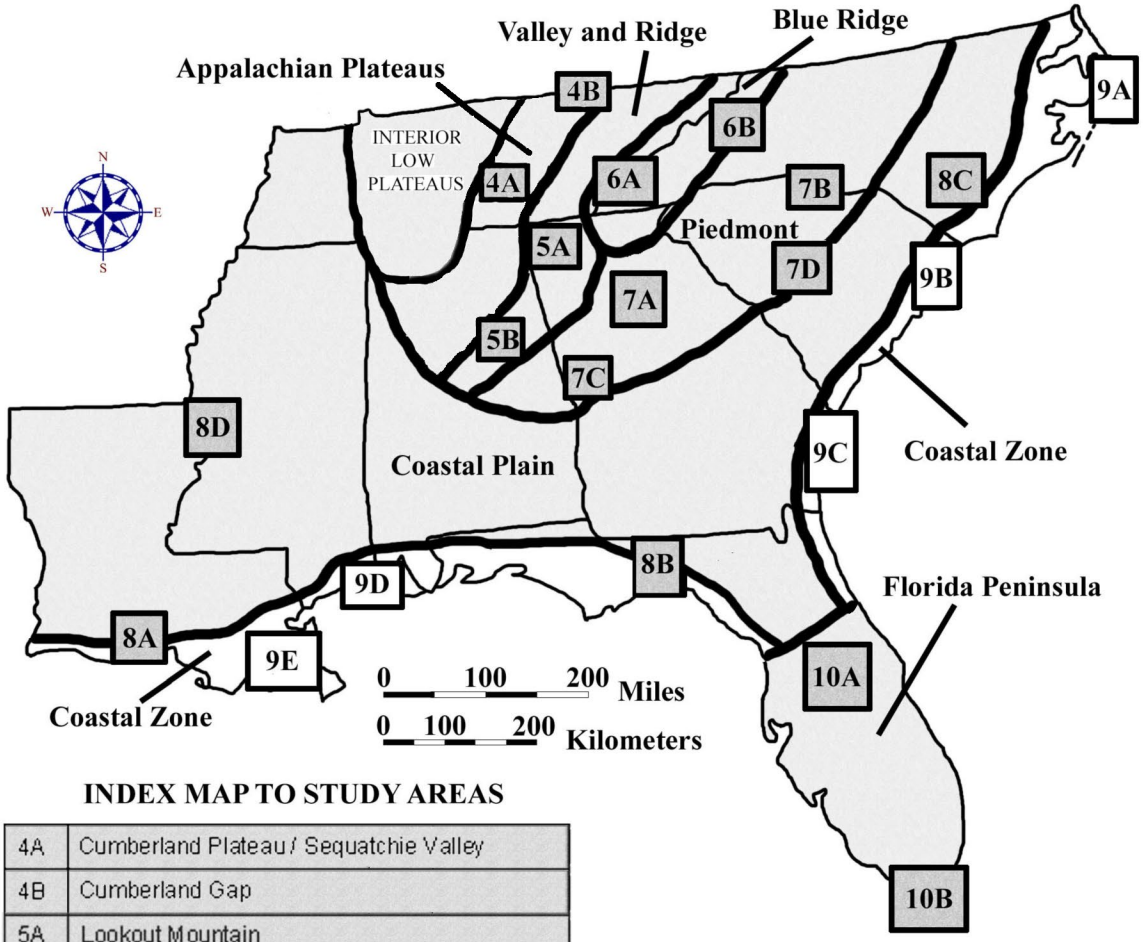
CHAPTER 9

COASTAL ZONE REGION



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BACKGROUND INFORMATION

Description of Landforms, Drainage Patterns, and Geological Processes

Characteristic Landforms of the Coastal Zone

The **Coastal Zone**, sometimes referred to as the tidewater area, extends from the coast inland to the farthest extent of tidal influence. This distance varies considerably from place to place but averages about ten miles. Elevations range from zero, at sea level, to approximately 25 feet; and local topographic **relief** is usually less than five feet. The water level and salinity of streams in the area are influenced by the daily cycles of the tides and many stream valleys widen into broad **estuaries** before they reach the ocean. Coastal beaches vary greatly in their shape and size, but are usually fairly wide and slope gently. Older, abandoned beach ridges often run parallel to the coast but occasionally intersect the modern shoreline. Beaches are interrupted by many inlets, estuaries, deltas, bays, and islands and often feature wide expanses of **marshlands** on their landward sides.

