4 (Bottom Left)
Recreational Anglers by Residential Area, Mississippi Gulf Coast (thousands of anglers)

Source: *U.S. Department of Commerce, National Ocean and Atmospheric Administration, National Marine Fisheries Service*

Figure 5 (Bottom Right)
Recreational Fishing Effort by Mode (thousands of trips)

Source: *U.S. Department of Commerce, National Ocean and Atmospheric Administration, National Marine Fisheries Service*





employment in Hancock County in 2010, 30 percent in Harrison County, and 10 percent in Jackson County.[274] Hurricane Katrina, the national recession, and the Deepwater Horizon oil spill have contributed to a decline in employment in this industry over the last decade.[275]

Archeological and Cultural Sites

The Gulf Coast not only holds recreational value for visitors, it also has cultural and historical assets that are related to water. The six southern counties form the Mississippi Gulf Coast National Heritage Area, which showcases and conserves the Coast's historically important sites, buildings, undeveloped waterways, islands, and forests.[276] Visitors to the Heritage Area explore and discover the waterways just as the first Native Americans did along the Coast and the area's rivers and bays.[277] The former homes and villages built by the explorers are marked along the shores of the bays, islands, and estuaries, and ceremonial centers consisting of earthen mounds can be visited along sites on the Pearl and Pascagoula Rivers and on Deer Island.[278]

Heritage tourists commonly tour the natural environments of the Mississippi Gulf Coast National Heritage Area via canoeing and kayaking along local rivers, streams, and the Sound. These areas showcase the aquatic and wetland habitats of the region with historic forms of transportation, and tours of the swamps and marshes are conducted by many government and non-profit groups to showcase the local flora and fauna.[279] In the area's estuaries and marshes, visitors experience the interconnectivity and interdependence of natural systems through first-hand observations of the flood control, water quality enhancement, and aquatic habitats.[280]

In addition to Heritage Area sites, the Mississippi Department of Archives and History and the U.S. Army Corps of Engineers have identified the locations of 18 historical ship wrecks that occurred off the coast of Mississippi as early as 1868.[281] Of these, most were located near to or along the shores of Ship Island. Two notable Ship Island wrecks include the iron-hulled steamship Josephine, first shown on a map by the Army Corps of Engineers in 1881, and a schooner named George Henry that is identified on an 1868 map of Fort Massachusetts.[282] In these same waters, nautical charts also show the existence of unexploded projectiles or ordnance.[283] Although there are certain regulations requiring the removal of ordnance from developed land, these regulations vary depending on location and will allow for the ordnance to remain on the ocean floor.[284]

Table 3
Tourists Serviced in 2008-2010 Calendar Year (CY) in Jackson and Hancock County Welcome Centers

Source: *U.S. Department of Commerce, National Ocean and Atmospheric Administration, National Marine Fisheries Service*

	Jackson	Hancock
2008	367,252	377,786
2009	329,379	350,584
2010	275,103	321,032

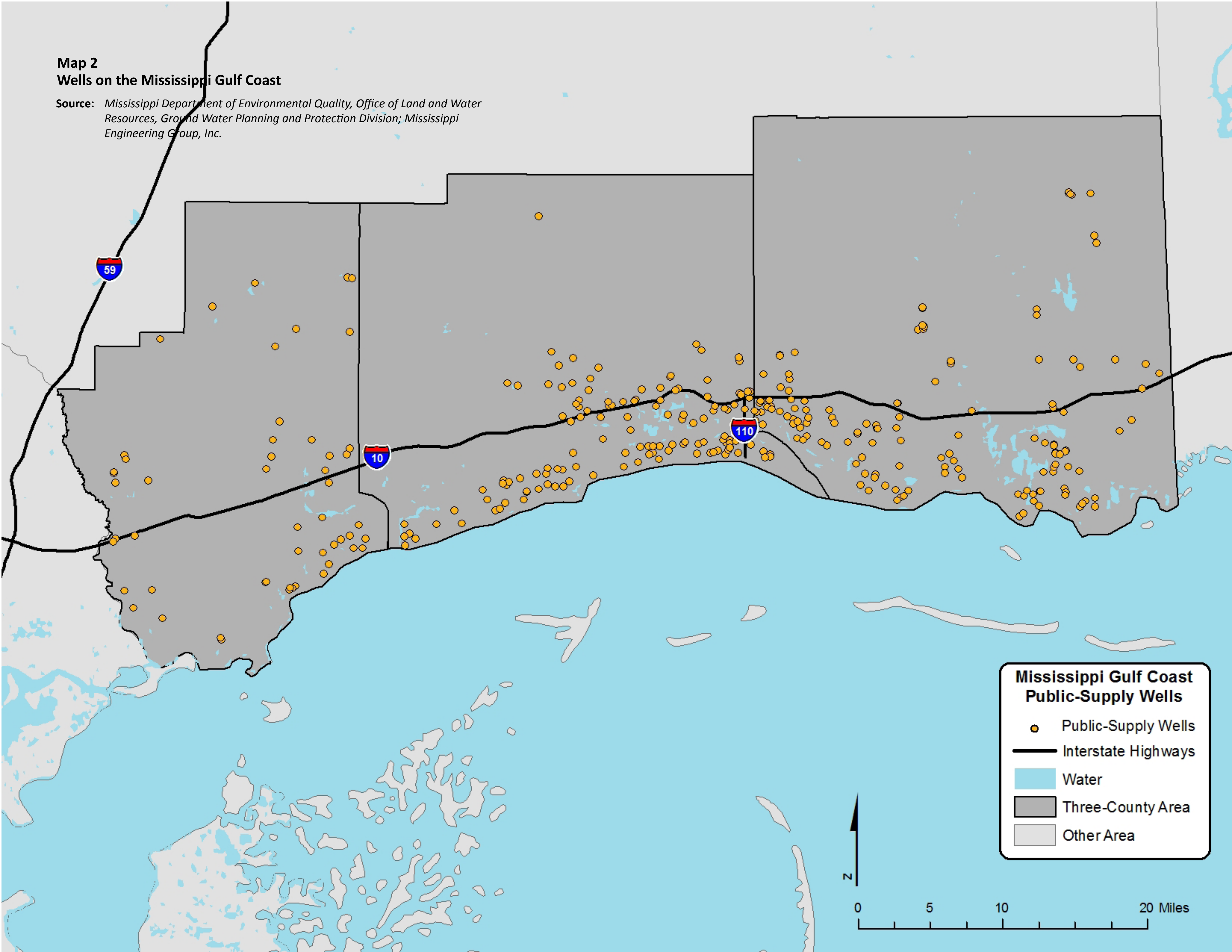
Potable Water, Wastewater, and Stormwater

Apart from recreational and commercial uses, the water resources in the Gulf Coast are extremely valuable in their provision of many basic human needs, such as drinking water. While most of the Gulf Coast's potable water demands are met by groundwater aquifers, surface water is still used to supply process water for many industrial activities. Waterways that supply process water include the Pascagoula and Escatawpa Rivers in Jackson County, the Biloxi River in Harrison County, and the canal system along the Pearl River in Hancock County.[285] As of 2007, there were only a handful of large-scale drinking water treatment facilities, all located in Jackson County.[286] The limited amount of facilities can be explained by the relatively high quality and quantity of groundwater per the current standards and population.

Total water consumption for all sectors across the three coastal counties totaled 474.71 million gallons per day in 2005. Of this amount, 390 million gallons came from surface water sources, 330 million gallons of which was consumed in Harrison County.[287] All water demand not met by surface sources is supplied by both public and private wells into the area's aquifers, the public of which can be seen in Map 2. It is estimated that approximately 38 percent of the Gulf region's population is served by private wells.[288] As can be seen in the figure, demand in the area is

Map 2
Wells on the Mississippi Gulf Coast

Source: *Mississippi Department of Environmental Quality, Office of Land and Water Resources, Ground Water Planning and Protection Division; Mississippi Engineering Group, Inc.*



high and physical growth and change in the area's industries are causing an increase in water usage. These trends have been accompanied by a 57.5 percent increase in impervious surfaces in the three coastal counties from 1972 to 2000.[289] This increase not only put a strain on existing infrastructure, it also contributed to recovery problems post-Katrina. Looking forward, Hancock, Harrison, and Jackson Counties all project steady increases in water demands that cannot be met by current water supply, treatment, and distribution infrastructure.[290] Current average consumption in the area is 2,000 gallons per resident per month, with the amount rising significantly during summer months.[291] The projected 31.0 percent growth in population from 2008 to 2035 will therefore bring approximately 217.6 million additional gallons of water demand on the system in the residential sector alone.[292] The projections were created immediately following Hurricane Katrina, actual redevelopment and new development has been uneven throughout the region leading to differing demand for water across the region.

Prior to Hurricane Katrina, the six southern Mississippi counties (George, Hancock, Harrison, Jackson, Pearl River, and Stone) acquired potable water from 185 distinct service providers, including municipalities, private entities, utility districts, and rural water associations.[293] These six counties included 481 permitted wastewater discharge facilities as well as over 85,000 on-site treatment systems that cover approximately 195,000 housing units and 7.3 million gallons per day.[294] Flood control, drainage, and stormwater management within these counties have been achieved through various channels, basins, reservoirs, and dams. None of the individual management systems were connected in a comprehensive network, although they cover three major watersheds and 27 sub-watersheds.[295]

Responses to Katrina came on all levels, culminating in the appropriation of more than $5 billion in long-term recovery assistance through the US Department of Housing and Urban Development (HUD).[296] Through efforts from the Governor's Commission on Recovery, Rebuilding, and Renewal and Senate Bill 2943 on the creation of county-wide utility authorities, a large portion of this assistance was to go toward funding water, wastewater, and stormwater infrastructure improvements along the Mississippi Gulf Coast. Specifically, $582 million was to provide new or enhanced infrastructure in the six southern counties.[297] In order to identify and prioritize these infrastructure needs, including the identification of feasible alternatives for consolidating facilities, the MDEQ and Mississippi Engineering Group, Inc., prepared the Mississippi Gulf Region Water and Wastewater Plan.

Since then, significant progress has been made on water infrastructure improvements across the coastal counties. Of the 13 projects in Hancock County, eight have already been completed, with four more to finish by the end of 2011.[298] The remaining projects are all scheduled for completion by the end of 2012, using $145 million in allocated funds.[299] These projects include increased water and sewer service coverage, connection of supply lines to the distribution system, and increased capacity throughout the system.[300] Harrison County is in the process of completing 25 projects for a total of $324 million.[301] So far these funds have provided for five new wastewater treatment plants and 12 new water towers and tanks, with two more tanks to be completed in the near future.[302] The improved infrastructure is being planned and implemented based on the projected 2025 demand.

Ocean Disposal

Based on Section 404 of the Clean Water Act, any sort of materials placement into U.S. waters requires permitting from the U.S. Army Corps of Engineers using EPA environmental criteria.[303] While nearly all material involved in ocean placement in the Gulf is dredged material from the ports, all placement requires the acquisition of permits that can limit the amount and type of dumped material, the impact on tidal waters and wetlands, the type of development allowed, the effects on stormwater and floodplains, the timeframe of the project, and numerous other elements.[304] In addition to permits, many projects are required to complete an Environmental Impact Statement before being allowed to dredge or dump.

Dredged material, if not used for beach nourishment in the area, commonly finds a place at one of the EPA-designated ocean materials placement sites along the Gulf Coast. The sites

Source: *Jennifer Evans-Cowley*

Fort Davis Bayou in Ocean Springs.

are managed and monitored so as to prevent unreasonable degradation or endangerment of human health and welfare, marine environments, or economic potentialities.[305] Three ocean materials placement sites are located off the shores of Mississippi, with two in Gulfport and one in Pascagoula. The eastern site in Gulfport covers 2.47 square nautical miles at a depth of 30 feet, while its western site covers 5.2 square nautical miles at a depth of 27 feet.[306] Both of these sites are used for any material meeting Ocean Dumping Criteria.[307] The third site in Pascagoula is the largest: 18.5 square nautical miles at a depth averaging 46 feet.[308] This site is limited to approved material from the Mississippi Sound region.[309]

Water Dependent Economy

The Mississippi Gulf Coast has many industries that are strategically dependent upon their location on the water, such as shipbuilding, advanced materials, marine science, fishing, and tourism.[310]

Shipbuilding

The Gulf Coast has the largest concentration of shipbuilding in the United States.[311] Overall, the U.S. has seen a decline of 25 percent in the number of shipyards between 1982 and 2005, while the Gulf Coast has seen a decline of only 6 percent. Employment in shipyards has declined more significantly—59 percent nationally and 21 percent on the Gulf Coast.[312] While the Gulf Coast has experienced consolidation and decline in shipbuilding, the Mississippi Gulf Coast has remained a strategic center of shipbuilding, with two shipyards that account for 57 percent of the $2.1 billion in annual shipbuilding and repair sales on the entire U.S. Gulf Coast (see Tables 4 and 5).[313] [314] [315]

The largest shipbuilder on the Mississippi Gulf Coast, as well as the largest private employer in Mississippi, is Northrop Grumman Shipbuilding, which builds surface warships, offshore drilling rigs, and cruise ships.[316] Huntington Ingalls Industries, Inc., a subsidiary of Northrop Grumman, produces high-tech composite ships and aerospace structures for the Navy, Coast Guard, and foreign customers.[317] Other military shipbuilders in Mississippi include VT Halter Marine, Inc. and Rolls-Royce Naval Marine, which manufactures Navy propulsors.[318]

Trinity Yachts, which moved to Bernard Bayou Industrial Park in Gulfport following Hurricane Katrina, builds of some of the world's largest leisure boats.[319] United States Marine focuses on military, patrol, and special warfare boats made with composites and aluminum. Gulf Ship, LLC provides propulsors for the high-tech oil service company Edison Chouest Offshore.[320] [321]

Advanced Materials

The demands of the shipbuilding and petrochemical industries have resulted in growth in advanced materials employment on the Mississippi Gulf Coast (see Table 6).[322]

The lower nine counties in Mississippi are home to five centers related to advanced materials, including centers in Gulfport, Pascagoula, and Bay St. Louis.[323] The University of Southern Mississippi (USM) houses a School of Polymers and High Performance Materials that has received an $8.2 million grant from the U.S. Department of Defense to establish a composite materials research and development center.[324]

The Bernard Bayou Industrial District in Gulfport focuses on composite companies.[325] In 2006, Seemann Composites, Northrop Grumman Shipbuilding, VT Halter Marine, and Trinity Yachts—along with USM, the Mississippi Gulf Coast Community College, and the Pearl River Community College—formed a research consortium to focus on composite use in shipbuilding.[326] The consortium contributed to workforce development and advancing research on composites in the region.

Pascagoula hosts many chemical-related companies. The Chevron Pascagoula Refinery processes oil extracted off shore and is one of the top ten petroleum refineries in the United States. It

Table 4
Major Shipbuilding and Boatbuilding Companies and Employment
Source: *Harrison County Development Commission, Southern Mississippi Planning and Development District*

Company	County Location	Total Employment
Northrop Grumman Shipbuilding	**Jackson**	**12,300**
Huntington Ingalls Industries, Inc.	**Harrison**	**550**
Trinity Yachts	**Jackson**	**500**
VT Halter Marine, Inc.	**Jackson**	**448**
Gulf Ship, LLC	**Jackson**	**292**
United States Marine, Inc	**Harrison**	**211**
Rolls-Royce Naval Marine	**Jackson**	**42**

Table 5
Shipbuilding/Boatbuilding and Repairing Sector in 2007
Source: *D&B. Compiled February 2007, Mississippi Gulf Coast Shipbuilding*

Sector	Location	Number of Businesses	Employees	Total Sales
Shipbuilding and repairing	**Mississippi Gulf Coast**	**10**	**10,533**	**$1.2 billion**
	Gulf Coast	**90**	**21,991**	**$2.1 billion**
	U.S	**1,034**	**91,855**	**$36.36 billion**
Boatbuilding and repairing	**Mississippi Gulf Coast**	**10**	**521**	**$142.7 million**
	Gulf Coast	**101**	**1,283**	**$219.5 million**
	U.S	**3,393**	**64,203**	**$9.1 billion**

produces paraxylene, which can be used in the textile and plastic industry, and benzeze and ethylbenzene, which can be used in tires, nylon, and pharmaceuticals. [327] Major chemical companies in Pascagoula also include Mississippi Phosphates Corporation and DuPont's First Industry Chemical.

Bay Saint Louis in Hancock County is a center for plastic-related companies centered in a waterfront industrial park.[328] Solvay Advanced Polymers produces Phamax, a lightweight plastic that can be used in defense. It also produces high performance plastic for the oil and gas industry.[329]

The USM's School of Polymers and High Performance Materials is focusing on the use of nanotechnology in the development of advanced materials to support current and future industries on the Mississippi Gulf Coast. [330] The Mississippi Polymer Institute is opening a 50,000-square-foot National Formulation Science Laboratory in the Biloxi Innovation and Commercialization Park. It is intended to help start-up companies pursue commercialization of new polymer products.[331]

Water-related Defense

The military employs more than 20,000 people on the Mississippi Gulf Coast. The Air Force, Navy, and Coast Guard all have water-dependent operations. Keesler Air Force base is home to the Hurricane Hunters, the 53rd Weather Reconnaissance Squadron, which flies into storms and measures them to predict hurricane development and movement. The Naval Construction Battalion Center (NCBC) in Gulfport has 7,000 employees and trains 20,000 students every year. NCBC had a $400 million annual economic impact in 2008.[332] The Coast Guard is responsible for patrolling a 1,870-square-mile area from Ocean Spring to Pearl River.[333] It has two stations in Pascagoula and Gulfport. The Gulfport station, which has 74 employees, focuses on protecting the maritime environment and guarding our natural resources. Their work includes responding to an average of 300 search and rescue requests per year.[334]

Marine Science

Marine science research has an important role in supporting the Mississippi Gulf Coast's economy. The Mississippi Gulf Coast

Table 6
Major Advanced Materials Companies and Employment
Source: *Harrison County Development Commission*

Company	County Location	Total Employment
Chevron USA, Inc. Pascagoula Refinery	**Jackson**	**1,569**
DuPont DeLisle	**Harrison**	**973**
Mississippi Phosphates Corporation	**Jackson**	**250**
First Chemical Corporation	**Jackson**	**150**

Table 7
National Marine Fisheries Service Landings in Mississippi
Source: *Office of Science & Technology, NOAA Fisheries, Annual Commercial Landing Statistics*

Year	Metric Tons	Pounds	Value ($)
2000	**98,777.0**	**217,763,858**	**58,751,487**
2001	**97,034.6**	**213,922,401**	**50,632,920**
2002	**98,869.5**	**217,967,609**	**47,565,219**
2003	**96,828.8**	**213,468,811**	**46,148,637**
2004	**83,261.5**	**183,558,261**	**43,618,143**
2005	**76,027.3**	**167,609,834**	**23,385,725**
2006	**100,571.7**	**221,720,414**	**21,586,062**
2007	**103,344.9**	**227,834,261**	**39,340,404**
2008	**91,545.9**	**201,822,002**	**43,696,487**
2009	**104,456.3**	**230,284,417**	**37,998,473**
GRAND TOTALS:	**950,717.5**	**2,095,951,868**	**412,723,557**

has 18 marine research units and three marine research centers.[335] The major research center is at the John C. Stennis Space Center, which is the largest center of oceanography in the United States. The Mississippi State University (MSU) Research and Extension Center at Biloxi researches aquaculture, coastal environments, fisheries, and seafood. Another center is the Gulf Coast Research Laboratory at Ocean Springs, which provides teaching and research facilities for marine science. It is also the headquarters for the Department of Coastal Science, the Gulf Coast Geospatial Center, and the Center for Fisheries Research and Development.[336] The National Data Buoy Center at Stennis observes the weather and ocean conditions with an automatic system. The Naval Research Laboratory at Stennis researches maritime applications of new technology, equipment, and materials.[337] Marine research is also conducted by both government agencies and universities. The Hydrographic Science Research Center is supported by both USM and the U.S. Navy. It studies hydrography and related science for government clients.[338] The development of marine science in the Mississippi Gulf Coast helps drive its transformation from a traditional economy to a technology-driven economy.[339]

Commercial and Recreational Fishing

Mississippi marine commercial and recreational fisheries are a $200 million industry that are a fundamental part of coastal Mississippi's economy.[340] Gulf Coast waterways are known for their abundance of seafood and other marine life, and commercial fishing has long supported many of the Gulf's residents as well as the local economy. The Gulf Coast constitutes 83 percent of U.S. shrimp landings and 56 percent of oyster landings.[341] The Gulf region averages 1.3 billion pounds of landings annually, with a yearly value of $662 million.[342] Within the Gulf region, Mississippi has the second highest percentage of commercial fishing landings—approximately 14 percent.[343] Landings figures for Mississippi can be seen in Table 7. Within the Mississippi market, the Port of Pascagoula is the most productive port—and the third most productive fishing port in the Gulf by poundage—with an average of 178 million pounds per year.[344] The average yearly harvest of 300,000 to 350,000 sacks of oysters is greatly influenced by oyster seeding and management.[345]

Recreational fishing also has a significant impact on the economy of Mississippi. Marine recreational fishing expenditures generated $417 million in sales and $105 million in personal income, with $162 million total value (gross domestic product of Mississippi) through trips and durable equipment in 2009.[346] More than 90 percent of the economic impact of recreational fishing is generated through durable equipment expenditures, which include the purchase of semi-durable goods (tackle, rods, etc.), durable goods (boats and accessories, boat storage, vehicles or homes, etc.), and angling accessories and multi-purpose items (magazines, specific clothing , etc.).[347] Total saltwater fishing trip and durable equipment expenditures in 2009 were $446 million.[348] Total angler's durable equipment expenditures in the Gulf of Mexico in Mississippi were $421 million in 2009, with 80 percent for boat expenses.[349]

Trade, Transportation, and Utilities

The Mississippi Gulf Coast is a major center for trade. Goods are imported through the ports and then transported by rail and truck to other locations across the country. The same is true of products being exported. The trade, transportation, and utilities sector is a large sector of the economy, constituting 27.3 percent of establishments and 19.5 percent of employment.[350] A portion of this activity is attributable to the water-dependent economy, such as marine transportation and the ports.