Some geographers separate the Atlantic and the Gulf of Mexico Coastal Zones into two separate regions, but the shoreline processes and coastal landforms are basically the same in both areas. The only major difference is in the slope of the underwater continental shelf which is extremely wide and shallow in the Gulf of Mexico while dropping off more steeply along the Atlantic coast. Ocean temperatures are not as different as might be expected because the warm Gulf Stream current along the Atlantic coast carries warmer tropical waters quite far to the north. Tidal effects along both coasts vary considerably from place to place due to differences in underwater topography and the geometric shape of the coastline. Both coasts are geologically defined as sand-dominated transgressive depositional shorelines that are slowly migrating landward in response to recent sea-level rise (with the exception of deltas where sediment is building seaward). Tectonically, both are part of the passive, stable trailing edge of the North American continent. However, certain coastal areas have seen relatively recent geologic uplift while other areas have experienced greater than average subsidence.

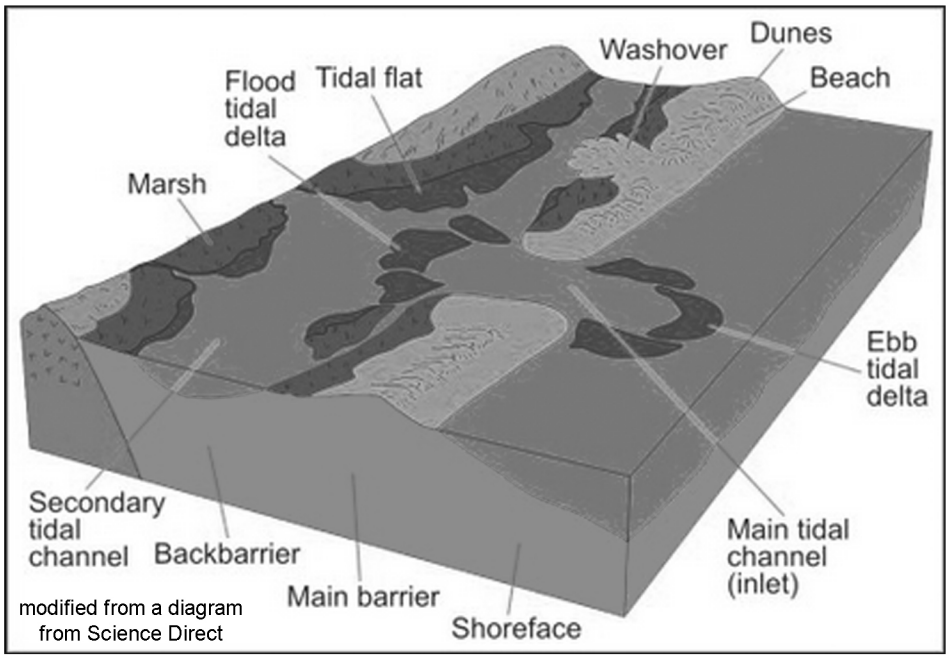
The term ‘shifting sands’ could describe most Coastal Zone landforms. Ocean currents and occasional storms such as hurricanes both build and destroy beaches and move enormous quantities of sand each year. The most common coastline configuration is a fairly straight chain of barrier islands, cut periodically by tidal inlets and estuaries, which separate the open ocean from landward bays, sounds, marshlands, lagoons, and rivers. A second type of shoreline is the Grand Strand of the Carolinas where localized uplift of the land has placed the ocean directly in contact with older Pleistocene beach ridges. A third infrequent, but important landform is the delta, a depositional feature that forms whenever a river brings sediment to the ocean at a faster rate than wave and tide action can remove it. The result is a thick wedge of sediment that grows slowly out into the open ocean and increases the amount of land acreage in that area. While the Mississippi River Delta is the

largest and most well-known, other deltas have formed in the Southeast, including the Santee River Delta in south Carolina which is the largest on the Atlantic coast.

Estuaries form when pre-existing river valleys have become flooded with seawater due to a rise in sea level. The result is a very wide, brackish water embayment often containing small islands of high ground and surrounded by wide expanses of **salt marshes** cut by winding tidal creeks. The deeper creeks hold water even at low tide level while only the peak of the six-hour tidal cycle floods the marsh surface. Most Southeastern rivers enter the ocean through estuaries. They are essentially wetland areas, where fresh water from inland sources joins incoming salt water from the oceans.