International trade is supported in the Mississippi Coast Foreign Trade Zone (FTZ) #92. Its 5,000 acres is spread across multiple sites, including airports, ports, and industrial parks across the three coastal counties.[351] [352] Multimodal connections to air, highway, and marine transportation encourage foreign trade activity.[353]

Marine Highway

The Gulf Intracoastal Waterway at the Mississippi Sound connects Mississippi to the other Gulf Coast states.[354] The Gulfport Sound Channel, the Biloxi East Access, and the Pascagoula-Upper and Lower Sound join the Gulf Intracoastal Waterway.[355] As seen in Map 2, the Gulfport Sound Channel joins the Intracoastal Waterway to the port of Gulfport at Gulfport Anchorage Basin. Biloxi East Access connects the Mississippi Sound all the way to Highway Interstate 10 through Davis Bayou, Biloxi Bay, Big Lake, and Biloxi River. Pascagoula Upper Sound and Lower Sound channel connect the Intracoastal Waterway to the Pascagoula . The navigable part includes Pascagoula Bay, Marsh Lake, and Pascagoula River. Saint Louis Bay is also navigable to the access of the Jourdan and Wolf Rivers.

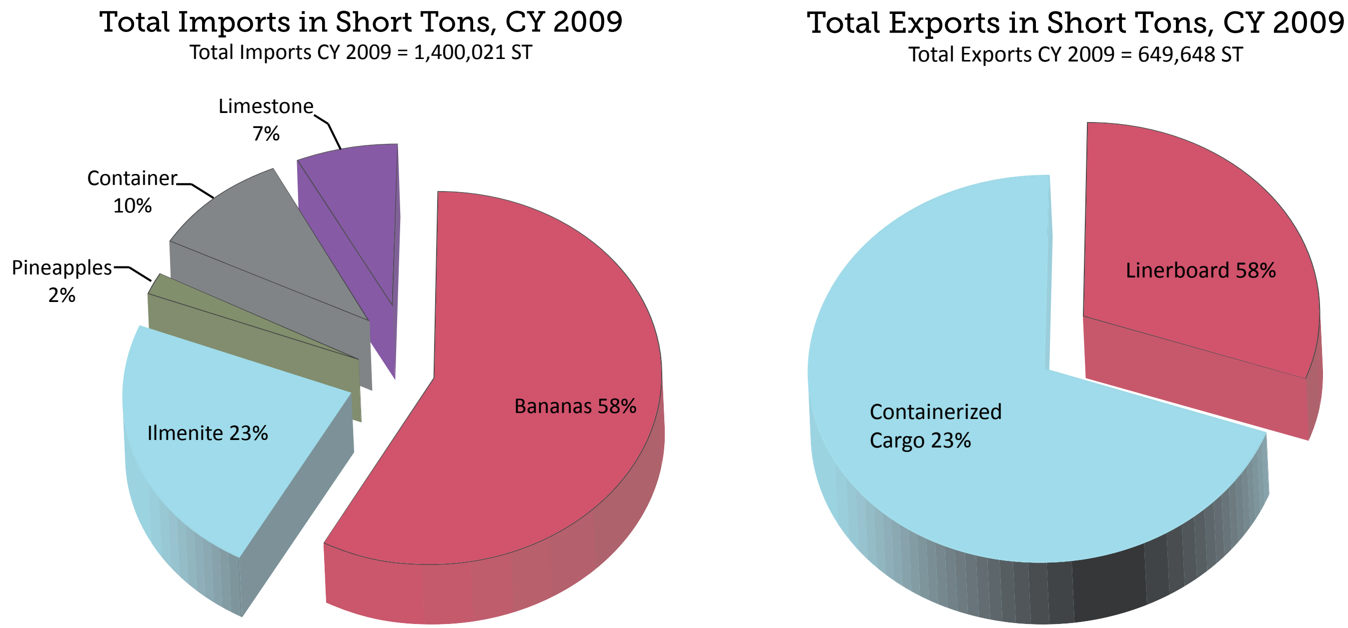
The Interstate Highway 10 corridor is an important asset supporting the ports of Pascagoula and Gulfport. The intermodal connections from I-10 to the port are critically important. There has been a significant growth in freight demand at the ports. The Interstate Highway 10 Corridor Freight Study found that there is a $12.6 billion shortfall in funding between 2004 and 2025 to support the freight corridor.[356] Freight tonnage is projected to grow 2 percent annually over the next three decades, while the volume of goods to be transported domestically is expected to double between 2002 and 2035.[357]

One way to alleviate the freight traffic on Interstate Highway 10 is through a marine highway. A study of freight traffic found that in 2003 more than 78 million trailer loads of highway and rail intermodal freight along the U.S. coasts could have been moved via marine highways.[358] The Gulf of Mexico to Florida was found to have approximately six million trailer loads per year that could have been moved via a marine highway. [359]

The Cross Gulf Container Expansion project, known as M-10, will create a 926-mile sea route across the Gulf of Mexico between Brownsville, Texas and Port Manatee, Florida. The M-10 project will utilize the Gulf of Mexico and the Gulf Intracoastal Waterway to connect to commercial navigation channels, ports, and harbors in Mississippi. It will also connect to the M-49 Corridor at Morgan City, Louisiana, the M-55 Corridor in New Orleans, and the M-65 Corridor in Mobile, Alabama. The expansion of the marine highway system is expected to help alleviate the projected growth of traffic and maximize travel times.[360]

In addition to the traffic benefits of a marine highway, Mississippi's shipbuilding industry could benefit by providing ships to support an increase in traffic.[361] However, the shipping industry argues that the Harbor Maintenance Tax is a disincentive to investment in marine traffic because domestic freight would be

Figures 6 and 7
Total Exports and Imports in Short Tons in the Port of Gulfport, CY 2009
Source: *Mississippi State Port Authority at Gulfport*



charged twice at a rate of 0.125 percent of the cargo value, once at the port of debarkation and again at the port of embarkation.[362] On the other hand, the waterways play an important role as recreational blueways. These blueways, as seen in Map 3, provide people with opportunities to access birds, wildlife, and sports.[363]

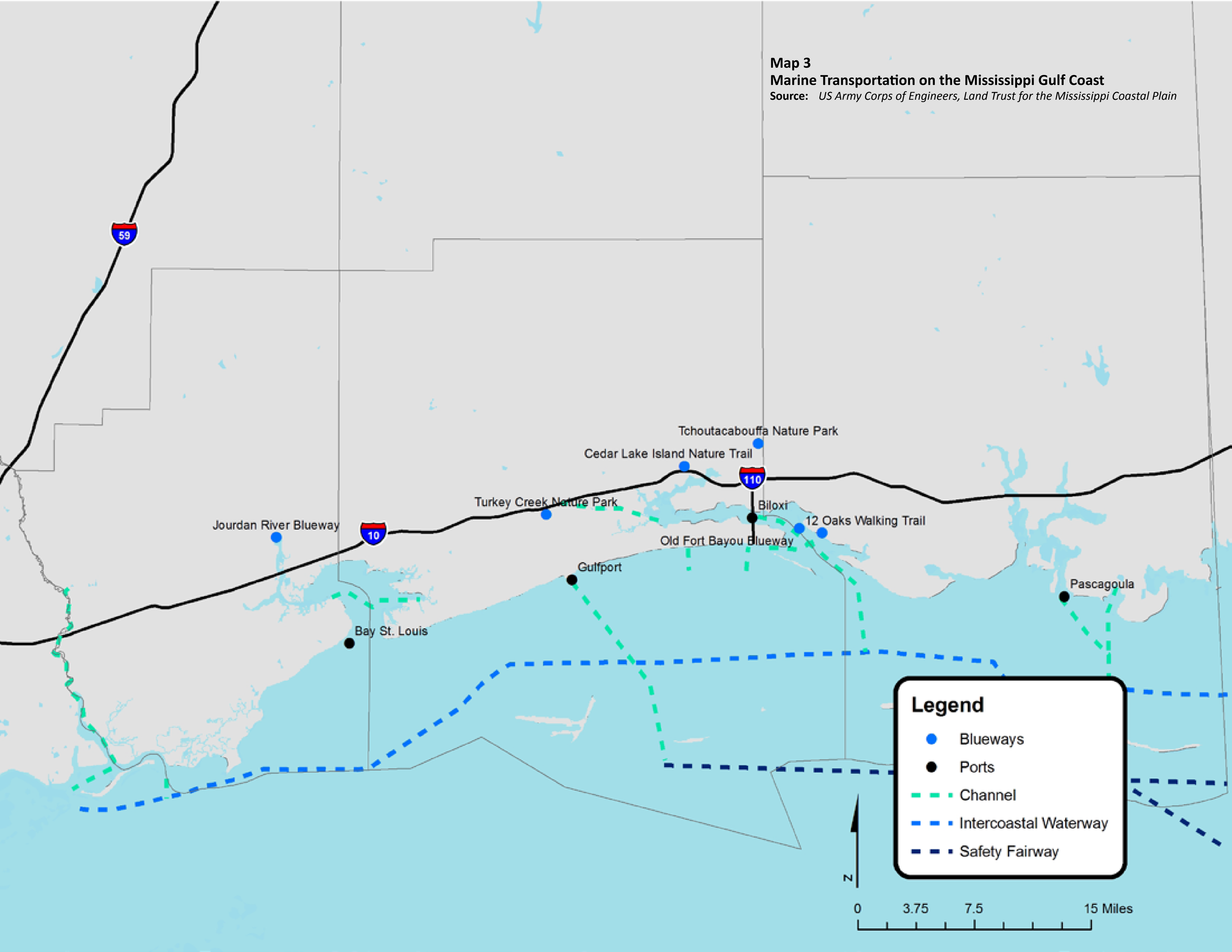
Ports

In 2009, Mississippi ranked 15 out of all U.S. states in total tonnage in waterborne traffic, with 52.2 million tons, and 10th in foreign tonnage, with 30.1 million tons.[364] In 2009, the Port of Pascagoula ranked 16 among the top 100 ports in the U.S. in short tons. The Port handles 620 ships per year, with 8.4 million domestic tons and 28.2 million foreign tons of cargo shipped from or received by the port yearly.[365] [366] In addition, there is a lightering zone off the coast of Pascagoula, more than 60 miles from the U.S. territorial sea, which controls the transfer of oil or hazardous materials.[367]

In 2008, the State Port of Gulfport ranked 21st in U.S. ports by container traffic. It is the second largest green fruit importer in the United States and the third busiest container port on the Gulf of Mexico.[368] [369] It has 172.5 thousand of twenty-foot equivalent units (TEUs) of containers and 2.3 million tons of cargo.[360] [361] In 2009, the types of cargo handled at the port included containerized bulk, break-bulk, and project cargo. Paper, clay, cellulose, fabric, cloth, yarn, and apparel hardware are the top export commodities. Bananas, garments, ilmenite ore, and hardwood lumber are the top import commodities, as seen in Figures 6 and 7.[362] The port handled 235 vessels in 2009 and 225 vessels in 2010.[363] In addition, the port of Gulfport has received $481 million of federal funding for expansion. The expansion is a six-year project that elevates the port to 25 feet to protect it from sea level rise and storm surge.[364]

Nonmarketable Economic Value of Ecosystem Services

Ecosystem services are natural ecological processes and landscapes that can provide services to sustain human and economic well-being.[365] [366] It is difficult to quantify the exact value of ecosystem services. For example, ecosystem services support healthy estuaries, which in turn support the seafood and recreational fishing industries.



Map 3
Marine Transportation on the Mississippi Gulf Coast
Source: US Army Corps of Engineers, Land Trust for the Mississippi Coastal Plain
59
10
110
Tchoutacabouffa Nature Park
Cedar Lake Island Nature Trail
Turkey Creek Nature Park
Jourdan River Blueway
Biloxi
12 Oaks Walking Trail
Old Fort Bayou Blueway
Gulfport
Pascagoula
Bay St. Louis
Legend
Blueways
Ports
Channel
Intercoastal Waterway
Safety Fairway
N
0
3.75
7.5
15 Miles

Changes to the ecosystem can result in disruption to the economy. For example, destruction or reduction in the quality of estuaries can cause a reduction in seafood productivity. With $38 million in seafood landings in 2009, reduction in productivity could have a substantial impact on the local economy.[367]

Another function of the ecosystem is to protect the built environment. The marshes and barrier islands provide protection from storms. According to the Mississippi Department of Insurance, $8.4 billion was paid to 240,000 claims in the three coastal counties within 12 months of Hurricane Katrina, but there would have been higher losses if they were not protected by the ecosystem.[368] Ecosystem services are very important to the coastal system and constitute a crucial part in the total coastal economy.[369]

Energy

Water-related energy industries include both fossil fuels and renewable energy sources.

Fossil Fuels

The Gulf of Mexico has the nation's largest oil and gas production industry. There are approximately 25,000 miles of active oil and gas pipelines and more than 4,000 oil and gas platforms across the Gulf of Mexico that are producing a mix of oil products.[380] The Gulf Coast produces 52 percent of the nation's crude oil and 54 percent of its natural gas. [381] It also has 47 percent of the crude oil refinery capacity in the nation.[382] Within 100 miles of the Mississippi Gulf Coast, as shown in Maps 4 and 5, there are approximately 5,950 miles of oil and gas pipelines, including 3,419 miles of active pipelines, 468 miles of proposed pipelines, and 2,063 miles of other pipelines. [383] There are also 330 oil and gas platforms in this region.[384]

Chevron's Pascagoula Refinery is Chevron's largest refinery company in the nation and one of the top ten petroleum refineries in the United States.[385] [386] Other energy-related companies include pipeline construction companies and gas supply companies. The Destin Pipeline and the Pascagoula Gas Processing Plant are two Pascagoula companies that build deep-water infrastructure for natural gas transmission and processing. In October 2008, Gulf LNG invested $1.5 billion to build a new natural gas terminal to supply natural gas for users throughout the southern United States.[387]

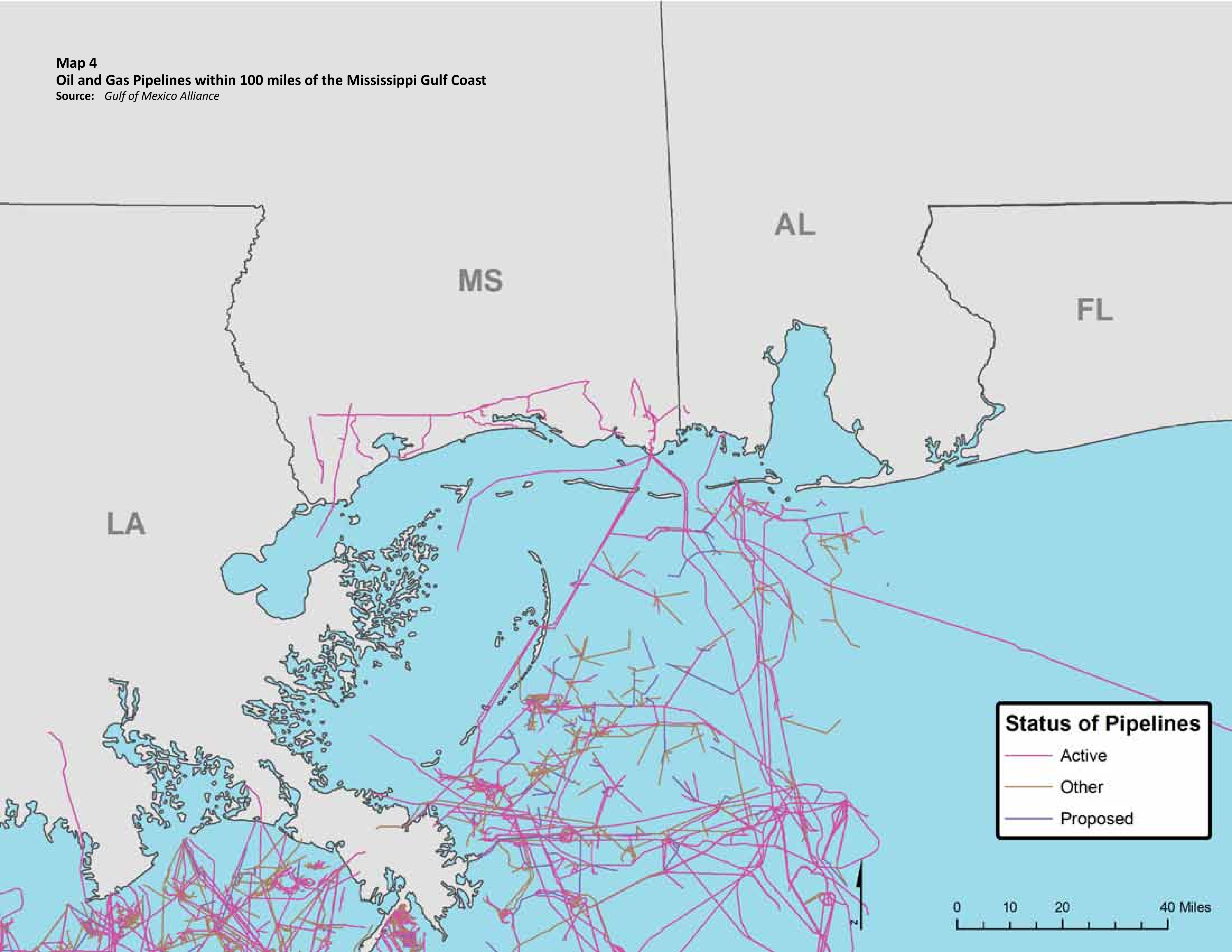
The Federal Energy Regulatory Commission (FERC) has issued permits to Gulf Energy Liquified Natural Gas to construct and operate an LNG import and receiving terminal in Jackson County. [388] In addition, there are several projects working to convert existing salt dome caverns in Forrest County near Hattiesburg, Mississippi into natural gas storage caverns.[389]

Beyond liquefied natural gas, there is the potential for a new form of natural gas called methane hydrate, which can be found in the ocean floor. Currently there are a number of research efforts underway to determine how to best extract the gas. According to the U.S. Geological Survey, there could be more than 2,000,000 trillion cubic feet of methane hydrate in the US EEZ.[390] This is more energy potential than all other fossil energy resources combined. The Gulf of Mexico Hydrates Research Consortium is establishing a hydrates monitoring station on the seafloor of the Gulf of Mexico.[391] It plans to install a seafloor observatory at Mississippi Canyon Block 118.[392] is the observatory will monitor ambient noise, fluid venting, and environmental conditions to understand how fluids migrate within the carbonate/hydrate mound.[393] If methods can be developed that would minimize the release of the methane into the atmosphere, this could become an important energy source.

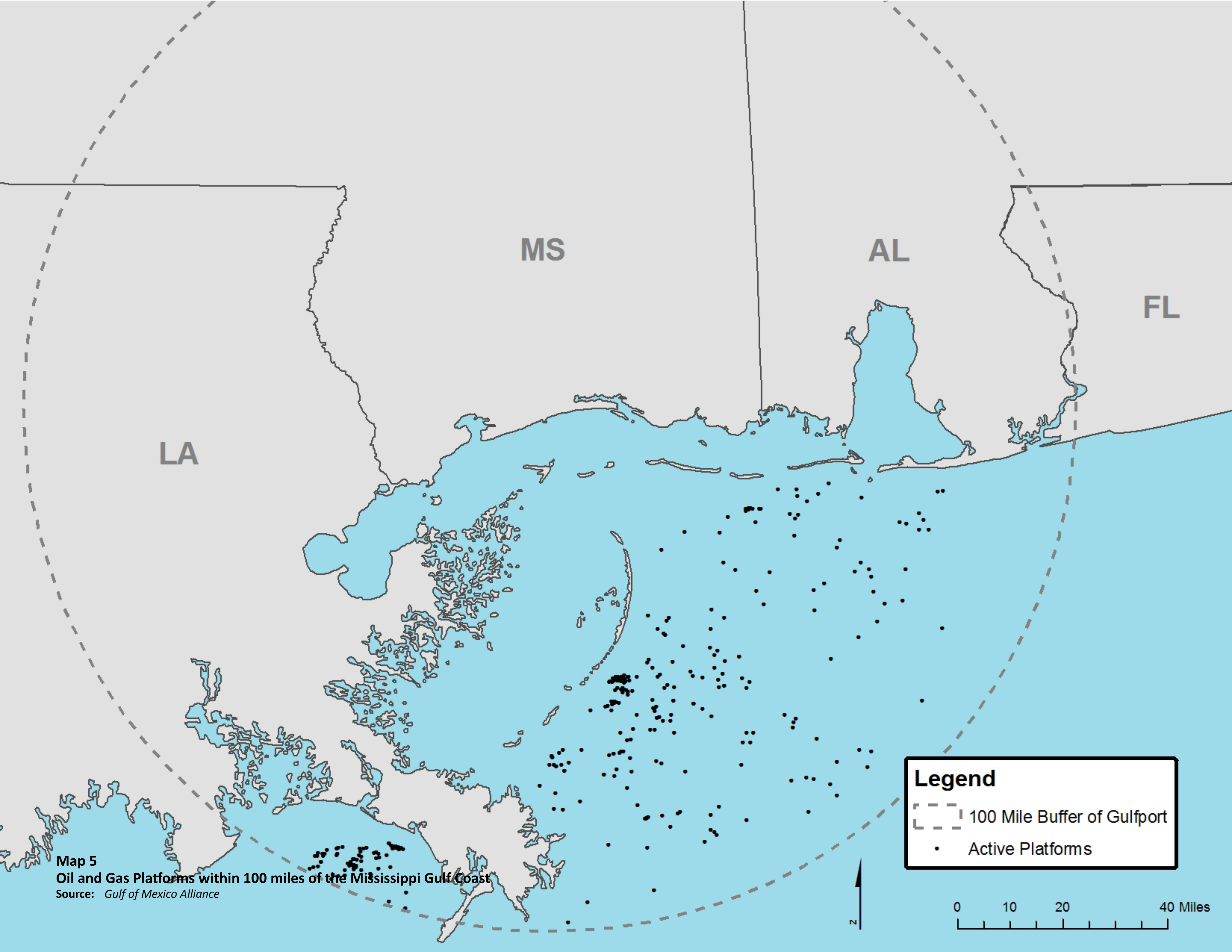
Renewable Energy

Mississippi does not currently have any offshore wind energy generation facilities, but it does have the potential to develop stations. Within Mississippi's state boundaries, development could be based on water depth and wind speed, as seen in Map 6.[394] Wind speeds exceed 6.5 meters per second (m/s) off the coast of Mississippi, and in some locations they are above seven

Map 4
Oil and Gas Pipelines within 100 miles of the Mississippi Gulf Coast
Source: *Gulf of Mexico Alliance*

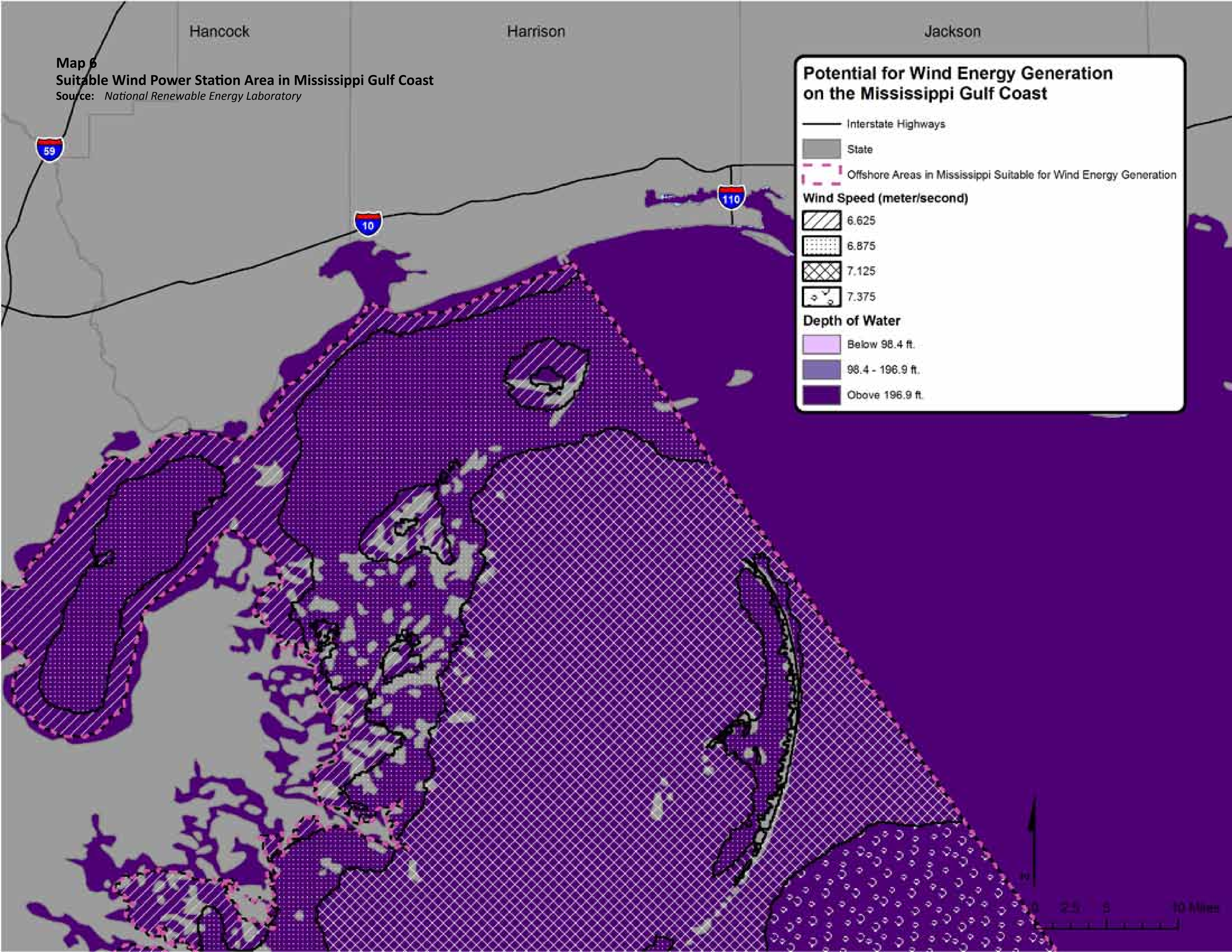


m/s. This, combined with Mississippi's shallow water and slow transition to deep water, this makes the Mississippi Gulf Coast suitable for wind energy generation facilities. Wind turbines can best be built in areas from 0 to 98.4 feet in depth. Between 98.4 to 196.9 feet, additional installation of tripods, jackets foundations, and truss-type towers should be used to help build the offshore wind power stations. Building a wind power station deeper than 196.9 feet is less feasible. "The distance a wind project is from shore determines a project's visibility from shore and whether it is located in state or federal jurisdiction."[395] The greatest potential for wind power projects is in federal waters approximately 11 to 15 miles offshore.



Map 5
Oil and Gas Platforms within 100 miles of the Mississippi Gulf Coast
Source: *Gulf of Mexico Alliance*

Map 6
Suitable Wind Power Station Area in Mississippi Gulf Coast
Source: *National Renewable Energy Laboratory*



Ecology

According to The Nature Conservancy's classification of ecoregions, the Mississippi Gulf Coast is located in the East Gulf Coastal Plain (EGCP). The EGCP is one of the five ecoregions that compose the Southeast Coastal Plain. It is characterized by a flat topography, a warm to hot, humid maritime climate, and its vicinity to the ocean, which endows the area with abundant surface water resources, diverse estuarine and tidal systems, and widespread wetlands. Because of these unique landscape features, the area has diversified ecological systems, many of which are home to a variety of endemic species. Therefore, this region has one of the highest degrees of biological richness in North America.[396]

Surface Water Bodies

The Mississippi coast has diverse fresh and saltwater landscapes and habitats. The coast is served by eight tidally influenced rivers that extend through estuarine habitat for over 85 miles and cover an estimated 4,500 acres. More than 300 tidal creeks and riverine bayous cover approximately 5,500 acres along the Mississippi Coast. The Mississippi Sound itself covers a surface area of approximately 500,000 acres.[397]

The Mississippi Coast has two embayments, Saint Louis Bay and Biloxi Bay. The bays mostly range in depth from one to 10 feet, but in some channel segments the depth reaches 30 feet. The bottom soils are characterized by textures ranging from muddy sand to sandy mud. The bays experience tidal surges of one to one and a half feet on average, but can reach four feet on occasion. Salinity levels are in a constant state of flux depending on the tides, weather, and season, all of which result in partially mixed to well mixed systems.[398]

The coast features more than 100 coastal estuarine ponds and lakes of varying sizes that cover an aggregate area of approximately 4,000 acres. The lakes range in depth from one to ten feet, and their ecology is similar to the embayments. The barrier islands also have hundreds of small ponds and lakes. However, because they can be shallow and are not always connected, they exhibit a wider range of temperatures and more consistent salinity levels than the mainland ponds. The barrier island ponds can quickly and radically change due to hurricane winds that cause overwash, erosion, and even species exchanges.[399]

Coastal tidal streams are further classified into three general types: tidal marsh creeks, coastal tidal creeks, and riverine estuary bayous. Coastal tidal creeks drain freshwater from the uplands, while tidal marsh creeks serve as drainage for estuarine marshes. The slow-moving, meandering riverine bayous act as distribution channels within the riverine estuaries. The bottom soils are characterized by muddy sand or sandy textures. Water salinity, pH, and turbidity change in a gradient along the upper reaches of tidal creeks to their estuary outlets.[400]

The Mississippi Sound is a linear body of water about 12 miles wide that extends along the southern coasts of Mississippi and Alabama. The portion within Mississippi's borders covers an area of about 400,000 acres.[401] A chain of barrier islands serves as the outer boundary of the Mississippi Sound and separates the coast from the deeper waters of the Gulf of Mexico. The Sound has three identifiable hydrological zones. The western zone is characterized by higher freshwater inflows. By contrast, the central zone has little freshwater inflow and poor circulation, but it experiences extensive tidal flushing. The eastern zone is characterized by water inflow from the Mobile Bay and Petit Bois Pass. Salinity levels in the Sound are within the polyhaline range and are typically lowest along the mainland, where levels fluctuate more widely. The bottom soils of the Sound include mud, sandy mud, and sand textures.[402]

Wetlands

Wetlands are widely spread over the region, occupying 31.7 percent of total land area in the three coastal counties.[403] The inherent and unique features of wetlands enable them to perform a number of ecological functions (e.g., filtering pollutants, storing floodwater, and providing wildlife habitats) that are of significant importance to humans and the ecosystem. Their distribution in the three coastal counties is shown in Map 7.

The existence of a large number of water bodies and wetlands, as well as the frequent interaction between ocean and land in the form of tides and storm surges, bestows the region with various types of near- or in-water habitats to support a number of wildlife and fish species.

Habitat Types

The Mississippi Department of Wildlife, Fisheries, and Parks has developed a Comprehensive Wildlife Conservation Strategy (CWCS) that details wildlife habitats in Mississippi. CWCS descriptions include vegetation and soil characteristics, geographical boundaries, and an assessment of wildlife habitat quality. The following pages briefly detail the habitats that occur within the three coastal counties of Mississippi.

Wet Pine Savannas and Flatwoods

Wet pine savannas are considered to be one of the most endangered ecosystems in the country due to their restricted range of habitat. Less than five percent of the total original acreage of wet pine savanna habitat remains in the Atlantic/Gulf Coastal Plain today.[404] Wet pine savannas are found on broad coastal flats and sloping plains that receive more than 60 inches of precipitation annually and remain saturated for much of the growing season. The ground cover within wet pine savanna stands is extraordinarily diverse; more than 200 understory plants can be found in this habitat.[405]

Approximately 150,000 acres of slash pine flatwoods remain today, which can also be found only in the coastal counties.[406] This subtype is frequently in poor condition due to the lack of prescribed fire, which controls potential shrub encroachment. When there are periods without fire, stands become impenetrable masses of thorny vines that are virtually inaccessible by humans. Forest stands can be found on broad lowland flats that border swamp forests near larger creeks.

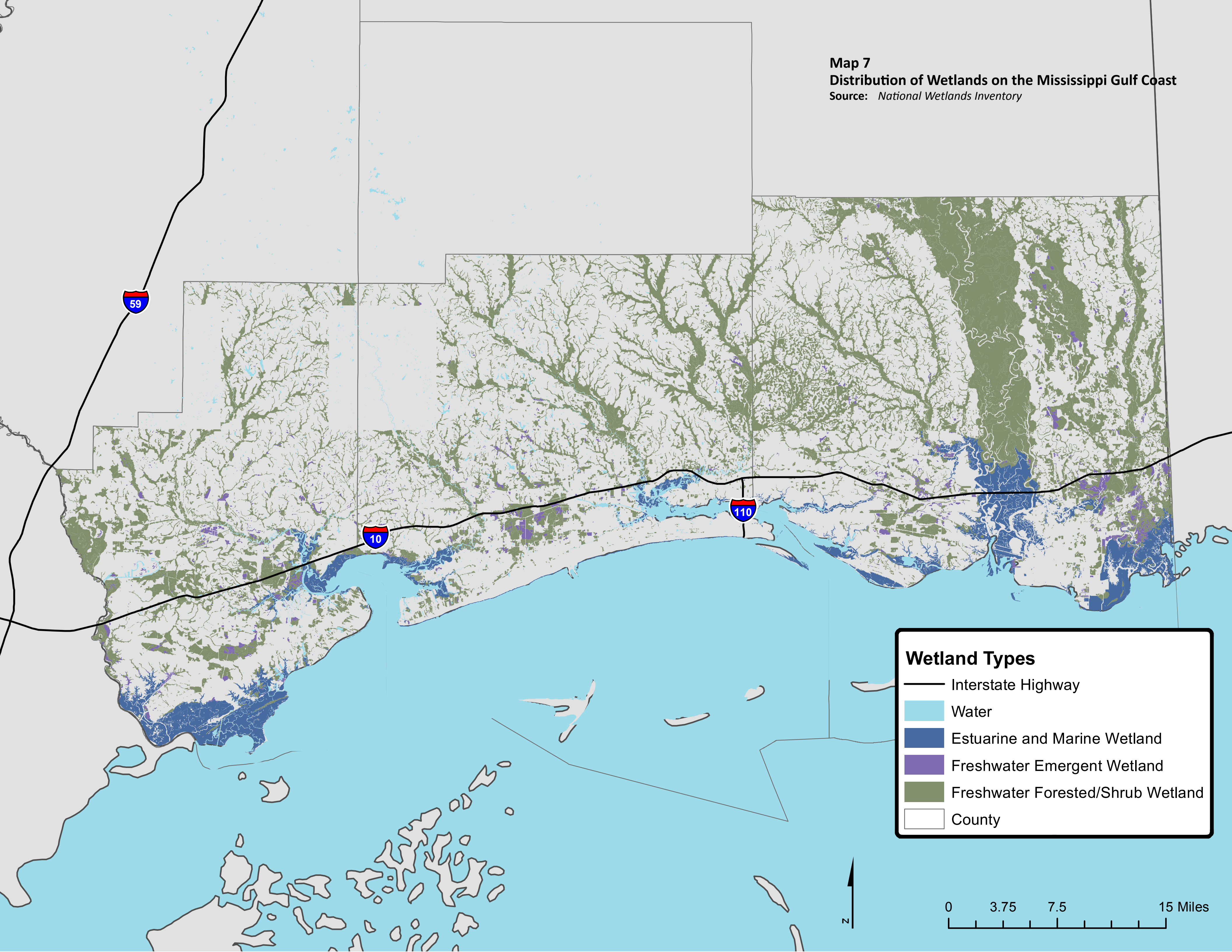
Riverfront Palustrine Floodplain Forests, Herblands, and Sandbars

Palustrine habitats consist of hydrophytic plants that grow and persist despite periodic low oxygen conditions in the soil.[407] Riverfront soils contain a lower amount of organic matter and higher pH levels than soils associated with other bottomland forests. Riverfront forests, which are dominated by black willow, eastern cottonwood, American sycamore, and river birch trees, aid in controlling shoreline erosion and efficiently reduce the amount of sediment flowing into rivers and streams. As the forests begin to age and decline, the aging canopy allows for more growth of shrubs, vines, and herbs, particularly along the shoreline. This habitat is referred to as herblands. Human activity, such as channelization and the use of dams and levees, greatly restricts the extent of this habitat.[408] Because sedimentation degrades aquatic habitats, often harming and killing aquatic organisms and fish, the ability of these forests to reduce sedimentation is very important.[409]

Sandbars are created alongside rivers and creeks during high spring flows, as loose, coarse sediment is deposited in the bends and points of river channels. Sandbars provide vital nesting habitat for several bird and turtle species. As stream flows and water levels change, the sizes of individual sandbars vary.[410]

Bottomland Hardwood Forests

Bottomland hardwood forests are located throughout the southeast United States, in Mississippi these forests are found


Map 7
Distribution of Wetlands on the Mississippi Gulf Coast
Source: National Wetlands Inventory
59
10
110
Wetland Types
Interstate Highway
Water
Estuarine and Marine Wetland
Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
County
N
0
3.75
7.5
15 Miles

along lowland stretches of the Pascagoula and Pearl Rivers.[411] Forest losses are due primarily to the conversion of forested land to agricultural land. Stands occur in river floodplains that experience periodic flooding from either nearby rivers or heavy rainfall. Stands can also occur in bottomland terraces, when they experience irregular or seasonal flooding that lasts several days to months. Forest stands that can be found in lowland sites where the water table is elevated during the winter and spring and soils are moist throughout most of the growing season.

Stands are dominated by various deciduous species of Gum (Nyssa sp.), Oak (Quercus sp.), and Bald Cypress (Taxodium distichum). Individual trees often display identifying features unique to bottomland hardwood forests, such as buttresses, knees, aerial roots, and fluted or flaring trunks.[412] Wet bottomland hardwood forests have been indicated as a critical habitat for bat species.

Bogs

Bogs are located on flats, swales, toe slopes, depressions, and creek terraces. A sublateral seepage flow from nearby uplands is required for mucky bogs to persist.[413] Due to their wet nature and exposure to fire, bogs remain primarily treeless and contain an extraordinarily diverse community of flora, grasses, and sedges. Bogs include one subtype habitat: pitcherplant flat/ bogs. Pitcherplant bogs have experienced a 97 percent loss in habitat along the Gulf Coast, leaving approximately 10,000 acres throughout southern Mississippi.[414]

Spring Seeps

Spring seeps can be found in the coastal counties.[415] Pine seeps are named after the piney woods region that is located throughout the southern half of the state of Mississippi. This subtype is considered imperiled due to the vulnerability of land use changes and small habitat size; an estimated 500 acres remain. Pine seeps may be destroyed when development occurs near the seeps due to changes in subsurface flow patterns that alter or destroy the seep habitat. [416]

Coastal Marshes

Coastal marshes, also referred to as estuarine marshes, are another type of maritime habitat commonly found in coastal Mississippi. They are extremely productive habitats and are classified into four types based on their salinity level: salt marshes, brackish marshes, intermediate marshes, and freshwater marshes.[417] Salt marshes, the dominant type among the four, are situated immediately adjacent to the seashore of the Gulf as well as the bays. As a result, they experience the most extensive tidal fluctuation and serve as an effective buffer against the tide and salinity, which in turn provides great protection for the other types of marshes that are located landwards.[418] Due to high salinity levels, these type of marshes have only a few plant species, such as black needlerush (also called needlegrass rush), smooth cordgrass, and seashore saltgrass.[419] Brackish marshes are usually found in the transitional area between salt and fresh marshes. Since the water is less saline, the dominant plant species are more diverse than they are in salt marshes. Commonly encountered plants include marshhey cordgrass, seashore saltgrass, Olney bulrush, and widgeongrass.[420] Intermediate marshes are located landwards from brackish marshes and, therefore, have lower salinity than brackish marshes do. Plants that are less saline tolerant can be found in this type of marshes, including marshhey cordgrass, common reed, sawgrass, bulltongue arrowhead, and coastal water-hyssop. Also in abundance are such submerged aquatic plant species as pondweeds and southern waternymph.[421] Freshwater marshes support the highest diversity of plant species because they have the lowest amount of salinity among the four marsh types. With the existence of a wide variety of emergent, submerged, and floating-leafed plants, they serve as an ideal habitat for numerous wildlife species. The freshwater marshes are not widely spread over the watershed of interest. Most of the coastal marshes in this region are situated parallel to the shoreline of the Mississippi Sound and can also be encountered in the narrow bands along the edges of bays or bayous. The major patches found are listed in Table 8.[422]

Seagrass Beds

There are approximately 2,000 acres of seagrass beds on the coast. They are found in shallow subtidal habitats in bays, bayous, and rivers along the mainland and in the Mississippi Sound. Sunlight penetrates down to where the plants are attached to the seafloor, allowing their growth.[423] Turtlegrass, shoalgrass, manateegrass, and halophila are the four species commonly found in seagrass beds in this region. These submerged aquatic vegetations provide many ecological benefits. For instance, they prevent nutrients and other pollutants carried by runoff and stream discharge from entering into coastal water bodies. They also serve as nursery habitats for finfish and shellfish and provide food for wintering waterfowl.[424] Seagrass beds are considered to be imperiled by the Mississippi Department of Wildlife, Fisheries, and Parks due to their very limited range of locations and the steep declines in seagrass bed population.[425] However, recently new seagrass beds have begun to appear in areas where they historically have not. This is due to changes in salinity regimes.