Tidal flats are mostly flat, low-lying areas flooded by seawater part of the time and exposed to the air part of the time. The total amount of land flooded depends on the tidal range and the effects of storms. In many ways tidal flats are similar to river **floodplains**; they drain the higher portions of the mostly featureless plains covered with marsh grass. The channels **meander** widely across muddier areas forming occasional **tidal channel levees** and sandy **point bar deposits**. The channels often interconnect, especially near the **tidal inlet**, which provides access to the open ocean. Some tidal flat systems are dominated by a very strong incoming tidal current. Sediments are pushed landward by these currents to form flood tidal **deltas**. If the outgoing tidal current is stronger, sediments will often be carried out into the open ocean, through the tidal inlet, to form ebb tidal deltas. The relative amount of erosion and deposition on any portion of the tidal flat depends on the height of that land above or below average sea level (mean sea level).

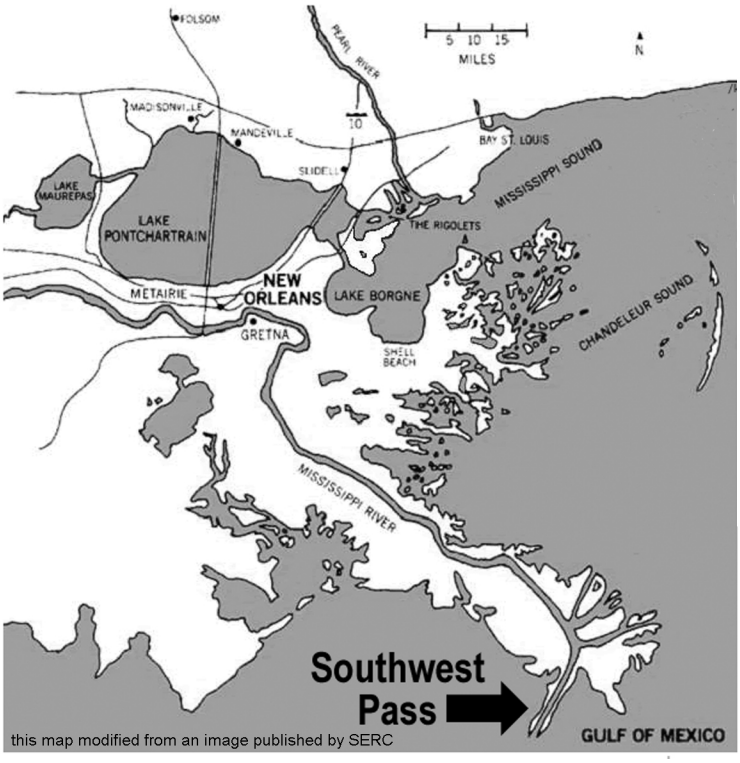
Figure 9-1: Features of a Barrier Island Coastline



Geographic Features and Localities of Special Interest

Both the Atlantic and Gulf of Mexico shorelines vary in shape and style from one location to another. Along the Louisiana coast, the Mississippi River has formed the largest delta complex in the United States and the seventh largest in the world. The 'birdfoot' shape of this feature is the result of the constant battle between the dominant flow of the river versus the wave and tide processes at work in the Gulf of Mexico. In the past, the river would build out sediment to a critical distance and then shift its channel to another outlet, building a new delta at a different location. In recent years, artificial levees along the river have prevented such course changes. Two other significant delta complexes have formed along the coast of the Southeast, the Appalachicola River Delta near Cape San Bias in Florida and the Santee River Delta in South Carolina. The Santee River has transported enough sediment to built the largest delta along the Atlantic coast.

Figure 9-2: Map of Mississippi River Delta



To the east, the Mississippi Gulf Coast stretches all the way from eastern Louisiana to near Mobile, Alabama. This is a barrier-island dominated shoreline that features a long and very wide back-barrier bay named the Mississippi Sound. The water depth in the Sound averages only about 10 feet (3 meters) and the barrier islands are thought to be remnants of offshore sand shoals that emerged around 4,000 years ago and are maintained solely by the addition of sand brought in by longshore marine currents. These islands are continually changing shape as the sand is redistributed by daily wave action and by storms. Primarily because of the prevailing southeasterly wind direction, sand is typically eroded from the eastern end of each island and re-deposited on the west end. Some of these islands have added over a mile (1.6 kilometers) of sand on their west ends over the last hundred years. A few have been cut in half by hurricane storm surges.