Salt Pannes

Salt pannes—water retaining depressions within salt and brackish marshes—form when a mat of organic debris known as wrack is deposited upon existing vegetation, killing it and creating slight depressions that are prone to water retention.[426] Upon successive cycles of inundation and evaporation, the salinity of a panne increases until it is higher than that of the larger body of water, which can lethal levels for most plants in the upper soil horizons. Salt pannes usually support a few short halophytic plants, such as saltwort, glasswort, turtleweed, seepweed, and saltgrass, but where salinity is extremely high they become barren.[427] Approximately 400 acres of salt pannes exist within the coastal estuary. They can be found along the transitions from the intermediate to high marsh zones, especially within the Grand Bay National Estuarine Research Reserve and on the east end of Deer Island. The salt pannes are classified by the Mississippi Department of Wildlife, Fisheries, and Parks as “critically imperiled” because of their extreme rarity.[428]

Oyster Reefs

There are more than 10,000 acres of oyster reefs found along the Mississippi Sound and bays where there is moderate salinity. Most of the beds are located in the western Mississippi Sound. [429] The reefs provide suitable conditions (hard substrate, temperature and nutrients, etc.) for oyster growth and harbor hundreds of other species.[430] The oyster reefs rely on high water quality and are vulnerable to increased water pollution.[431] [432]

Table 8
Major Coastal Marsh Patches in Mississippi Gulf Coast
Source: *Gulf Coast Joint Venture*

Location	Acreage (As of 2002)
End zones of Pearl River and Pascagoula River	**28,000**
Brand Bay/Bangs Lake	**14,000**
Graveline Bayou	**2,330**
Biloxi River	**4,020**
Jourdan River	**6,420**
Wolf River	**2,425**

Barrier Passes

The barrier island passes are natural tidal flow channels between the barrier islands. It is a sandy habitat because muddy sediment is unable to settle from the water column due to the strong tidal currents in the pass areas. There are approximately 500 acres of tidal pass habitat.[433] The tidal current allows for the exchange of water and fauna between estuarine and marine waters. Some of the passes have been dredged to support marine transportation. However, dredging activities may have disrupted the normal westward movement of sand along the southern shores of the islands.[434]

Coral Reefs

Coral reefs are known to increase biodiversity in the ocean through the creation of habitat for reef fish and invertebrates and the formation of barriers along coasts and islands that provide protection from storms.[435] Although elkhorn (Acropora palmata) and staghorn (Acroproa cervicornis) corals were once the most abundant corals in the Gulf of Mexico, they are both now listed as threatened species under the Endangered Species Act.[436] Elkhorn coral is found in water three to 15 feet deep on the seaward face of reefs and staghorn coral is found in water ranging from 15 to 45 feet and typically grow in fore- and back-reef areas.[437] Coral populations are threatened due to habitat degradation caused by land-based pollution, such as coastal dredging, pollution runoff, sewage discharge, increased nutrient levels, increased predation, invasive species, overfishing, and coral bleaching.[438]

Deep sea coral communities can be found in hardground bottoms within the Gulf of Mexico. One of the most well known and ecologically important deep sea corals is scleractinian (Lophelia pertusa), which forms large reefs found at depths greater than approximately 984 feet.[439]

Cold Seeps

Cold seeps are located on rocky or hardbottom grounds of the ocean floor where hydrogen, sulfide, methane, and hydrocarbon fluid seepage occurs.[440] The first community of hydrocarbon seeps and tubeworms living in the north central Gulf of Mexico Continental Slope were discovered in 1984; this was a unique discovery as both species are typically associated with deep ocean basins.[441] Tubeworms (Lamellibrachia luymes) often reach ten feet long, have no mouths or guts, and extract their energetic needs from hydrocarbon seeps.[442] Three species of mussels living in the Gulf of Mexico also live in cold seep areas of the ocean floor.[443] Many of the unique marine species living in the Gulf's continental shelf are supported by geological features that are also of great interest to the oil and gas industry.[444]

Habitat Loss

Loss of coastal wetland habitat has occurred for a number of reasons, including dredging and filling, subsidence, erosion, and sea level rise.[445] By 1972, 12 percent of the intertidal marshes on the Mississippi coast had been drained, filled, or fragmented.[446] Following the State's passage of the Coastal Wetland Protection Act, wetland loss due to developments fell dramatically while coastal erosion became the major contributor of wetland loss.[447] According to the Mississippi Department of Marine Resources (MDMR), the average erosion rate in the Hancock County marshes has been 12.8 feet per year over the past seven decades.[448] Sea level rise is another important driving force of wetland habitat loss. A rise in sea level inundates the coastal vegetated lands, converting them into areas of open water and resulting in a loss of wetland functions.[449] Although new wetlands may be created further towards the inland if the coastal topography is ideal (i.e., in the presence of gradually increasing slope), whether or not they can make up the loss due to sea level rise largely depends on the extent of land development on the newly flooded area, as well as the rate at which the replacing wetland ecosystem functions can be fully established.[450]

Seagrass beds have also experienced severe loss in the past five decades. Approximately 11,676 acres (58.4% of original acreage) were lost as a result of Hurricane Camille in 1969, while an additional 3,458 acres disappeared between 1971 to 1975 because of changes in salinity.[451] In addition to these natural causes, seagrass bed loss is also largely attributed to disturbances, including manmade diversion of freshwater into the Mississippi Sound, urban development, dredging, and boat traffic.[452] Development results in higher sediment loads and contaminants and elevated nutrient levels, which reduce water quality and affect seagrass.[453] Another estimate shows that between 1969 and 1999, more than 13,000 acres of seagrass have been lost from the areas around the barrier islands.[454]

Salt pannes have been lost primarily in Hancock and Harrison Counties, where they are now rare, while they remain stable in Jackson County.[455] Similarly, loss of those aforementioned inland habitats is of concern. Estimates indicate less than five percent of the original acreage of wet pine savannas is present in the Gulf Coastal Plain.[456] The loss is partly due to a lack of prescribed fires. Their absence allow native savannas to be out-competed by invasive pines and shrubs. Another contributor to habitat loss is urban development in the coastal counties.[457]

In some cases, the acreage of a certain type of habitat may not be reduced, but its quality may deteriorate. This is especially true for habitats such as rivers, estuaries, bays, and the Sound. This degradation is discussed further in the section on environmental quality.

Habitat Threats

The Comprehensive Wildlife Conservation Strategy (CWCS) developed by the State of Mississippi includes a list of potential threats to the wildlife habitat of each subtype in Mississippi that are assigned a high, medium, or low rank of identified threats. The potential "high" threats to the aforementioned habitat types are listed in Table 10.[458] Sewage outflows into coastal waters can cause toxic chemical contamination of oysters and mussels.[459] Over exploitation of certain species, such as Sturgeon, is a threat to the coastal habitats.[460] Furthermore, dredging in Biloxi Bay is also a threat to oyster habitats. Prop scarring threatens seagrasses by disrupting the beds. Stagnation of water in the bays, lakes, and tidal streams can cause fish kills and higher pollution levels can result in algae blooms. Land development indirectly impacts many of the coastal habitats by increasing the level of pollutants in stormwater and reducing habitat area.

Protected Habitats

Under the Coastal Preserves Program launched in 1992, the MDMR manages 54,808 acres across the three coastal counties.[461] The program takes advantage of a Wetland Use Plan and establishes guidelines to regulate coastal activities in those designated areas in order to minimize adverse impacts on the natural habitats.[462] The protected areas are mainly coastal marshes associated with bays, bayous, and rivers. MDMR also regulates oyster harvesting by issuing commercial and recreational licenses to harvesters in order to protect natural oyster reefs. MDMR manages 17 natural oyster reefs, many of which lie in the Mississippi Sound.[463] State parks also serve an important role in habitat conservation. There are two state parks in the region: Buccaneer State Park in Waveland and Shepard State Park in Gautier.[464]

There are two federally managed wildlife refuges located along the Mississippi Gulf Coast. The goal of the Mississippi Sandhill Crane National Wildlife Refuge is to protect the endangered sandhill cranes and their unique wet pine savanna habitat.[465] This habitat evolves with fire, making fire management essential to sustaining a healthy habitat for the 110 sandhill cranes residing within the 19,716 acres of the Refuge.[466] The Grand Bay National Wildlife Refuge, founded in 1989, has a total area of 14,060 acres that encompass portions of Jackson County, Mississippi and Mobile County, Alabama. Tidal marshes and pine savannas are the two natural habitats preserved in this refuge.[467] The De Soto Ranger District on De Soto National Forest, which protects approximately 150,000 acres of longleaf pine ecosystem, is also managed by the U.S. Forest Service.[468]

In 1971, the Gulf Islands National Seashore was created under the management of the National Park Service. All five of the Mississippi Barrier Islands, with the exception of a portion of Cat Island, fall under this management. In 1978, 4,080 acres were designated as Gulf Islands Wilderness, the highest level of conservation protection for federal lands.[469] The Davis Bayou Area is the only segment of the National Seashore accessible by automobile; all other access to the islands is by boat.

Collaborative efforts between the state and federal government have been undertaken to reserve a variety of estuarine systems. For instance, the Grand Bay National Research Reserve established in 1999 is managed by MDMR and the National Oceanographic and Atmospheric Administration (NOAA). With 18,400 acres spread across Mississippi and Alabama, the Reserve consists of many different types of habitats, such as coastal swamps, estuarine marshes, wet pine savanna, shallow water bays, oyster reefs, and bogs.[470]

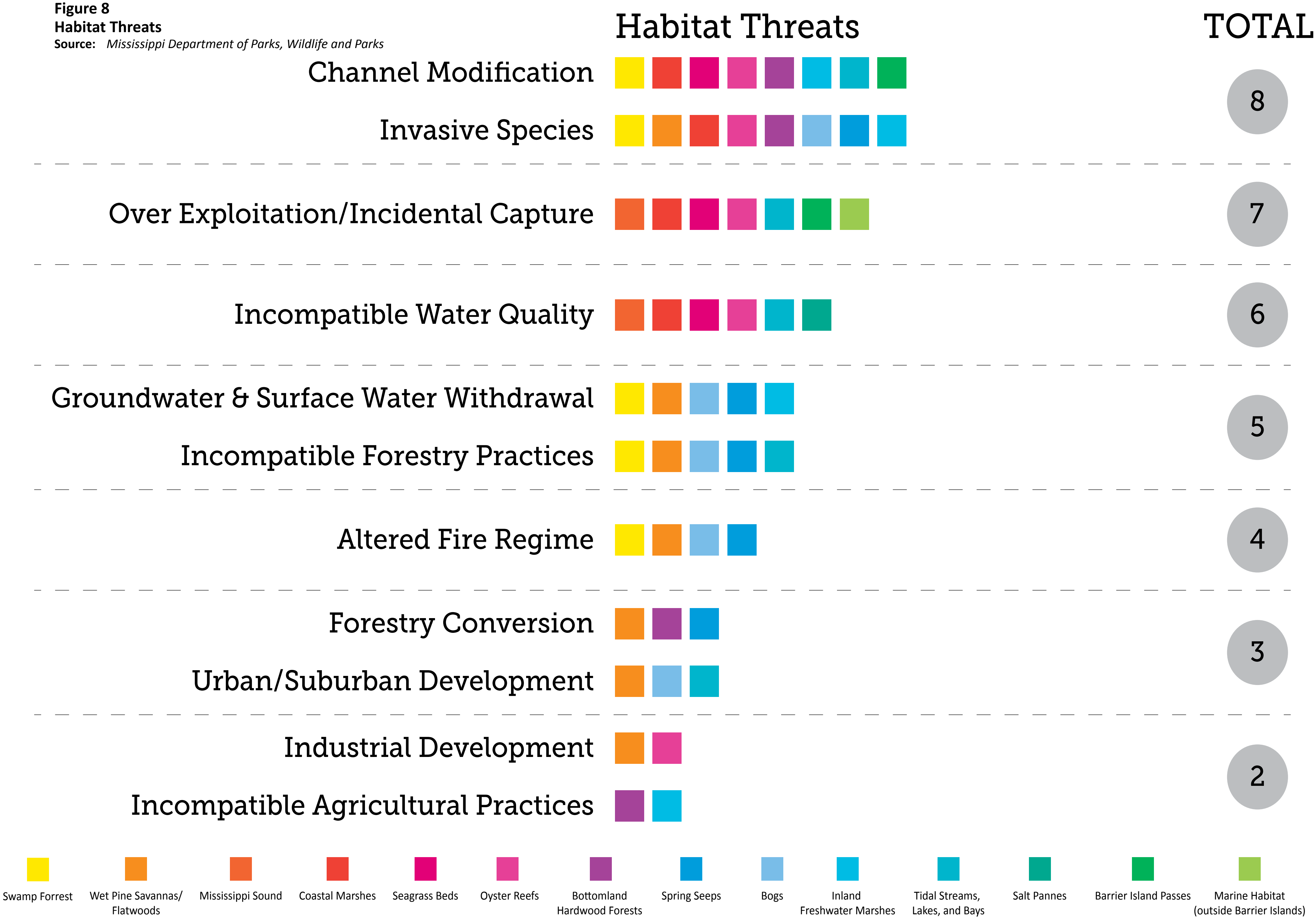
The MDMR manages 20 coastal preserves ranging from bayous, rivers, islands and marshes, including Bayou Lacroix, the Escatawpa River, Round Island, and Spoil Bank.[471] In addition, the Land Trust for the Mississippi Coastal Plain protects more than 30 properties across the coast, totaling more than 1,450 acres across the three coastal counties.[472]

Endangered and Threatened Species

There are a significant number of species that the U.S. Fish and Wildlife Service classifies as endangered or threatened in the three coastal counties, as shown in Appendix B.[473] These listed species are under the protection of the Endangered Species Act. Some of them are listed along with identified critical habitats, referring to areas that have physical and biological features essential to conservation of these species. [474]

NOAA is responsible for protecting the nation's marine mammals and habitat. The MDMR is dedicated to enhancing, protecting, and conserving marine interests of the state my managing all marine life to provide for optimal commercial, recreational, educational and economic uses consistent with environmental concerns and social values. There are 28 species of marine mammals known to utilize the Gulf of Mexico, all of which are listed on the Marine Mammal Protection Act, as well as in Appendix B. Six of the species are also listed as endangered under the Endangered Species Act, including sperm, sei, fin, blue, humpback, and North Atlantic right whales.[475] Of the six

Figure 8
Habitat Threats
Source: *Mississippi Department of Parks, Wildlife and Parks*



whales listed, only one species, the sperm whale, is considered to commonly occur.[476] Three of the 28 protected marine mammals are commonly found in nearshore waters.[477] Nearshore waters are defined by the boundary beginning within estuarine waters and extending to the continental shelf edge (zero to 656 feet).[478] Offshore waters are those areas that extend beyond the shelf edge.[479]

Marine mammals have a large home range. This is due to numerous oceanic features that provide different life-supporting functions. These areas can be utilized seasonally during migration as well as for basic needs, such as shelter, feeding, and reproduction.[480] Oceanic features such as seafloor relief (shelf edges and canyons), water temperatures, ocean currents, and eddies influence the distribution and abundance of marine mammals.[481] Many of these species live or travel through the areas off the coast of Mississippi.

The Mississippi Department of Wildlife, Fisheries, and Parks has identified species of the greatest concern in the coastal habitats. These includes species beyond those identified as endangered or threatened at the federal level, as seen in Appendix B.[482]

The Gulf provides vital habitat for coastal waterfowl, wading birds, and shorebirds. Each year millions of birds migrate across or near the coast of the Gulf.[483] A total of 173 bird species rely on the unique habitats located within the Gulf, such as estuaries, salt marshes, mangroves, intertidal mudflats, beaches and coastal inshore waters, as listed in Table 9.[484] The entire global population of saltmarsh and seaside sparrows are dependent upon the coastal marshes of the United States.[485] Coastal habitats are vital to birds as they migrate between wintering and breeding grounds. For example, migratory birds making the minimum 18-hour flight over the open ocean often utilize barrier islands along the northern Gulf coast as their first opportunity for landfall; these islands provide vital stopover sites.[486]

Invasive Species of Plants and Fish

A major challenge with invasive species is that their populations can increase dramatically due to a lack of predators. As a result, they compete with the native species for limited resources and become a potential threat to both the native species and their

Table 9
Seabirds and Shorebirds Sighted in the Northern Gulf of Mexico, Including Migratory and Year-round Species
Source: *U.S. Geological Service*

Arctic tern Sterna paradisaea	Magnificent frigatebird Fregata magnificens
Audubon's shearwater Pumas lherminieri	Manx shearwater Puffinus puffinus
Band-romped storm-petrel Oceanodroma castro	Masked booby Sula dactylatra
Black tern Chlidonias niger	Northern gannet Mores bassanus
Bridled tern Sterna anaethetus	Parasitic jaeger Stercorarius parasiticus
Brown noddy Anous stolidus	Pomarine jaeger Stercorarius pomarinus
Common tern Sterna hirundo	Red-billed tropicbird Phaethon aethereus
Cory's shearwater Calonectris diomedea	Royal tern Sterna maxima
Greater shearwater Puffinus gravis	Sandwich tern Sterna sandvicensis
Herring gull Larus argentatus	Sooty shearwater Puffinus griseus
Laughing gull Larus atricilla	Sooty tern Sterna fuscata
Leach's storm-petrel Oceanodroma leucorhoa	White-tailed tropicbird Phaethon lepturus
Least tern Sterna antillarum	Wilson's storm-petrel Oceanites oceanicus
Long-tailed jaeger Stercorarius longicaudus	

habitats.[487] Invasive plants and animals commonly found in coastal wetlands are indicated in Appendix B.[488]

Man-made Habitat, Mitigation, and Restoration

Artificial reefs have long been used to mitigate damages to existing natural reefs and restore marine habitat.[489] Additional hard bottom habitats made with artificial reefs can alleviate the stresses placed on existing natural reef habitats. The development of artificial reefs in the Gulf of Mexico is guided by the Mississippi Artificial Reef Plan in order to enhance Mississippi's marine waters and adjacent federal waters.[490] Artificial reef construction first took place during the 1960s off the coast of Mississippi, when automobiles were placed offshore near the barrier islands.[491] In 1972, the National Defense Reserve Fleet, in coordination with Mississippi Marine Conservation Commission and the Mississippi Gulf Fishing Banks, Inc., placed five steel hulls on two permitted sites south of Horn Island.[492] Today there are a total of 15 permitted offshore sites covering approximately 16,000 acres; each site ranges from three to 10,000 acres.[493] Offshore reef sites are identified as those sites south of the barrier islands in the Gulf of Mexico. The reefs are constructed of steel hull vessels, concrete culverts, and "Florida Limestone" artificial reef pyramids.[494]

The MDMR, Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), and the petroleum companies have collaborated on a project commonly referred to as "Rigs to Reef". This project utilizes abandoned oil and gas production structures as habitats for marine species and to enhance commercial and recreational fishing.[495] Typically, platform jackets, ranging in size from two to three acres, provide hardbottom habitat for marine invertebrates and fish, which support both the reef ecosystem and marine organisms.[496]

Inshore artificial reefs are located north of the barrier islands off the coast of southern Mississippi. The reefs are constructed of various materials, including oyster shells, crushed concrete, and limestone.[497] A total of 67 sites are located around fishing piers, which are accessible by shore fisherman, wade fisherman, and small boats.[498] The artificial reefs support a diverse habitat for fish and invertebrate species. According to the MDMR, the inshore reef development has increased the number of high quality fishing sites in Mississippi.[499]

Bulkheads (also referred to as seawalls) are artificial retaining walls used to improve shoreline habitat and decrease beach erosion. However, artificial bulkheads can limit habitat productivity.[500] The MDMR is working to implement an assistance

Table 10
List of Wetland Mitigation Banks

Source: *Environmetnal Law Institute Database*

Name of Bank	Service Area	Bank Sponsor	Umbrella Bank*
Stennis Space Center Mitigation Bank	**Hancock**	**NASA**	**N**
Dead Tiger Mitigation Bank		**Wetlands Solutions**	**N**
Devil's Swamp Mitigation Bank		**Wetlands Solutions**	**N**
Mississippi Wetlands Bank	**Jackson**	**Wetlands Solutions**	**N**
Old Fort Bayou Mitigation Bank		**The Nature Conservancy**	**N**
South Mississippi Mitigation Bank	**Hancock, Harrison, Jack-son, Pearl River, Stone, and George**	**Little Biloxi Wetland Trust, Inc.**	**Y**
Mississippi Band of Choctaw Indians(MBCI) Mitigation Banking Program Agreement	**MBCI Tribal Lands within drainage**	**MBCI**	**Y**
Mississippi Highway Department Mitigation Bank	**State of MS**	**Mississippi State Highway Dept**	**Y**

*Umbrella banks: banks developing multiple compensation sites under a single instrument

plan that will improve the shoreline habitat altered by bulkheads and create an overall increase in productivity of estuarine waters.[501] The MDMR is working with landowners and businesses to convert current bulkheads to natural shoreline habitat fringed with Junus and Spartina grasses.[502]

Wetland mitigation banks are a third-party compensatory mechanism whereby developers are allowed to purchase credits from the "bank" to offset unavoidable development impacts on wetlands. Banks plays an important role in balancing land development with wetland conservation to achieve "no net loss" of wetlands as stipulated by Section 404 of the Clean Water Act.[503] There are eight wetland mitigation banks in the coastal counties, as seen in Table 10.[504] The Old Fort Bayou Mitigation Bank, operated by The Nature Conservancy, was the first wetland mitigation bank in Mississippi. It occupies 1,700 acres in Jackson County and is located six miles landward from the Gulf.[505] The Wetland Solutions, founded in 2001, have completed hundreds of mitigation projects in the six southern Mississippi counties, including government, residential, commercial, and industrial development. Currently, this company is managing more than 10,000 acres of mitigated wetlands, and having 200 credits available for purchase.

Apart from creating manmade habitats to alleviate pressures and performing mitigation to compensate losses, there are a handful of restoration projects focused on re-establishing "naturally occurring, but degraded wetland ecosystems".[506] The Bennett Bayou Tidal Marsh Restoration Project aims to restore the 1.5 acres of marsh wetland that were destroyed largely through the deposit of dredged materials from marina construction, as well as from marina activities. Native plants were re-planted at the restoration site after removal of building construction materials, impervious areas and invasive plants.[507] Similarly, the Bayou Auguste Greenway Restoration Project also targets tidal marsh wetlands in order to restore ecological functions.[508] In addition, there are larger ecological restorations like the Deer Island restoration, the barrier island restoration, the Coastal Preserves restoration; and the Sandhill Crane Refuge is also engaged in long-term ongoing restoration of thousands of acres.

Environmental Quality

Water Quality

Residents of the Mississippi Gulf Coast depend on both freshwater and marine saltwater and brackish water resources to meet their living, economic, and recreational needs. For this reason, it is important that the environmental health and safety of these resources be maintained to meet the needs of the citizens. The Clean Water Act requires that all states develop and adopt water quality standards.[509] Water quality standards must include designated uses, water quality criteria, and an anti-degradation policy. Mississippi classifies its water bodies into five different categories: fish and wildlife, public water supply, recreation, ephemeral, and shellfish harvesting. Waters may hold more than one type of these classifications.

Each class of water body carries its own level of protection. The strictest criteria are on public water supplies and shellfish harvesting. MDEQ ensures these waters comply with the Interstate Shellfish Sanitation Conference shellfish standards, which are published in their Guide for the Control of Molluscan Shellfish. These standards are in place to protect human health and ensure that shellfish does not become contaminated.[510] On the opposite end of the spectrum, areas designated for fish and wildlife have different regulations because they are considered secondary contact to humans.[511] The minimum water standards set out by the MDEQ include a narrative criteria that require water to be free of the following: substances attributed to municipalities, industrial, agricultural uses that form putrescent (sledge); floating debris, oil, scum, unsightly materials, etc.; substances that produce odor, color, taste; suspended solids creating a nuisance or rendering water bad for public health; and toxic substances or wastes.[512]

In an effort to better address the issues facing Mississippi's water resources, the Mississippi Department of Environmental Quality (MDEQ) has divided the state's water bodies into river basin regions. MDEQ monitors the streams and rivers for impairments in each basin region. When water bodies become impaired by a pollutant, a Total Maximum Daily Load (TMDL) Report is created to outline the maximum amount of the pollutant that can be in the water without violating standards.[513] These reports are used as planning tools in implementation of activities to restore water quality. The Gulf Coast, which is located within River Basin IV, includes the Lower Pearl River Basin, the Pascagoula River Basin, and the Coastal Streams River Basin. Two of the most frequent impairments in these basins are mercury and pathogens.[514] Presently there are no impairments due to sedimentation or metals. MDEQ continues to monitor to ensure the designated uses are being met.

MDEQ releases a biannual water quality report in which impaired water bodies in the state of Mississippi are listed by river basin. These river basins are then grouped into four geographical basins. The Gulf Coast Region, which includes the three coastal counties, is included within Basin IV. In the past five years, there have been four impaired water bodies reported in Basin IV. In 2010, a TMDL report was created for Orphan Creek in Hancock County due to sedimentation.[515] In 2007, Bayou Caddy and Bayou La Croix were identified for exceeding toxicity levels and Heron Bayou was identified for nutrient impairment.[516] In 2007, the tributaries of the Bay of St. Louis were studied for nutrient and

Table 11
Water Quality in the Waters of the Mississippi Gulf Coast, 2010
Source: *MDEQ 2010 Biannual Water Quality Report*

Classification	Dissolved Oxygen		Temperature		pH	
Large Estuaries	**Attaining**	**100%**	**Attaining**	**98.2%**	**Attaining**	**100%**
	Not attaining	**0%**	**Not Attaining**	**1.8%**	**Not Attaining**	**0%**
Small Estuaries	**Attaining**	**97.2%**	**Attaining**	**94.4%**	**Attaining**	**100%**
	Not Attaining	**2.8%**	**Not Attaining**	**5.6%**	**Not Attaining**	**0%**
All Mississippi Coastal Waters	**Attaining**	**99.3%**	**Attaining**	**97.3%**	**Attaining**	**100%**
	Not Attaining	**0.7%**	**Not Attaining**	**2.7%**	**Not Attaining**	**0%**

enriched organic levels and low dissolved oxygen, but report results showed the water to be within the acceptable levels for dissolved oxygen.[517] While pathogens, specifically fecal coliform and enterococci, are important to monitor in the coastal region, the last impaired water body was the Back Bay of Biloxi in 2002.[518] Several factors, such as urban development, septic tank failure, and illegal dumping, may have caused higher than acceptable counts of bacteria in the water.[519]

MDEQ standards state that water must have a dissolved oxygen average level of five mg/l daily and a four mg/l instantaneous reading; pH level must be within the range of six to nine mg/l; and water temperatures must not exceed five degrees Fahrenheit above normal stream temperatures while also never exceeding 90 degrees Fahrenheit.[520] The 2010 report, as shown in Table 11, illustrates that most Mississippi coastal waters are in attainment for. Some small estuaries have low dissolved oxygen primarily attributable to high water temperatures, mixing of saline and fresh water, and interactions with salt marshes. Localized dissolved oxygen problems due to anthropogenic pollution sources can and do occur, though.[521]

Aquifers

Section 106(e) of the Clean Water Act requires that each state monitor the quality of its surface and groundwater resources and report the status to Congress every two years in its State 305(b) Report. As mentioned earlier in this document, groundwater resources provide approximately 90% of the water in public water systems. The most notable issue facing Mississippi groundwater is natural coloration of certain aquifers.[522] Most of the documented cases of groundwater contamination in Mississippi have involved shallow unconfined aquifers that remain widely used in some areas of the state as domestic drinking water sources.[523] According to the report submitted on April 2011, water quality testing data indicates that all public water systems are compliant for volatile organic chemical, synthetic organic chemical and nitrate (NO3) concentrations.[524]

The report includes two aquifer systems in the Mississippi Gulf Coast, the Great Gulf Aquifer System, referred in the report as Miocene Aquifer, and the Citronelle (Terrace Deposits) Aquifer. The Miocene Aquifer has a range of dissolved solids above the recommended 1,000 mg/l in a few wells in Jackson County, but this is in a very limited area.[525] Other parameters, such as pH, special conductance, iron range, nitrate range, and color are also within acceptable ranges. The Citronelle Aquifer or Terrace Deposits may be high in iron and manganese in some areas and possibly have high total dissolved solids near the coast.

The United States Geological Survey (USGS) is involved in a project within Harrison County that includes monitoring groundwater changes in the region and analyzing water samples collected from twenty five wells.[526] As part of the project, the USGS also measures other factors, such as temperature, pH, specific conductance, color, and concentrations of chloride and manganese.[527] The Office of Land and Water Resources continues to monitor static water levels and water quality annually across all of the coastal area.

Toxicity

As the many rivers in Mississippi drain into the Gulf of Mexico, it is important to monitor the runoff. Sediment runoff can be classified in five categories: nutrients, bulk organics, halogenated hydrocarbons or persistent organics, polycyclic aromatic hydrocarbons, and metals.[528] When these materials flow into the Mississippi Sound, they can become toxic and harm the benthic environment. Toxicity standards are designated by the U.S. EPA and can be found in section 304 (a) of the federal Clean Water Act.[529] Major fish toxicant issues are currently under investigation by MDEQ, which maintains a comprehensive fish tissue monitoring program to ensure that toxicity levels are not harmful to humans or fish.[530]

Two of the biggest impairments facing the Gulf coast are dichlorodiphenyltrichloroethane (DDT), a halogenated hydrocarbon used as a pesticide, and nutrients. While monitoring pesticides and polychlorinated biphenyl (PCB) is important in the Mississippi Gulf Coast, it does not require an advisory cause at this time.

Mississippi currently has three water bodies in the Gulf Coast under fish consumption advisories. They are the Escatawpa and Pascagoula Rivers and the Gulf of Mexico, which are all under mercury advisory. High levels of mercury can cause irreversible damage to the developing nervous systems of fetuses and young children.[531] Therefore, it is important to protect coastal waters from high levels of mercury in order to preserve the quality of shellfish, shrimp, and fish that will be consumed by humans. The fish included in the advisories are large predators, such as largemouth bass and large catfish in freshwater bodies and king mackerel in coastal waters.[532]

The availability and distribution of chemical elements in acceptable proportions and combinations plays a vital role in the quality of ecosystems and survival of life forms. Elements known as heavy metals can be toxic and may present a risk to humans, animals, or plants. Systematic determination of the levels and spatial distribution of these elements across a landscape is necessary in order to identify potential risks and make decisions about potential land uses. Heavy metals occur naturally in the environment but rarely in toxic concentrations. Contamination levels can result from some industries, the use of manmade products such as batteries, paints, fertilizers, and pesticides, and the improper management of wastes. Excess heavy metal accumulation in sediment, soil, and water can create a route of exposure for humans, animals, and plants. Harmful heavy metal exposure to humans is typically chronic and associated with transport up the food chain. Ingestion of or dermal contact with heavy metals is rare but can cause acute poisoning.[533]

The MDEQ Office of Geology conducted a statewide geochemical survey of the distribution of the following heavy metals: arsenic, copper, mercury, lead, selenium, and zinc. Analyses were conducted in stream sediments and soil samples. According to the survey, the distribution of the heavy metals in the watersheds that include the coastal counties has remained within geological background content, which would suggest that anthropogenic activities are not greatly impacting heavy metal concentrations. The distribution of these metals in the coastal region is among the lowest in the state.[534]

Oil

Throughout the history of off shore drilling in the Mississippi Gulf, there have been few incidents within Mississippi's aquatic border. On September 18, 1989, a man who was dredging Bayou Cassotte about 2.5 nautical miles east-southeast of Pascagoula, Mississippi punctured a 90-mile-long, 20-inch Chevron Oil pipeline that was reportedly buried 20 feet beneath the bottom of the ship channel. The pipeline contained 5,000 barrels of Basrah Light crude, which began to leak into the water.[535] The other significant oil spill was the Deepwater Horizon oil spill of 2010. The explosion that led to the spill released between 492,000 and 627,000 tons of oil, becoming the worst oil spill in U.S. history and causing oil to enter both the Gulf of Mexico and the Mississippi Sound.[536] Although there has not been any solid conclusion on the long-term impact of this unprecedented release of petroleum hydrocarbon on the health of both marine ecosystems and humans, one study has already shown evidence of oil carbon entering the planktonic food web and moving across the trophic levels.[537]

Algal Blooms

Harmful algal blooms, groups of algae that feed off sediments and nutrients, are cause for concern in the Mississippi Sound. They can appear with increases of phosphates, nitrates, or other sediments. Algal blooms are dangerous for two reasons. First, they drain oxygen from the water, leaving dead zones where fish and other marine animals cannot survive. Second, algal blooms can create toxins or neurotoxins that can be deadly if consumed by fish and/or humans. Algal blooms can have between 500,000 ->1,000,000 cells/l.[538]

In 1996, *Karenia brevis (K. brevis)* was found throughout the Mississippi Sound and in the waters to the south of the Barrier Islands.[539] During Hurricane Katrina, K. brevis was noted to have been pushed from its more southerly location in the middle to south area of Florida northward into the Mississippi, Alabama, and the Florida panhandle region. In October 2005, two different water samples collected from the Mississippi Sound by MDMR had high counts of K. brevis.[540] Reports suggested a potential link to a prolonged K. brevis HAB event following Hurricane Katrina and corresponded to reports of bloom events occurring on the Florida panhandle and in the Mobile Bay.

Ambient Noise

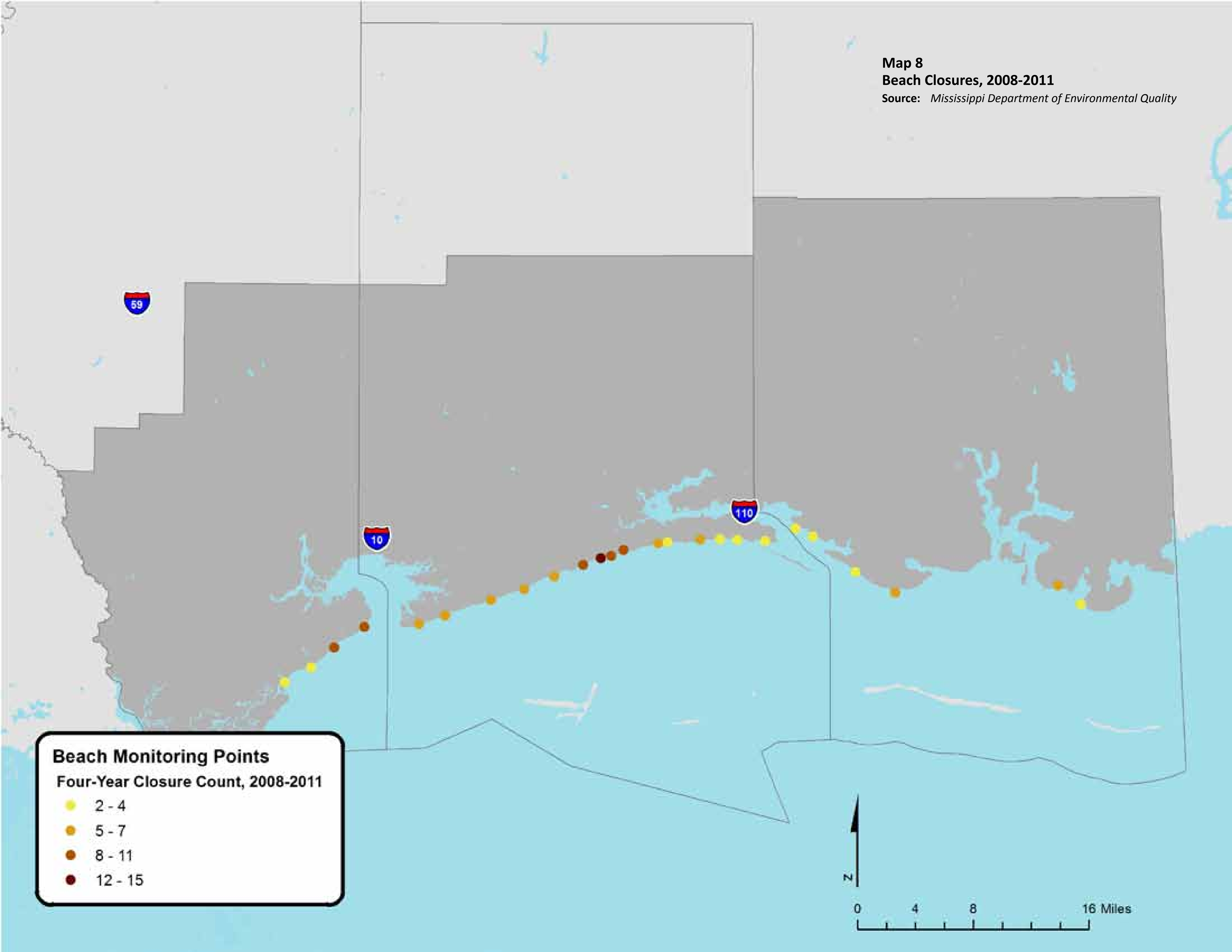
Ambient noise can be disruptive to marine animals, especially mammals such as the bottlenose dolphin. A study was conducted measuring noise in eight locations in the Mississippi Sound to get a range of noise levels. The sites were spread along the Mississippi Coast, including areas along the beaches, casinos, bridges, barrier islands, Blanes (an intersection of three shipping lanes about six miles off the coast of Biloxi) and Glanes (a two-lane-wide shipping passageway.[541]

The sites near the bridges, casinos, and near ports had the highest levels of ambient noise.[542] The bridge site experienced more or less constant noise from overhead automotive traffic. The harbor site experienced daily noise highs as ships left and returned to port. The constant action at the casino also proved to bring a consistent level of ambient noise to the waters nearby. The beaches, while they are open to the public, proved less noisy. The occasional jet ski would generate noise, but it remained lower than that of other measuring locations.[543] The causes of noise increases include the presence of shrimp boats, shipping boats, and automobiles.

Beach Closures

MDEQ administers the Mississippi Beach Monitoring Program, which maintains water sampling stations along Mississippi's 22 public access beaches stretching over 40 miles.[544] These sampling stations check the levels of Enterococcus bacteria, which is an indicator bacteria for other disease-causing microorganisms.[545] If the water near public access sands becomes hazardous to human health, MDEQ can issue either a beach advisory or a closure, based on the severity of pollution.[546] Advisories are generally issued when bacteria levels become higher, typically due to natural events such as heavy rains and high winds, which result in increased stormwater runoff.[547] Map 8 illustrates the location of beach closures and advisories.

Map 8
Beach Closures, 2008-2011
Source: *Mississippi Department of Environmental Quality*



Coastal Vulnerability

The term "coastal vulnerability" generally describes conditions that can lead to changes that will impact a coastal environment. The Coastal Zone Management Subgroup of the Intergovernmental Panel on Climate Change defines it as the "... ability to cope with the consequences of an acceleration of sea level rise and other coastal impacts of global climate change".[548] While the vulnerability of coastal areas begins with physical effects, it extends to the impacts posed by these effects on socio-economic and ecological systems.[549] It can be stated in an even broader sense as characteristics of a coastal community and environment in terms of its vulnerability to risk.[550] A full assessment of coastal vulnerability, therefore, necessitates an examination of a wide range of factors.

Sea Level Rise

The rise and fall of the sea over time has been a major factor in the shaping of coastlines. There is increasing concern about accelerated sea level rise associated with climate change and ice melt in the polar regions. There are varied estimates as to exactly how this will impact the future of sea level rise, but even according to the most conservative predictions, substantial flooding of coastal areas appears to be likely.[551] At the present time, there is a limited amount of local and regional sea level rise data for the Mississippi Gulf Coast.[552] NOAA operates tide gauging stations throughout the northern Gulf of Mexico, from which data can be used as one indicator of future sea level rise. However, Mississippi's gauges lack the historical data found at other stations, such as Pensacola, Florida and Dauphin Island, Alabama.[553] The linear trend for the Mississippi Tide stations is statistically consistent with the trend shown by these other stations operating in geomorphically similar circumstances. Based on this data, Mississippi expected a minimum sea level rise of approximately 10 inches by the year 2100. However, gaps in the data available and a lack of long term historical trends may affect the accuracy of this prediction.[554]

A commonly used measure for evaluating the vulnerability of coastal areas to sea level rise is the United States Geological Survey (USGS) Coastal Vulnerability Index (CVI).[555] The vulnerability classification is based upon the relative contributions and interactions of the following variables. Tidal range and wave height contribute to inundation hazards. Coastal slope (steepness or flatness of the coastal region) is related to the exposure of a coast to flooding and how rapidly shorelines retreat. Shoreline erosion rates are an indicator of how a specific area of the shoreline has been eroding. Geomorphology demonstrates the relative erodibility of a given section of shoreline. Historical rates of relative sea-level rise correspond to how the global (eustatic) sea-level rise and local tectonic processes (land motion, such as uplift or subsidence) have affected sections of shoreline.[556] The CVI depicts Mississippi as having 100 percent of its shoreline in the high or very high vulnerability categories, with 83 percent in the very high vulnerability category.[557] According to one study, sea level rise could range from 0.8 feet at Pensacola, Florida to 5.5 feet in Grand Isle, Louisiana by 2050 and be 2.3 feet to 6.5 feet, respectively, by 2100.[558] The USGS and NOAA have created models illustrating the potential flooding if there were a three or six foot sea level rises. Sea level rise is expected to increase barrier island overwash during storms.[559] It also has the potential to reduce the barrier islands to a sandy shoal by 2100.[560] If wetlands are able to migrate inland as sea level rises, the yield of shrimp and other estuarine-dependent fisheries could increase or decrease, depending on the size and quality of the new habitat.[561]

Rising sea levels pose numerous potential hazards for the coastal region, including inundation of wetlands and other low-lying lands, beach erosion, intensified flooding, and increased salinity of rivers, bays, and groundwater tables.[562]

Vulnerability to Coastal Hazards

Coastal communities are vulnerable to a number of hazards, including storms, high winds, inland flooding, tornados, and pollutant spill hazards.[563] The top three hazards identified by the 2010 State of Mississippi Standard Mitigation Plan for the entire state are all coastally related: hurricanes, tornados, and flooding.[564] The majority of the population of the Mississippi coastal counties is south of Interstate 10 in areas likely to be affected by potential sea level rise and the related impacts of storm surge and increased flooding.[565] Table 12 shows the 50-year landfall probability of hurricanes in the coastal region. The region is also susceptible to tornados, with Harrison County ranked as high risk, Hancock County ranked as medium risk, and Jackson County ranked as medium-high risk.[566] These coastal hazards could pose an enormous economic threat to the region. Table 13 shows the losses in dollar amounts and percentages of lost buildings based on estimated damage caused by a 100-year flood. [567]

While the number or paths of tropical storms and hurricanes is unlikely to change in the future, the intensity of the storms is expected to increase.[568] Storm surge simulations predict worst-case storm surge conditions that could exceed 20 to 30 feet along the central Gulf Coast. [569] When combined with a sea level rise of three to six feet, this could effectively raise the height of storm surge to 33 feet by 2100.[570]

Flooding

In 2006, Mississippi had the fifth largest land area in riverine and coastal floodplains in the United States, with more than 5.2 million acres, or 15 percent, of the State's total area.[571] The coastal counties are at risk from flooding that results from the rivers in the region as well as flooding that results from storm surge.

The 100-year floodplain is defined as "the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year."[572] A large number of the residents of the Gulf Coast counties are located within the 100-year floodplain: 55 percent of the population (or 23,681 residents) of Hancock County, 33 percent (or 62,704 residents) of Harrison County, and 45 percent (or 59,312 residents) of Jackson County.[573] Also within the 100-year flood zone is vital infrastructure, such as 44 percent of the road miles in Hancock County, 22 percent of the road miles in Harrison County, and 24 percent of the road miles in Jackson County.[574] Critical facilities located within FEMA-designated flood zones include 45 schools, four police stations, eight fire stations, one emergency center, and two communications facilities.[575] Beyond the 100-year flood plain, property is still at risk in the 250-year and 500-year flood plains. Properties within the 500-year flood plain are considered at moderate risk.[576]

Floods have been the most economically destructive natural disaster for the citizens of Mississippi, resulting in over $2.8 billion in flood insurance claims between 1978 to 2010.[577] Between 1998 and 2007, Mississippi experienced seven flood-related, federally declared disasters, including Hurricane Katrina in 2005, which is the largest flooding disaster in U.S. history. Three years prior, Tropical Storm Isidore caused more than $16.5 million in insured flood damages in the state.[578] The coastal counties have an average of 40 or more Severe Repetitive Loss Properties (SRL), as defined by FEMA.[579] An SRL Property is defined as a residential property covered under a National Flood Insurance Program (NFIP) flood insurance policy that has at least four NFIP claim payments (including building and contents) over $5,000 each, with the cumulative amount of such claims payments exceeds $20,000 or that has at least two separate claims payments (building payments only) that have been made with the cumulative amount of the building portion of such claims exceeding the market value of the building. In both situations, at least two of the referenced claims must have occurred within any ten-year period, and they must be more than 10 days apart.[580]

Communities that participate in NFIP reduce their exposure to flood risk in several ways. Lower flood insurance rates are available

Table 12
50-Year Hurricane Landfall Probability
Source: *The United States Landfalling Hurricane Web Project at William Graey's Tropical Meteorology Research Project at Colorado State University and the GeoGraphics Laboratory at Bridgewater State College*

County	Hancock	Harrison	Jackson
Probability of 1 or More Named Storms Making Landfall	**82.7%**	**90.3%**	**92.5%**
Probability of 1 or More Named Hurricanes Making Landfall	**57.3%**	**67.6%**	**71.4%**
Probability of 1 or More Intense Hurricanes Making Landfall	**31.8%**	**39.7%**	**42.9%**
Probability of Tropical Storm Force (>=40mph) Wind Gusts	**>99.9%**	**>99.9%**	**>99.9%**
Probability of Hurricane Force (>=75mph Wind Gusts)	**99.6%**	**99.6%**	**99.6%**
Probability of Intense Hurricane Force (>=115mph) Wind Gusts	**82.3%**	**82.3%**	**82.3%**

Table 13
100-Year Flood Loss Estimation
Source: *Mississippi Emergency Management Agency*