Figure 9-3: Map of Mississippi Gulf Coast

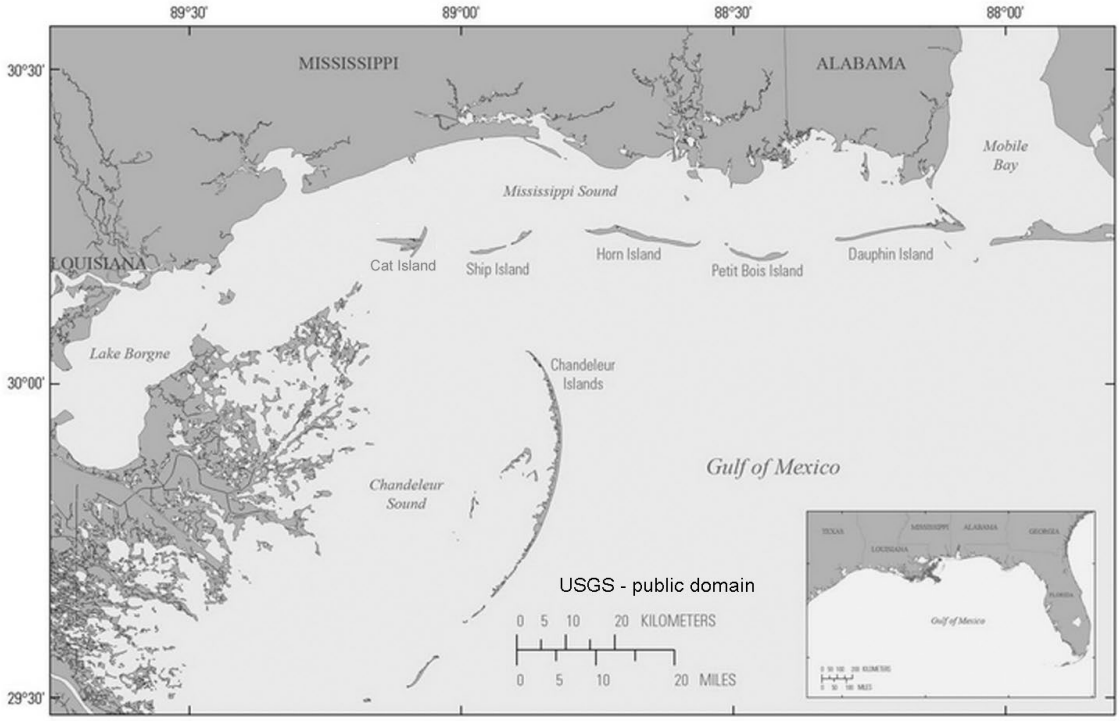
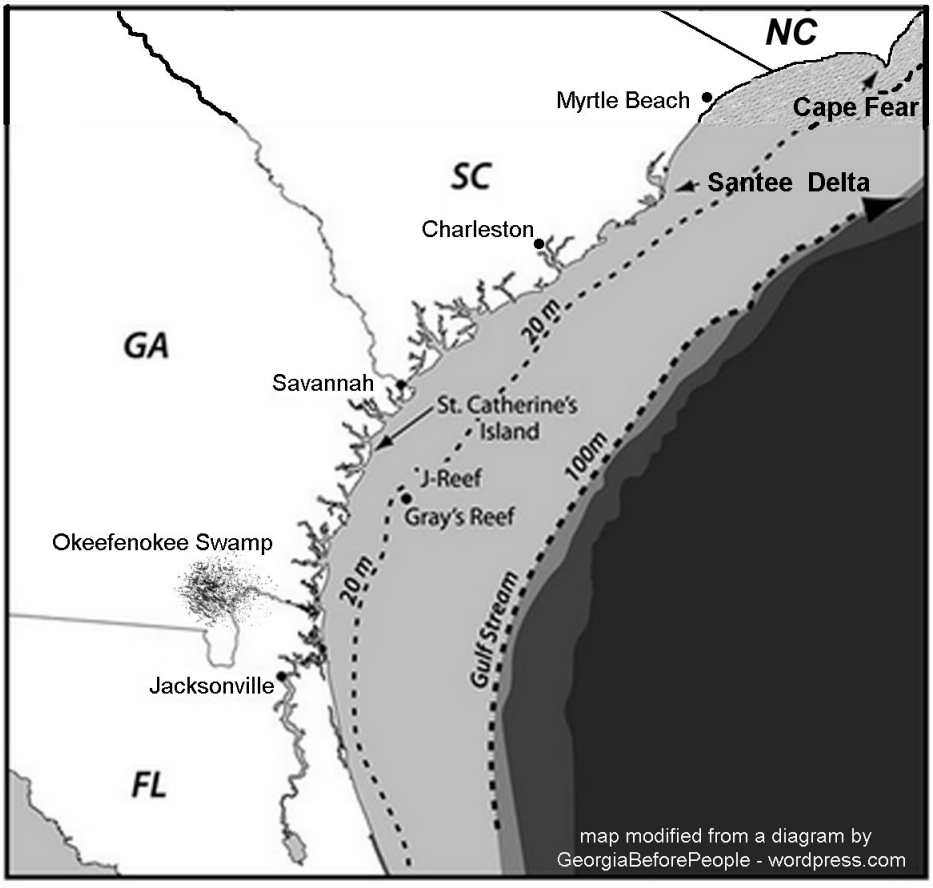