County	Total Building Loss	Total Income Loss	Total Building & Income Loss	Building Loss Ratio
Harrison	**$1,703,818,000**	**$11,921,000**	**$1,715,739,000**	**17.3%**
Jackson	**$1,397,087,000**	**$9,504,000**	**$1,406,591,000**	**17.3%**
Hancock	**$989,489,000**	**$5,247,000**	**$994,736,000**	**32.5%**

to communities evaluated by the Community Rating System under the NFIP. A point system evaluates a community on a 1-10 scale, with 10 being not evaluated at all to 1, having all credits applied. There are 18 activities categorized by Public Information, Mapping and Regulation, Flood Damage Reduction, and Flood Preparedness that equate to credits which reduce a communities rating.[581] Property owners who purchase flood insurance are able to financially protect their existing structures. In addition, through the local Floodplain Development Permit Process, property owners in the 100-year floodplain are guided to build new structures in a safer way through sharing of regulatory flood heights and proper construction methods for flood-prone areas. Also, risk information that can assist property owners to make informed development choices in the high risk areas is shared. This permit process is informed by the FEMA-provided Flood Insurance Rate Maps (see Map 9), which give guidance about flood risk.[582] Another way that risk is reduced through this process is when structures that were previously grandfathered have met the locally adopted damage or improvement threshold (minimally 50% of the pre-damage/ improvement market value), which means that these structures must also be brought into compliance with locally adopted flood safety standards through the Floodplain Development Permit Process. Many times this approval necessitates the use of flood resistant methods, materials, anchoring, and utilities, along with elevation of the lowest floor to or above the base flood elevation. It is also common to see areas in the floodplain converted into common or public open space so as to protect homes and businesses from flooding; some examples of uses for these open spaces include recreational areas, playgrounds, reforestation, parking, gardens, pasture, accessory structures, and man-made wetlands.[583]

In addition to these measures, the U.S. Army Corps of Engineers is responsible for the Mississippi Coastal Improvement program, which aims in part to reduce flood rise. The High Hazard Area Risk Reduction Program (HARP) aims to purchase over 2,000 tracts of land in high risk areas to be used for non-development purposes. The HARP will save approximately $22-33 million in annual flood damages at an estimated cost of $407 million.[584] There are more specific projects currently underway for Waveland, Turkey Creek and the Forest Heights Levee, with 13 additional projects

Table 14
High Risk Populations Living Within FEMA Floodplains in Mississippi Coastal Counties
Source: *NOAA, Coastal County Snapshots, based on 2000 US Census Records*

	Total Population		Over 65		In Poverty	
Hancock County	**42,967**		**6,010**		**6,137**	
Inside FEMA floodplain	**23,681**	**55%**	**3,384**	**56%**	**3,371**	**55%**
Outside FEMA Floodplain	**19,286**	**45%**	**2,626**	**44%**	**2,766**	**45%**
Harrison County	**189,601**		**21,022**		**26,597**	
Inside FEMA floodplain	**62,704**	**33%**	**7,617**	**36%**	**9,261**	**35%**
Outside FEMA Floodplain	**126,897**	**67%**	**13,405**	**64%**	**17,336**	**65%**
Jackson County	**131,420**		**13,588**		**16,504**	
Inside FEMA floodplain	**59,312**	**45%**	**6,703**	**49%**	**7,741**	**47%**
Outside FEMA Floodplain	**72,108**	**55%**	**6,885**	**51%**	**8,763**	**53%**
Total for all 3 counties	**363,988**		**40,620**		**49,238**	
Inside FEMA floodplain	**145,697**	**40%**	**17,704**	**44%**	**20,373**	**41%**
Outside FEMA Floodplain	**218,291**	**60%**	**22,916**	**56%**	**28,865**	**59%**

Table 15
Total Potential Damage to State-Owned or Operated Buildings, Critical Facilities, and Infrastructure
Source: *Mississippi Environmental Protection Agency, The State of Mississippi Standard Mitigation Plan*

County	Government Buildings	Transportation Lifeline Systems	Lifeline Utility Systems	Essential Facilities
Hancock	**14**	**103**	**4**	**34**
Harrison	**34**	**320**	**21**	**129**
Jackson	**48**	**487**	**42**	**113**

aimed at reducing the risk of flooding.[585] Storm Smart Coast is a collaboration between agencies working with local governments in the region on flood risk reduction through siting and elevation of structures.[586]

Social Vulnerability

A full assessment of vulnerability requires identifying the portions of the population most at risk to the effects of coastal hazards.[587] Social vulnerability describes the degree to which people, property, resources, systems, and cultural, economic, environmental, and social activities are susceptible to harm, degradation, or destruction by being exposed to a hostile agent or factor—in this case, sea level rise.[588] Elderly residents who have limited mobility may require additional time and assistance during an evacuation. Those living in poverty are frequently at greater risk because they have the least amount of resources to prepare for or deal with a disaster event.[589] These residents often have additional difficulties evacuating before and after major storms hit.[590] Social vulnerability can turn a coastal storm into a disaster.[591] Table 14 shows the numbers and percentages of high risk populations in the Mississippi Coastal Counties. There are more than 38,000 high risk persons living within FEMA floodplains in the region. Map 10 provides a graphic representation of where high risk population blocks are located within the coastal region.

Effects on Critical Infrastructure and Facilities

Critical infrastructure and facilities may also suffer serious damage as a result of coastal hazards, further increasing the threat to those most in need during such events. Critical Infrastructure is defined by the Mississippi Emergency Management Agency (MEMA) “as systems so vital to the State of Mississippi that the incapacity of those systems would have a debilitating impact on security, economics, public health, safety, or any combination of those factors, including any infrastructure designated by local governments in their Hazard Mitigation Plan”.[592] Table 15 provides an estimate of the number of critical facilities that would be damaged or destroyed in the event of a category five hurricane.

Vulnerability of Fresh Water Supply

Increasing population and development place rising demands on existing water resources, and the effects of a changing climate

Map 9
Mississippi Coastal Counties 100-year and 500-year Floodplain
Source: *Mississippi Automated Resource Information System. DFIRM-FEMA Flood Hazard Zones*

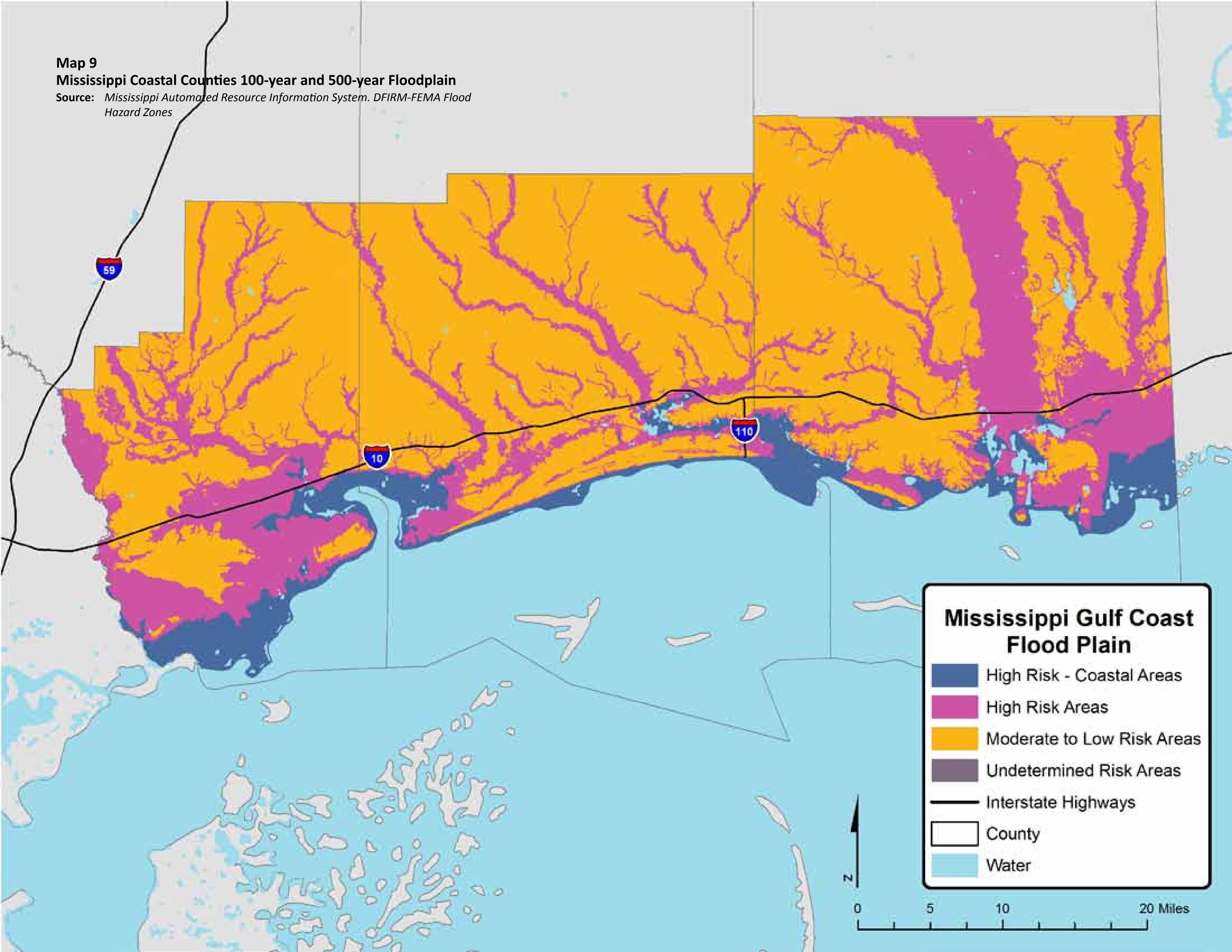


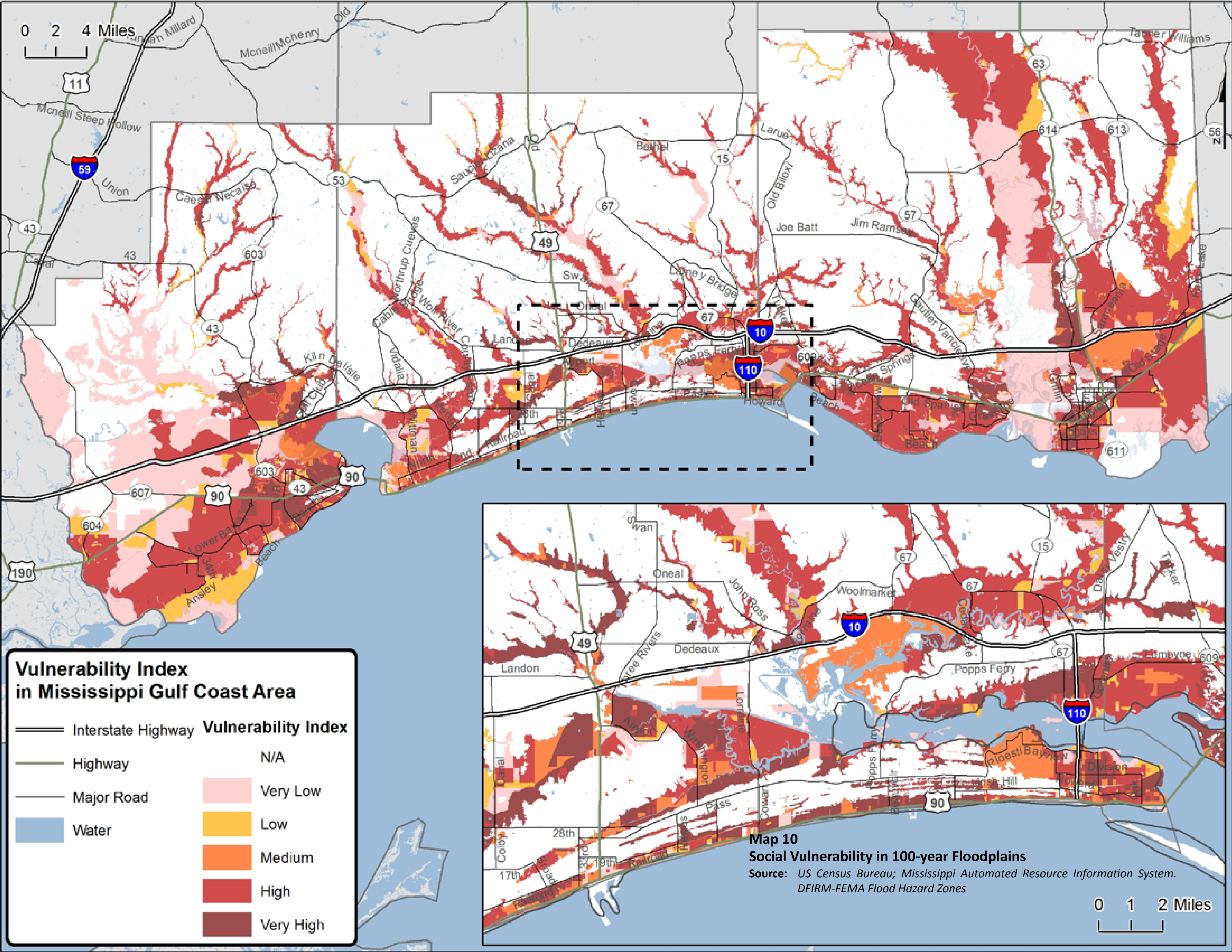
Table 16
Water Sustainability Index for 2050 Factoring Climate Change
Source: *Natural Resources Defense Council*

COUNTY NAME	Extent of development of Available Renewable Water (>25%)	Groundwater Use Index (>25%)	Susceptibility to drought (summer deficit <-10 inches)	Increase in summer water deficit (deficit increase > 1 inch)	Growth in Water Demand (> 10%)	Total Index
Hancock	0	1	0	1	0	2
Harrison	0	1	0	1	0	2
Jackson	0	1	0	1	1	3

may make matters worse. Concerns about the sustainability of water resources in decades to come is common in many parts of the world.[593] An analysis published in 2010 by the consulting firm Tetra Tech for the Natural Resources Defense Council looked at the effect of global warming on water supply and demand in the contiguous United States.[594] It ranked counties based on whether they met established criteria within an index of five key indicators to determine susceptibility to possible future water shortages. The indicators are: projected water demand as a share of available precipitation, groundwater use as a share of projected available precipitation, susceptibility to drought, projected increase in freshwater withdrawals, and projected increase in summer water deficit.[595] Based on the results of this study, Hancock and Harrison Counties are considered to be at moderate risk, having met the criteria for two of the five indicators. Jackson County met the criteria for three and is considered to be at high risk.[596] One study argues that saline water has started intruding into freshwater aquifers in the region due to declining groundwater levels along the coast and the injection of saline waste water from oil-field production zones.[597] Jackson County is at high risk for losses in agricultural production, while Harrison and Hancock counties have moderate risk of loss.[598] This could result in changes in crop yield, prevalence of crop diseases, and insect pests.[599]

Moisture deficits and drought are likely to increase across the Mississippi Gulf Coast.[600] This is partially a result of a projected increase in the number of dry days, or time between rainfall events. It is also possible that average soil moisture and runoff could decline. Under drier conditions along the Mississippi coast, and without increased irrigation, there could be a decrease in agricultural production.[601] Even with extended drought water is expected to continue to remain available. Should the shallow aquifers water supplies become low, the confined aquifers would continue to provide a source of water through a water treatment process.

Heavy rainfall events have been increasing, which contributes to increases in runoff.[602] Runoff has increased an estimated 36 percent since 1919. In the future, runoff is expected to remain relatively unchanged or decline slightly. This is dependent on the balance of precipitation and evaporation. However, extreme rainfall events and the corresponding extreme runoff can result in pollution of coastal waters.[603]



Map 10
Social Vulnerability in 100-year Floodplains
Source: *US Census Bureau; Mississippi Automated Resource Information System. DFIRM-FEMA Flood Hazard Zones*

Indicators

Local governments, business owners, farmers, residents, schools, and many other entities are making significant changes in the governance of water. There have been changes to policy, products, and services on the Mississippi Gulf Coast in an effort to create healthy watersheds for the region. How does a region measure the success of these changes over time? Having tools by which to measure baseline conditions and the success of a region's water sources are critical to its continued implementation and revision as a community works toward goals to improve the health of its residents and the environment. For example, the region should be interested in discovering if water quality is improving, if there is an increase in public access points to water, and if residents are able to take advantage of a healthier, more equitable recreation system.

Efforts have been made to create indicators that effectively evaluate the health of watersheds. A study of indicator assessments was undertaken by the Wallace Center with funding from the W.K. Kellogg Foundation.[604] This study combined with others[605] leads to clear guidelines for what should define an indicator.

- Based on goals: The indicator measures progress towards the given goal or goals.
- Opportunities-based: The indicator measures progress towards the goals (positive) rather than regression away from the goals (negative).
- Measurable at a regional level or smaller: The indicator data must be available at the MSA or smaller level, rather than for the U.S. or Mississippi, and must be quantifiable.
- Available: The data must be available to the public.
- Relevant: The most important trends and impacts related to these attributes must be addressed.
- Stable, reliable, credible: The data must be from a reliable and credible source, collected in a rigorous and consistent way and replicable from one time period to the next.
- Cost-effective: The data must be accessible with little monetary input.
- Understandable and usable: The indicator must be easily grasped by potential interpreters of the data so that they can apply it in their own communities.
- Sensitive to change: The indicator must respond to change over a reasonable length of time, not take hundreds of years to show progress.
- Support decision making: The indicator must promote learning and effective feedback to decision making.

While there are a multitude of indicators that could be considered, those selected should most directly measure the health of a region's water sources and be sensitive to changes in how the region makes decisions about land use, policy, zoning, and infrastructure. As goals are set by residents and stakeholders, the indicators can be selected to measure progress toward each goal depending on the availability and scale of accurate data.

Additionally, the most desirable indicators are those that "are transparent, based on publicly accessible data and open to interpretation by the stakeholders."[606] The Wallace Center collected data from established sources at the national level for its study, but an effort was made to select indicators that can be adapted to state, regional, and local levels.

The following is a summary of key potential indicators and the data available. These indicators are organized around the concept of water security. Water security can be defined as "sustainable access on a watershed basis to adequate quantities of water, of acceptable quality, to ensure human and ecosystem health."[607] Water insecurity indicates limited or uncertain access to adequate supplies of clean water or limited ability to acquire water for consumption. Water security is "a holistic approach that accounts for multiple stressors to the water supply" with five key components, including governance, resources, ecosystem health, human health, and infrastructure.[608]

Governance

Governance indicators are based upon governing water wisely, protecting the rights of the public, increasing financial capacity of governments, education and sensitivity to transboundaries, and the recognition that water is a shared resource between states and jurisdictions. A review of a number of studies identified the following possible indicators that could be used to measure governance capacity.

Cooperation between governments and water-related utilities/services: Increased cooperation between governmental entities and water-related utilities and services through working together on items such as grant applications for various water quality initiatives (such as infrastructure improvements) could be a positive indicator of progress.[609] Success could be tracked by evaluating how many jointly filed grant applications are successful and how much money is granted to various entities over time.

Coordination of data collection: One of the most difficult things to do when it comes to water quality is establishing a broad-reaching yet deep source of data. By greater coordination of data collection efforts, redundancies can be prevented and efficiency of data collection can be greatly improved. Positive progress on this indicator could be measured by determining if there have been more joint grant applications for the purpose of collecting data, a greater number of data collection points, and shared clearinghouse data resources between departments.

Access to data after collection: Following collection of data, an indicator of positive progress would be to identify if data pertaining to water quality indicators is publically accessible via the internet. A survey could be conducted to examine what types of data are readily available and published online, potentially making way for a clearinghouse of the selected indicators and updates on progress.

Awareness of what water quality means: Increased awareness of what water quality means through the education of people in the three counties along the Gulf Coast could be an indicator of progress. Simple surveys and interviews with residents could be used to establish a baseline of where residents stand on knowledge of water quality, with additional surveys tracking progress.

Awareness of pollutants and their consequences in water: There are a variety of major point-source pollutants, including but not limited to pesticides, herbicides, heavy metals, and non-organic chemicals. An indicator of progress could be an increased and wider awareness of these pollutants, which could be measured with simple surveys, workshops, and interviews with residents after a baseline is established.

Awareness of practices to improve water quality: There are many organizations in southern Mississippi and the Gulf of Mexico that seek to improve the region's water quality. An indicator of progress could be an increased awareness of appropriate practices that improve water quality. Educating recreationalists, farmers, and other residents of simple practices that improve water quality should be a component of a large regional plan. A simple survey, workshops, or interviews with residents could establish a baseline and more data for analysis, with additional surveys to track indicator progress.

Willingness to improve water quality: While many citizens understand that water quality is important, an indicator that would show positive progress could be citizens increased willingness to improve the water quality of the region. A simple survey, workshops, or interviews with residents could establish a baseline and more data for analysis.

Willingness to take action to improve water quality: Willingness to improve water quality is a step in a positive direction, but willingness to take action to improve water quality could be another useful indicator in showing forward progress. Through surveys and workshops, a baseline of the indicator could be established and progress could be tracked.

Progress toward level 3 and 4 EPA Water Quality Standards for biological data: Currently MDEQ uses Level 2 Standards to evaluate water quality for their biological assessments.[610] Having designated uses for water, as well as a developing a biocriteria index, are important steps in developing more specific protocols, such as those in Maine, Ohio, Vermont, Florida, Maryland, Kentucky, and Oregon. Becoming a leader and moving to Level 3 and Level 4 Bioassessment programs could increase the understanding of the ecology along the Gulf Coast while also giving policy makers more information to make decisions.

Water Resources

Evaluating how water resources are shared and their availability, effects on the economy, and supply and demand are all important factors in a secure watershed and ecosystem. Water resources can be measured through consumption. For most Gulf Coast residents, this consumption happens through residents' taps at home, work, and recreational sites; through watering of lawns, gardens, and swimming pools, and additional commercial uses. Furthermore, having access to water for uses of any kind is important when working toward a sustainable future for Mississippi. Below are indicators measuring the water resources available to the Mississippi Gulf Coast.

Water quantity/volume: Measuring water quantity/volume could be an important indicator. Variations from the normal flows of inland rivers and streams could greatly affect fish production and the ecosystems that depend on that water source, as well as many of the other indicators.[611] The flooding of Spring 2011 serves as a reminder of the negative effects that large jumps in streamflow can have on the Gulf ecosystem.

While this would be a very useful indicator, data collection of water flow is difficult to come by in most of the Mississippi Gulf Coast.

Jobs and income related to the Gulf of Mexico: NOAA produces a snapshot report that it compiles specifically for ocean jobs for each of the counties along the coastline. As of 2008, there were 11,432 jobs, accounting for over $173 million in wages and $345 million in goods and services for the three gulf counties along the Mississippi Gulf Coast.[612]

These reports also look at the job makeup and trending of jobs in each county, breaking down ocean jobs into six categories: tourism and recreation, ship and boat building, living resources, offshore mineral extraction, marine transportation, and marine construction. The reports are updated on a fiscal year basis by NOAA, and progress could be shown through an increase of jobs associated with the Gulf of Mexico.

Total water consumption: This is the grand total of water consumption in gallons per year used by both residential and commercial entities. It is a useful indicator because it measures gross water usage, not just residential potable water like other cases. Positive progress on the indicator could be shown through a lowering of total consumption of fresh water. The United States Geological Survey (USGS) tracks water usage and publishes data on a 5 year basis. In 2000, the average person consumed 738 gallons of freshwater and 408 gallons of saline water per day, totaling 1,146 gallons of water per day.** In 2005, the average person consumed 473 gallons of freshwater and 219 gallons of saline water per day, totaling 692 gallons per day.** The 2010 estimates have not been published at the time of the writing of this report.[613]

Water Use Per Capita: In 2005, the average person in the Mississippi Gulf region required approximately 117 gallons of water per day from the public water supply to carry out their daily activities, including both direct and indirect water uses.[614]

In 2000, that number was 103 gallons per day. With this data set, it is possible to track industrial, agricultural, and irrigation uses in addition to residential and commercial uses. However, one must also consider that people using wells instead of a public water supply in 2000 used 29% more water than their public supply counterparts, while in 2005 they used 9 percent less than their public supply counterparts.

Public Supply Water Withdrawals: Residential water consumption could be a useful indicator in determining watershed health. In 2005, the three coastal counties represented 11.9 percent of the people using the public water supply in Mississippi, with the average person along the Mississippi Gulf Coast using 117 gallons of water per day. An indicator of positive movement could be a decrease in the overall usage of water in the region, with a loss of average consumption controlling for percentage of population.

Self Supplied Industrial Use (Saline & Fresh): Self supplied water consumption for Industrial Uses could also be a useful indicator in determining watershed health. In 2005, industrial units in Mississippi used 1.7 million gallons of water per day, representing 29 percent of all water used in the region. In 2000, industrial units used 1.5 million gallons, representing 28 percent of all water used. An indicator of positive movement could be a decrease in the overall industrial usage of water in the region in terms of gallons.

Water consumption versus Total Annual Precipitation: Consumption of water versus the total annual precipitation could be an important water resource indicator because if freshwater is being depleted faster than the hydrologic cycle can replace it, the resource could be depleted more quickly than initially anticipated. To measure progress on the indicator, the community could be engaged to set the proper ratio with significant involvement from federal, state, and local governmental entities.

Water resource depletion rates: Tracking the amount of water used compared to the amount of water available is called a water resource depletion rate, which can be used as an indicator. This indicator is important in understanding the water demand of a region and long-term risks that are associated with water depletion. Success could be indicated if the amount of water available for use grew or if the rate at which water is being depleted significantly slowed.

Number of fishing licenses and permits: The Mississippi Department of Wildlife, Fisheries, and Parks, along with the Mississippi Department of Marine Resources manages the number of fishing permits and hunting licenses issued. Assuming that fish populations equal or increase, an increase in the number of fishing licenses and permits could be considered a positive indicator of greater access to water for recreational purposes. The Mississippi Department of Wildlife, Fisheries, and Parks, and Mississippi Department of Marine Resources both collect data on a yearly basis and it is available through their offices.

Ecosystem Health

Measuring and evaluating ecosystem health can be done with a variety of water quality indicators. After governance indicators, these are the most common indicators to measure a sustainable watershed. For the Mississippi Gulf Coast Region, a healthy ecosystem and watershed is important in supporting the seafood and tourism industries, as well as promoting human and environmental health. Currently the state of Mississippi uses a Level 2 Water Quality Standards Program (WQS), which the EPA refers to as the basic program for aquatic life use protection.[615] This program is useful in identifying current state indicators. Furthermore, a review of a number of studies identified other possible potential indicators that could be used to measure water quality.[616] [617]

Presence and health of benthic macroinvertebrates: Benthic macroinvertebrates are typically found at the bottom of water bodies and are responsive to a variety of environmental stresses. It is useful to measure them because they tend to be immobile and are typically tied to their ecosystems' past.

NOAA, EPA, and along with numerous state and federal organizations maintain, an Oracle-based database called SEA Map that crosses many boundaries to effectively monitor the presence of sea organisms. The data is retrievable, but at the time of this writing on-site visits are necessary. Currently, there is a program being developed to make the information more "user

Table 17
Chemical Levels
Source: *Mississippi Department of Environmental Quality: Water Quality Standards, April 14, 2011*

CAS	Parameter	Fresh Water		Salt Water		Human Health	
		Acute	Chronic	Acute	Chronic	Organisms Only	Water & Organisms
309,002	**Aldrin**	**3.0**		**1.3**		**0.000000**	**0.000000**
7,664,417	**Ammonia**	**f**	**f**	**f**	**f**		
7,440,382	**Arsenic (III), Total Dissolved**	**340 e**	**150 e**	**69**	**36**		
7,440,382	**Arsenic, Total Dissolved**					**24 h**	**0.078 h**
7,440,439	**Cadmium, Total Dissolved**	**1.03 b,e**	**0.15 b,e**	**40**	**8.8**	**168**	**5**
57,749	**Chlordane**	**2.4**	**0.0043**	**0.09**	**0.004**	**0.00080**	**0.00080**
7,782,505	**Chlorine**	**19**	**11**	**13**	**7.5**		
18,540,299	**Chromium (Hex), Total Dis-solved**	**16 e**	**e**	**1,100**	**50**	**1,470**	**98**
16,065,831	**Chromium (III), Total Dissolved**	**323 b,e**	**42 b,e**			**140,468**	**100**
7,440,508	**Copper, Total Dissolved**	**7.0 b,e**	**5.0 b,e**	**4.8**	**3.1**	**1,000**	**1,300**
57,125	**Cyanide**	**22.0 g**	**5.2 g**	**1.0 g**	**1.0 g**	**140**	**140**
50,293	**4,4 DDT**	**1.1**	**0.001**	**0.13**	**0.001**	**0.00020**	**0.00020**
60,571	**Dieldrin**	**0.24**	**0.056**	**0.71**	**0.0019**	**0.000100**	**0.000100**
1,746,016	**2,3,7,8 TCDD (Dioxin)**					**5.1 x 10-9**	**5.0 x 10-9**
959,988	**alpha-Endolsulfan**	**0.22 i**	**0.056 i**	**0.034 i**	**0.0087 i**	**89**	**62**
33,213,659	**beta-Endosulfan**	**0.22 i**	**0.056 i**	**0.034 i**	**0.0087 i**	**89**	**62**
1,031,078	**Endosulfan Sulfate**					**89**	**62**
72,208	**Endrin**	**0.086**	**0.036**	**0.037**	**0.0023**	**0.060**	**0.059**
76,448	**Heptachlor**	**0.52**	**0.0038**	**0.053**	**0.0036**	**0.000100**	**0.000100**
58,899	**gamma-BHC (Lindane)**	**0.95**	**0.08**	**0.16**		**1.8**	**0.98**
7,439,921	**Lead, Total Dissolved**	**30 b,e**	**1.18 b,e**	**210**	**8.1**		**15**
7,439,976	**Mercury (II), Total Dissolved**	**2.1 e**	**0.012**	**1.8**	**0.025**		
7,439,976	**Mercury**					**0.153**	**0.151**
7,440,020	**Nickel, Total Dissolved**	**260 b,e**	**29 b,e**	**75**	**8.3**	**4,600**	**610**
108,952	**Phenol**	**300**	**102**	**300**	**58**	**860,000**	**10,000**
87,865	**Pentachlorophenol**	**8.7 c**	**6.7 c**	**13 c**	**7.9 c**	**3.0**	**0.27**
	Total PCB	**0.2**	**0.014**	**1.0**	**0.03**	**0.000100**	**0.000100**
7,782,492	**Selenium, Total Dissolved**	**11.8 a,e**	**4.6 e**	**290 e**	**71 e**	**4,200**	**170**
7,440,224	**Silver, Total Dissolved**	**0.98 b,e**		**1.9**			**100**
8,001,352	**Toxaphene**	**0.73**	**0.0002**	**0.21**	**0.0002**	**0.00030**	**0.00030**
7,440,666	**Zinc, Total Dissolved**	**65 b,e**	**65 b,e**	**90**	**81**	**26,000**	**7,400**

a. "The CMC = 1/[(f1/CMC1) + (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and CMC1 and CMC2 are 185.9 µg/l and 12.83 µg/l. The value in the table is calculated assuming a worst case scenario in which all selenium is present as selenate."

b. "Hardness dependent parameter. Criteria are indicated at hardness of 50 mg/l as CaCO3. Equations for criteria calculation of hardness dependent parameters can be found in Quality Criteria for Water. The equation is applicable for instream hardness ranges from 25 mg/l to 400 mg/l. If instream hardness is less than 25 mg/l, then a hardness value of 25 mg/l should be used to calculate the criteria. If instream hardness is greater than 400 mg/l, then a hardness of 400 mg/l should be used to calculate the criteria."

c. "Criteria for pentachlorophenol are based on a pH dependent equation as found in Quality Criteria for Water. Values listed are for a pH of 7.0 s.u."

d. Site specific criteria for Mississippi Sound.

e. Parameter subject to water effects ratio equations where: CMC = WER * Acute, CCC = WER * Chronic

f. Ammonia criteria are dependent on pH, temperature, and/or salinity. See Section II.6.C.

g. Expressed as µg free cyanide (as CN)/L.

h. Refers to the inorganic form only.

i. Applies to the sum of α and β isomers.

j. "Chemical Abstracts Service (CAS) registry numbers, which provide a unique identification for each chemical."

friendly" that utilizes a GIS MapViewer through the internet. This is scheduled to go into commission in late fall of 2011.

Presence and health of fish: Fish are important long-term indicators for ecosystem health because they live in a variety of habitats and are long lived and mobile, but they are still responsive to environmental changes. For this indicator to be used effectively, all fish species need to be identified.

Again, the SEA Map database could be useful in getting this information, but the data is retrievable only by making an on-site visit.

Presence and health of periphyton or phytoplankton: Periphyton and phytoplankton are also good indicators of environmental change because they are present in a large number of streams and shallow areas and are very sensitive to environmental change. Furthermore, they are quick to regenerate, which allows for rapid response to exposure and subsequent recovery from an environmental event. They are typically suspended in the water or floating close to the surface, making it fairly easy to conduct grab tests.

Again, the SEA Map database could be useful in getting this information, but the data is retrievable only by making an on-site.

Presence and health of aquatic macrophytes (aquatic grasses and forbs): Aquatic macrophytes are aquatic plants that are either submerged in water or visible above the surface. They are valuable as habitats for fish and waterfowl and serve as good indicators in estuaries. They are responsive to environmental changes, so measuring their quality and quantity could be an important indicator.

Research indicates that MDEQ does not currently collect information on aquatic macrophytes.

Hydrologic modification: Changing the landscape of inland streams and shorelines can greatly impact the health of the Gulf. By modifying these water bodies, habitats' complexities that are crucial to maintaining a healthy ecosystem at any point along the channel or shore could be lost. Taking inventory of many of the channels, dams, and shorelines would serve as a good baseline by which to evaluate changes over time, including the changes that manmade improvements have on bodies of water.

The Gulf Sea Grant program is currently working to develop an inventory of hydrological restoration sites, and this inventory would be useful for this indicator. Also: the U.S. Army Corps of Engineers has a large program called MsCIP that seeks to restore several large wetlands as well as alter landscapes to provide greater storm water retention and protection. However, much of their data is site exclusive and was conducted as assessments of how to best build at each site, not to measure change over time over a large area, which would make this source of data difficult to use.

Dissolved Oxygen: Dissolved oxygen (DO) concentration impacts almost all aquatic organisms. It affects not only the quantity of fish and seafood, specifically oysters, but also the quality and regenerative abilities of other organisms crucial to the ecosystem.

If DO levels in seawater fall below the threshold of 5.0 mg/l, the ecosystem will begin to suffer from stress. Furthermore, if the DO level is not corrected and it remains under 1-2 mg/l, the potential exists for a widespread loss of aquatic organisms in a phenomenon called hypoxia. Guarding against hypoxia is especially important in the Gulf of Mexico, as it is a major source for the U.S. seafood industry, with 72% of shrimp, 66% of oysters, and 16% of commercial fish coming out of the Gulf.[618] Many communities like high amounts of dissolved oxygen in their freshwater supply because it makes tap water taste better, although it shortens the lifespan of water pipes. High levels of DO also impacts sewer/stormwater systems. Many jurisdictions try to keep their DO levels below .007 ppm because in overflow events, released wastewater with high levels of DO, can often lower the natural amounts of DO in seawater. This can lead to hypoxia in a larger area, known as a "dead zone", where aquatic life struggles and often dies.

In Mississippi, and along with the majority of the Gulf Coast, the NOAA (National Oceanographic and Atmospheric Administration) monitors the amounts of dissolved oxygen in the water annually in different sections of the Gulf of Mexico for a project called Hypoxia Watch, which is part of a program called the Southeast Area Monitoring and Assessment Program (SEAMAP) that uses the NOAA ship Oregon II. The ship set buoys throughout the Gulf of Mexico at different times of the year to collect data. This information is readily available in both raw and GIS formats for these periods, and in JPEG images for quick reference.[619]

The United States Geological Survey also has two real-time dissolved oxygen monitoring stations. One is at the Mississippi Sound and East Ship Island Light and the other is at the Pearl River NSTL Station. These stations have real-time information available through the USGS Website.[620]

The State of Mississippi also tracks DO information for Clean Water Act compliance. Mississippi states in its compliance plan that the daily average concentration of DO should not be less than 5.0 mg/l with an instantaneous minimum loss of not less than 4.0 mg/l.

While current levels of DO did increase above the average because of the Mississippi River flooding of 2011, the resulting hypoxic dead zone was substantially smaller than what had been anticipated by NOAA.[621] [622] A way to measure success of the dissolved oxygen indicator would be to maintain DO levels at satisfactory levels.

Water temperature: Water temperature can be used as a water quality indicator because aquatic organisms are directly affected by the temperature of the water around them. Water temperature also affects a number of other indicators. If large temperature shifts occur, both a significant change in indicators and displacement of organisms that live in the Gulf could occur.

Therefore, monitoring water temperature could be an important indicator to study. Currently, the USGS has 10 monitoring points in the Gulf and three monitoring points inland, all of which are kept in real time. All 13 of these monitoring points are in the study area.[623]

The MDEQ also monitors temperatures of water and temperatures of wastewater that is discharged into other bodies, stating that the maximum water temperature in streams, lakes, and reservoirs cannot exceed 5°F (2.8°C) above each water body's natural temperature and no water body can exceed 90°F (32.2°C). It further stipulates that any wastewater discharge cannot alter a water body's temperature by more than 5°F (2.8°C) above natural conditions.

However, there is a separate regulation regarding coastal waters, stating that the maximum temperature is not allowed above 90°F (32.2°C). It further stipulates that any wastewater discharge cannot alter a coastal water body's temperature by more than 4°F (2.2°C) above natural conditions during the months of May through October and more than 1.5°F (.8°C) above natural conditions during the months of June through September.

Conductance: Another common measure of water quality is conductance, or the ability of water to conduct electricity. Conductance is the measure of dissolved inorganic solids, with most measures based on the location of a body of water; it is commonly used to measure salinity of water. Deviations from normal conductance often indicates an event in the local water system. For instance an, increase in flooding or sewage would raise conductance because of the presence of chloride, phosphate, and nitrate, while an oil spill event would lower the conductance.[624]

The USGS also does real-time monitoring of conductance in both the Gulf and key inland points. It has10 monitoring points in the Gulf and 1 monitoring point inland, totaling 11 monitoring points in the study area. [625]

pH: The alkalinity of water is another important measure of water quality. Through the measurement of pH, one can determine how acidic/basic water is on a scale of 0 - 14, (7= Neutral, < 7 Acid, >7 Basic). This is important because an imbalanced pH could harm organisms in the water; specifically those organisms on which Mississippi's economy relies.[626]

MDEQ monitors the pH of bodies of water, stating that the pH of the water must be maintained between 6.0 and 9.0, with no more than 1.0 unit of deviation. However, it stipulates that blackwater bodies of water may be lower than 6.0 due to natural conditions.

Toxic Organic Carbon and chemicals: Toxic Organic Carbons (TOCs) are typically manufactured organic chemicals, such as pesticides and herbicides, that are used on land but seep into water. They are important indicators of water quality because an accumulation of TOCs could drastically alter the characteristics of the ecosystems in the Gulf.[627]

As of 2011, the Mississippi DEQ maintains records to comply with the Clean Water Act and measures 31 different chemicals in fresh water, salt water, and potable water sources. These include Aldrin, Chlordane, 4 DDT, Dieldrin, alpha-Endolsulfan, beta Endolsulfan, Endrin, Heptachlor, gamma-BHC (Lindane), Pentachlorophenol, and Toxaphene, which are/were commonly used pesticides/insecticides.

The MDEQ also monitors other chemicals in water such as 2, 3, 7 and 8 TCDD, Ammonia, Arsenic, and Chlorine. Most of these chemicals are harmful to the environment, and while they are controlled and many of them have been banned, some are still necessary to protect crops on the land.

Infrastructure

Watershed infrastructure is an important component of a sustainable watershed and ecosystem. One of the more important facets of watershed infrastructure is water conservation and the reduction of the amount of water consumed, as well as measuring effects of erosion, environmental loss, and the quality/quantity/access to water bodies.[628]

Wetland, estuary and bayou land loss: Habitats for native species are important to the infrastructure of a healthy and sustainable watershed. By establishing the existing amount of wetlands, positive indicator progress could to be demonstrated by the slowing or stoppage of wetland, estuary, and bayou loss, and potentially even the restoration of these habitats. Data about existing wetlands could be gathered though geospatial analysis of aerial photographs and on-the-ground surveys. Historically, the U.S. Fish and Wildlife Service has conducted wetland inventories to determine wetland loss from 1870-1980 and 1986-1996.[629] Currentl,y the U.S. Army Corps of Engineers is working on its MsCIP program to restore many of the lost wetlands, but their site analysis is project site exclusive.

Erosion: Similar to land loss, erosion usually stems from channel flows, either from precipitation events or movement of water. Measuring changes of streams and channels and evaluating the existing infrastructure could be done through aerial photography and ground-level surveys and then evaluated over time by any number of organizations or entities. Professionals in the field could also conduct surveys on the ground at key points along channels.

Gallons of water used daily per person: In 2005, the average person in the Mississippi Gulf region used about 123 gallons of public supply water per person a day through such basic domestic activities as washing clothes and dishes, taking showers, and flushing toilets. Water for toilets and landscaping are the largest water wasters in both the commercial and residential sectors.[630] In 2000, the average person used 87 gallons per day. An indicator of positive movement could be a decrease in the number of gallons of water per person used on a daily basis.

Amount of wastewater treated: By tracking the amount of wastewater treated, a useful indicator can be created that acts as a measure of infrastructure quality. However, at this time there is not a data source that could be found that measures the amount of total wastewater treated at the county level.

Proximity to quality water bodies: Not every body of water is equal in terms of quality and access for recreation, both of which are important social indicators. Establishing access to various water bodies and evaluating their quality could serve as a baseline for future analysis, although metrics for what quality means would have to be developed. This could be done through community outreach.

Human Health

Human health indicators are needed to ensure that the basic need for water is met and that water is healthy for consumption, recreation, or use. Below are indicators that evaluate how healthy the water is to humans.

Enterococci: Enterococci is a bacterium found in human and animal waste. Whether or not it is present is useful in determining if water is safe for recreation and drinking. The EPA has monitored the presence of Enterococci since the 1970s throughout most of the United States, and specifically in recreational waters, to prevent illness from exposure.

In Mississippi, the measurement of Enterococci is the responsibility of the MDEQ, which monitors the amount of E. coli present at beaches and in recreational waters. Information is kept on a weekly basis and can be found online by visiting MDEQ's website reporting tool.[631]

However, by monitoring the number of days that beaches and recreational waters are closed, the indicator can also track improvement in the conditions near water bodies by focusing on the decrease in number of days closed.

Fecal coliform bacteria: The presence of Fecal coliform bacteria (FC bacteria) comes from warm-blooded mammals and humans and when detected in water indicates fecal contamination. It is typically associated wastewater or sewage sludge and is easy to detect. It is also directly related to pathogens that may be present in the water, thus endangering organisms and humans that use it. Currently MDMR tracks FC bacteria. Lowering incidents of FC bacteria would indicate less wastewater and sewage spilling into non-contaminated water.[632]

Heavy metals: The monitoring of heavy metals in water is typically coordinated with testing for toxics and other chemicals. Heavy metals, such as cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc, are all tested for. MDEQ has regulations regarding the acceptable quantity of each heavy metal and the amounts that are healthy for surface waters and in discharge events, as found in Table 20.

Residential water consumption: Residential water consumption could be a useful indicator in determining watershed health. In 2005, the three coastal counties represented 11.9% of the people using the public water supply in Mississippi, with the average person along the Mississippi Gulf Coast using 123 gallons of water per day. An indicator of positive movement could be a decrease in the overall usage of water in the region, with a loss of average consumption controlling for percentage of population.

Industrial water consumption: Industrial water consumption could also be a useful indicator in determining watershed health. In 2005, industrial units in Mississippi used 1.7 million gallons of water per day, representing 29% of all water used in the region. In 2000, industrial units used 1.5 million gallons, representing 28% of all water used. An indicator of positive movement could be a decrease in the overall industrial usage of water in the region.

Matching indicators to goals

Recent indicator studies have used an indicator selection process that begins with clarifying the goals and visions of sustainable water sources that are appropriate to the scale of each study. Stakeholders should be intimately engaged in the indicator selection process to support the belief that "indicators are useless if they are not used as such, it is essential that stakeholders understand and support the set of indicators selected."[633] Stakeholders include farmers, recreational fishers, industry, tourists, recreation businesses, ports, residents, nonprofit organizations (including institutions), elected officials, and professional organizations. Participants and experts should provide feedback on data content and data sources and rate their acceptability. Identifying existing data gaps is also necessary, as "interpreting data across fields and institutions has proved challenging." [634]

Goal-oriented indicator studies lay out goals appropriate to their respective levels (state, regional, or county level) and then identify indicators that can be used to measure progress toward reaching those goals. Indicators should be proposed and presented complete with trend data, source information, data particulars, and analysis of strengths and limitations.

As part of the Silicon Valley watershed plan several ways to evaluate progress towards goals were identified.[635] One of the most important goals to the Silicon Valley area is access to and use of water. The plan grew out of the larger Santa Clara County watershed plan that broke down issues specifically facing water quality. [636] The issues identified as being the most important in the analysis were DO (Dissolved Oxygen), presence of freshwater

clams, streamflow and depth, spread of non-native invasive species in the watershed, hydrological modifications, and watershed restoration projects.

Maryland conducted a statewide assessment of indicators in 2000. It looked at four broad categories— aquatic system indicators, biological diversity indicators, terrestrial system indicators and water quality indicators—and developed measures for each. The aquatic system indicators is the broadest reaching category of the four, with 14 indicators that look at everything from species of fish and their spawning areas to vegetation and riparian buffering. [637]

Another set of indicators focusing on the social side of watershed quality were developed by researchers at University of Wisconsin and Purdue University. [638] They developed five goals that could be easily used by other watershed plans: 1) Increased awareness of among target audience; 2) attitudes among target audience supportive of management actions; 3) reduced constraints for using appropriate practices; 4) increased capacity to address management issues in project area and; 5) increased adoption of management practices by target audience. Each of these goals has an intended outcome, and several indicators to show progress towards those outcomes.[639]

End Notes





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Appendix A Glossary

Alluvium is unconsolidated terrestrial sediment that has been deposited by water. It is typically composed of sorted or unsorted sand, gravel, and clay.

Aquifer is defined by the Mississippi Department of Environmental Quality as "a saturated geologic layer that is porous and permeable enough to yield useable quantities of water to wells, springs, or surface water bodies."

Bayou is a slow-moving body of water typically located in low-lying, flat areas within the Gulf Coast region of the southern United States. It also refers to a marshy lake, wetland, or an extremely slow-moving stream or river.

Bathymetry is defined by the Merriam-Webster Dictionary as "the measurement of water depth at various places in a body of water".

Benthic organisms are organisms which live on or just beneath the sediment surfaces of oceans or lakes, such as oysters, clams, and crabs, etc.

Blackwaters refer to "coffee-colored" rivers originating in the Gulf Coastal Plain, typically with a high content of organic acids.

Brackish water is water with salinity higher than that of fresh water but lower than that of seawater. It contains 0.5 to30 grams of salt per liter, often expressed as 0.5 to 30 parts per thousand (ppt).

Confined aquifer is defined by the Department of Environmental Quality as the aquifer zone where groundwater is overlaid and isolated by relatively impermeable layers and is under pressures greater than atmospheric pressure.

Culvert is defined by the Environmental Protection Agency as "a closed conduit used to convey water from one area to another, usually from one side of a road to the other side".

Exclusive Economic Zone is defined by the National Oceanic and Atmospheric Administration as the zone where the United States and other coastal nations have exclusive rights to explore, exploit, conserve and manage natural resources. It includes waters three to 200 miles offshore (or nine to 200 miles offshore in Western Florida and Texas).

Ecoregion is defined by The Nature Conservancy as "large units of land and water delineated by characteristic biotic and abiotic factors".

Ecosystem services are benefits provided by ecosystem structures and functions to human societies, such as wetlands filtering pollutants and storing water during floods.

Embayments are subtidal areas that are protected on three sides by land.

Endangered species are plant and animal species with extremely low populations and are in danger of becoming extinct.

Geologic epoch is defined as a subdivision of the geologic timescale based on rock layering. In order, the higher subdivisions are periods, eras and eons. We are currently living in the Holocene epoch (of the Quaternary period, of the Cenozoic era, of the Phanerozoic eon).

Estuary is a transition zone connecting river and marine environments and therefore is influenced by both of the environments. Typical riverine influences to estuary includes flows of fresh water and sediment, while most common marine influences are tides, waves, and the influx of saline water.

Foreign Trade Zone is a designated location in the United States where companies engaged in international trade related activities can use special customs and procedures to compete with foreign producers.

Geomorphology is a discipline that studies landforms and the associated processes that shape them.

Groins are man-made structures designed to intercept sands that are moved down towards the beach by longshore drift.

Holocene is a geological epoch which started around 10,000 years ago following the Pleistocene epoch and continues to the present. The Holocene is part of the Quaternary period.

Hummock is a tract of forested land that rises above an adjacent marsh in the southern United States.

Hydrophytic plants are plants growing partly or wholly in water.

Hypoxia refers to the condition where dissolved oxygen is below the level necessary to sustain most animal life. Generally a dissolved oxygen level below 2 mg/ l ppm is considered hypoxia.

Interglacial periods are periods of warmer climates within an ice age. The Holocene Epoch is the current interglacial period.

Invasive Species are non-native species that are introduced from other regions and causes economic and/or ecological problems to the receiving regions.

Jacket is a steel pipe support structure with special casts on its junction points.

Karenia brevis (K. brevis) is a toxic dinoflagellate (i.e. a unicelluar protist) that causes red tides. It is commonly found in the Gulf of Mexico along the Texas and Louisiana coasts, the east coast of Florida, and as far north as North Carolina.

Lightering zone is an area where a sea vessel may transfer oil or hazardous materials. This allows for the transfer of liquid cargo from a vessel that is too large to enter a port to smaller vessels that then transfer the cargo to an on-shore facility.

Liquefied natural gas is defined by Shell as “a clear, colorless, non-toxic liquid that forms when natural gas is cooled to around negative 160ºC”. It is easier to store and transport since the volume is significantly reduced after converting to liquid phase from gas phase.

Mercury is a type of heavy metal that is toxic if it accumulates in human bodies. Exposures to mercury can affect the human nervous system and harm the brain, heart, kidneys, lungs, and immune system.

Miocene refers to a geological epoch of the Neogene Period and extends from about 23.03 to 5.332 million years ago.

Mitigation bank is defined by the Environmental Protection Agency as “a wetland, stream, or other aquatic resource area that has been restored, established, enhanced, or (in certain circumstances) preserved for the purpose of providing compensation for unavoidable impacts to aquatic resources permitted under Section 404 or a similar state or local wetland regulation”.

Non-point source pollution is pollution coming from diffused sources. It is caused by rainfall or snowmelt moving over and through the ground, which picks up and carries away natural and man-made pollutants and finally deposits them into surface water bodies and ground waters.

Pangaea is the hypothetical supercontinent that existed during the Paleozoic and Mesozoic eras about 250 million years ago when the current continents were not formed.

Physiography, also known as physical geography, is a discipline that deals with the natural features of the earth’s surface, especially in its current aspects, including land formation, climate, currents, and distribution of flora and fauna.

Pleistocene is a geological epoch that extends from 2,588,000 to 11,700 years before present time. It starts at the end of the Pliocene Epoch and is followed by the Holocene Epoch.

Pliocene is geological epoch that extends from 5.332 million to 2.588 million years before present time, making it the second and youngest epoch of the Neogene Period in the Cenozoic Era. It starts at the end of the Miocene Epoch and is followed by the Pleistocene Epoch.

Polyhaline is a salinity category term applied to brackish water with salinity from 18 to 30 ppt.

Project cargo is cargo that is too large or bulky to be transported in a container, such as parts of cranes or wind power stations, turbines, or ship propellers.

Renourishment is also referred to as beach replenishment; this is a process where sand or other sediments removed by longshore drift or erosion are replaced from sources other than the eroding beach.

Sedimentary is a type of rock resulted from sedimentation processes where minerals or organic particles settle out or precipitate from a solution.

Subduction describes the process of one tectonic plate moving under another tectonic plate and sinking into the Earth’s mantle at the convergent boundary when the two plates converge.

Tides describe the phenomenon of the rise and fall of sea levels resulting of the gravitational attraction exerted on Earth’s waters by the moon, sun and to a lesser extent by other celestial bodies.

Threatened species are defined by the Environmental Protection Agency as “plants and animals that are likely to become endangered within the foreseeable future throughout all or a significant portion of its range”.

Trophic level is a term in ecology describing the position that an organism occupies in the food chain.

Water column is a conceptual cylinder of water from the surface to the bottom of a water body such as a stream, lake, or ocean. The concept is used to study the stratification or mixing of thermally or chemically stratified layers in a water body by measuring the physical, chemical and biological properties within the column.

Wetlands are defined by Environmental Protection Agency as “areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions”.

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Appendix B Tables

Table A
Endangered and Threatened Species
Source: *US Fish and Wildlife Service*

Species	Hancock	Harrison	Jackson
Louisiana black bear *Ursus americanus luteolus*	**T**	**T**	**T**
Piping Plover *Charadrius melodus*	**TCH**	**TCH**	**TCH**
Gopher tortoise *Gopherus polyphemus*	**T**	**T**	**T**
Ringed map turtle *Graptemys oculifera*	**T**		
Green sea turtle *Chelonia mydas*	**T**	**T**	**T**
Loggerhead sea turtle *Caretta caretta*	**T**	**T**	**T**
Gulf sturgeon *Acipenser oxyrhynchus desotoi*	**TCH**	**TCH**	**TCH**
Inflated heelsplitter *Potamilus inflatus*	**T**		
Louisiana quillwort *Isoetes louisianensis*	**E**	**E**	**E**
Leatherback sea turtle *Dermochelys comacea*	**E**	**E**	**E**
Kemp's ridley sea turtle *Lepidochelys kempii*	**E**	**E**	**E**
West Indian manatee *Trichechus manatus*	**E**	**E**	**E**
Pearl darter *Percina aurora* (Pearl River System)	**C**		**C**
Mississippi gopher frog *Rana capito sevosa* (DPS)		**E**	**E**
Alabama red-bellied turtle *Psuedemys alabamensis*		**E**	**E**
Red-cockaded woodpecker *Picoides borealis*		**E**	**E**
Black pine snake *Pituophis melanoleucus ssp. Lodingi*		**C**	**C**
Yellow-blotched map turtle *Graptemys flavimaculata*			**T**
Mississippi sandhill crane *Grus canadensis pulla*			**ECH**

Codes: E = Endangered T = Threatened C = Candidate ECH or TCH = Listed with Critical Habitat

Table B
Protected Marine Mammals within the Gulf of Mexico
Source: *NOAA National Marine Fisheries Service*

Protected Marine Mammals within the Gulf of Mexico	
Atlantic Spotted Dolphin *Stenella frontalis*	**Melon-Headed Whale *Peponocephala electra***
Blainville's Beaked Whale *Mesoplodon densirostris*	**Minke Whale *Balaenoptera acutorostrata***
Blue Whale *Balaenoptera musculus*	**North Atlantic Right Whale *Eubalaena glacialis***
Bottlenose Dolphin *Tursiops truncatus*	**Pantropical Spotted Dolphin *Stenella attenuata***
Bryde's Whale *Balaena mysticetus*	**Pygmy Killer Whale *Kogia breviceps***
Clymene Dolphin *Stenalla clymene*	**Risso's Dolphin *Grampus griseus***
Cuvier's Beaked Whale *Ziphius cavirostris*	**Rough-Toothed Dolphin *Steno bredanensis***
Dwarf Sperm Whale *Kogia sima*	**Short-Finned Pilot Whale *Globicephala macrorhynus***
False Killer Whale *Pseudorca crassidens*	**Sie Whale *Balaenoptera borealis***
Fin Whale *Balaenoptera physalus*	**Sowerby's Beaked Whale *Mesoplodon bidens***
Fraser's Dolphin *Lagenodelphis hosei*	**Sperm Whale *Physeter macrocephalus***
Gervais' Beaked Whale *Mesoplodon europaeus*	**Spinner Dolphin *Stenella longirostris***
Humpback Whale *Megaptera novaeangliae*	**Striped Dolphin *Stenella coeruleoalba***
Killer Whale *Orcinus orca*	

Table C
State Identified Species in Need of Greatest Conservation
Source: *Mississippi Department of Wildlife, Fisheries and Parks, MDMR and NOAA*

Birds	Fish	Reptiles
American Bittern *Botaurus lentiginosus*	**Alabama Shad* *Alosa alabamae***	**Gulf Salt Marsh Snake *Nerodia clarkii clarkii***
American Black Duck *Anas rubripes*	**Alligator Gar *Atractosteus spatula***	**Mississippi Diamondback Terrapin *Malaclemys terrapin pileata***
American Oystercatcher *Haematopus palliatus*	**Bluespotted Sunfish *Enneacanthus gloriosus***	
American White Pelican *Pelecanus erythrorhynchos*	**DuskyShark* *Carcharhinus obscurus***	
Bald Eagle *Haliaeetus leucocephalus*	**Goliath Grouper *Epinephelus itajara***	
Black Rail *Laterallus jamaicensis*	**Largetooth Sawfish* *Pristis perotteti***	
Black Skimmer *Rynchops niger*	**Least Killfish *Heterandria formosa***	
Black-Crowned Night-Heron *Nycticorax nycticorax*	**Nassau Grouper* *Epinephelus striatus***	
Brown Pelican *Pelecanus occidentalis*	**Night Shark* *Carcharhinus signatus***	
Dunlin *Calidris alpina*	**Northern Starhead Topminnow *Fundulus dispar***	
Gull-Billed Tern *Sterna nilotica*	**Pygmy Killfish *Leptolucania ommata***	
King Rail *Rallus elegans*	**Saltmarsh Topminnow *Fundulus jenkinsi***	

Birds	Fish	Reptiles
Least Bittern *Ixobrychus exilis*	**Sand Tiger* Shark *Carcharias taurus***	
Lesser Scaup *Aythya affinis*	**Speckled Hind* *Epinephelus drummondhayi***	
Little Blue Heron *Egretta caerulea*	**Striped Bass *Morone saxatilis***	
Marbled Godwit *Limosa fedoa*	**Warsaw Grouper* *Epinephelus nigritus***	
Migrant Shorebirds	**White Marlin* *Tetrapturus albidus***	
Mottled Duck *Anas fulvigula*		
Nelson's Sharp-Tailed Sparrow *Ammodramus nelsoni*		
Northern Pintail *Anas acuta*		
Osprey *Pandion haliaetus*		
Pelagic Birds		
Purple Gallinule *Porphyrula martinica*		
Red Knot *Calidris canutus*		
Royal Tern *Sterna maxima*		
Sandwich Tern *Sterna sandvicensis*		
Seaside Sparrow *Ammodramus maritimus*		
Short-Eared Owl *Asio flammeus*		
Snowy Egret *Egretta thula*		
Tricolored Egret *Egretta tricolor*		
Western Sandpiper *Calidris mauri*		
White Ibis *Eudocimus albus*		
Wilson's Plover *Charadrius wilsonia*		
Yellow-Crowned Night-Heron *Nycticorax violaceus*		
Yellow Rail Coturnicops noveboracensis		

* Species of concern identified by NOAA's National Marine Fisheries Service

Table D
Non-Native/Invasive Plant Species
Source: *Gulf Coast Research Laboratory, Mississippi Aquatic Plants Website*

Common Name	Scientific Name	Means of Introduction	Concerns
Alligatorweed	***Alternanthera philoxeroides (Mart.) Griseb.***	**Ballast Water (from South America), introduced in 1897**	**Clog waterways, interfere with navigation and water flow**
Wild Taro	***Colocasia esculenta (L.) Schott***	**Horticultural trade**	**Shade aquatics and displace native wetland margin plants**

Common Name	Scientific Name	Means of Introduction	Concerns
Waterhyacinth	***Eichhornia crassipes (Mart.) Solms***	**Introduced in New Orleans as a decorative pond plant in 1884**	**Chokes waterways, shades native aquatics, and reduces water quality, interfere with feeding pattern of aquatic wildlife**
Brazilian Elodea	***Egeria densa***	**Introduced from Brazil through the aquarium trade**	**Habitat alteration, interference with boating activities**
Water Thyme	***Hydrilla verticillata (L. f.) Royle***	**Introduced from Africa through the aquarium trade in 1960**	**Replace native aquatic plants, provides excellent habitat for mosquitoes**
Indian Swampweed	***Hygrophila polysperma Hygrophila***	**Imported from the East Indies in 1945**	**Replace native submerged vegetation, degrade water quality**
Limnophila/Asian Marshweed/Ambulia	***Limnophila sessiliflora***	**Introduced from India and South East Asia through the aquarium trade in 1961 near Tampa**	**Replace native submerged aquatic plants**
Purple Loosestrife	***Lythrum salicaria***	**Introduced from Europe and Asia in the early 1800s for medicinal uses**	**Rapidly replace native wetland plants**
Parrot Feather	***Myriophyllum aquaticum***	**Introduced from Amazon through aquarium trade**	**Replaces native aquatics, alters habitat, and degrades water quality**
Eurasian Watermilfoil	***Myriophyllum spicatum L.***	**Introduced in the early 1900s through aquarium and pond plant trades**	**Shades out native aquatics, interferes with boating and swimming, provides prime mosquito habitat, clog water intakes**
Spinyleaf or Spiny Naiad/ Holly-leaf Naiad	***Najas marina***	**Native to parts of Texas and Florida**	**Interfere with boating and swimming, replace native aquatic plants, alter habitat and species distributions**
Watercress	***Nasturtium officinale***	**Introduced in the 1700s to bog habitats from water gardens, used as culinary herb and in folk medicine**	**Chokes streams, and considered an exotic aquatic pest**
Sacred Lotus	***Nelumbo nucifera***	**Cultivated as an ornamental pond plant and for Chinese medicinal uses**	**Replace submerged aquatic vegetation (e.g.water lilies), altering habitat and water quality**
Torpedo grass	***Panicum repens L.***	**Introduced from Australia**	**Rapidly growing, chokes out native species, particularly dune plants, interfere with water movement in ditches and canals, limit recreational use of beach and shoreline areas**
Water lettuce	***Pistia stratoites***	**Introduced from the ballast water**	**Clogs waterway, blocks sunlight, replaces other aquatic plants, and negatively affects habitat and water quality**
Curlyleaf Pondweed	***Potamogeton crispus L.***	**Introduced through water used to transport fish**	**Restricts water flow and recreational water access, alters habitat and water quality**
Giant Salvinia	***Salvinia molesta Mitchell.***	**Imported through pond and aquarium trade from southeastern Brazil**	**Rapid growing**
Water Aloe	***Stratiotes aloides***	**Native to Europe**	**Quickly spread, shade, and replace native aquatic vegetation**

Common Name	Scientific Name	Means of Introduction	Concerns
Cogon grass	***Imperata cylindrica***	**Introduced through the Port of Mobile in 1912 as packing material used in shipping**	**Spreads rapidly, replaces native grasses and plants in habitats ranging from sand dunes to pine savannahs and swamps, difficult to eradicate**
Chinese tallow tree	***Triadica sebifera (Sapium sebiferum)***	**Introduced from China as an ornamental in Charleston SC**	**Replaces native wild plants, degrading water quality by producing more leaf litter and seeds**
Japanese honeysuckle	***Lonicera japonica***	**Introduced in 1864 as a horticultural cultivar**	**Shades native plant species, alters habitat, topple trees from its weight in areas of dense growth, blocking waterways.**

Table E
Non-Native/Invasive Aquatic Animal Species
Source: *Gulf Coast Research Laboratory*

Common Name	Scientific Name	Means of Introduction	Concerns
Rio Grande cichlid	***Cichlasoma cyanoguttatum***	**Through aquarium trade in the early 1990s; accidentally introduced into Florida and other parts of Texas from fish farms**	**Very aggressive, competes with sunfish for food and nesting space**
Tilapia	***Oreochromis sp. and Tilapia sp.***	**Accidentally introduced through aquaculture**	**Very aggressive, competes with sunfish for food and nesting space**
Common carp and grass carp	***Cyprinus caprio and Ctenopharyngodon idella***	**Deliberately stocked into rivers and lakes to control vegetation growth**	**Destroy nursery habitat for native fish species, make hunting food difficult for game fish like bass**
Silver carp and bighead carp	***Hypophthalmichthys molitrix and H. nobilis***	**Accidental release into the wild from aquaculture facilities or deliberate release into reservoirs and ponds to control algae blooms**	**May reduce food availability for larval native fishes**
Zebra mussel	***Dreissena polymorpha***	**Released into the Great Lakes in ballast water of ships from Europe, spread southward down the Mississippi River.**	**Clogs water intake pipes, encrusts boat hulls and buoys**
Brown swimming crab	***Callinectes bocourti***	**Through ballast waters (presumed)**	**May compete with the blue crab for habitat**
Australian spotted jellyfish	***Phyllorhiza punctata***	**Enter Mississippi Sound in 2000 via the Loop Current from LA**	**Larvae of commercially or recreationally important species may be consumed**
Big pink jellyfish	***Drymonema dalmatinum***	**Enter Mississippi Sound in 2000 via the Loop Current from LA (presumed)**	**Consumes other jellyfish**
Malaysian prawn	***Macrobrachium rosenbergii***	**Released from aquaculture facilities**	**May out-compete native Macrobrachium species**
Mussels	***Brachidontes domingensis, Mytilus edulis, Perna perna, P. viridis***	**Sea water piping systems or ballast waters in ships**	**Encrust any exposed surface including buoys, boat hulls, or water intake pipes; may out-compete native mussel species**

Common Name	Scientific Name	Means of Introduction	Concerns
Asian clam	***Corbicula fluminea***	**Believed to have been brought to the US as a food item by Chinese immigrants**	**Clogs intake pipes of power plants and other industrial water systems, competes with native clam species**
Pacu, Tambaquí and Pirapatinga	***Colossoma macropomum and Piaractus brachypomus***	**Introduced through the aquarium trade**	**May compete with larvae of native fish species for plankton**

Mississippi Gulf Coast Water Assessment