Figure 9-4: Map of the Georgia Bight

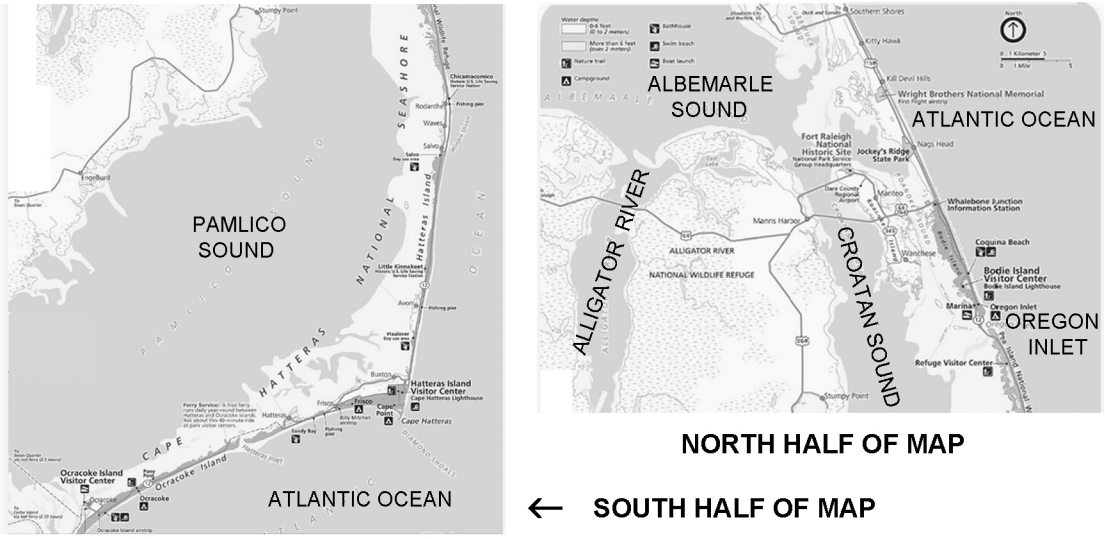


The West Florida coastline, usually referred to as the 'panhandle' region, consists of mainly sandy beaches, broad capes, and a few narrow barrier islands. Beaches are primarily located on the mainland and are characterized by calm water, white powdery sand and a lot of broken shell material. Very little sand is added to the mix by coastal rivers. The short, narrow barrier islands are uninhabited and prone to washover events by storm waves. Cape San Blas protrudes into the Gulf waters as part of the Appalachicola River delta complex. The lower 30 miles (48 kilometers) of that river is surrounded by extensive swamps and wetlands, except at the coast.

On the Atlantic coast, the Georgia Bight, an inward curvature of the coastline, stretches 746 miles (1,200 kilometers) from Jacksonville, Florida to Cape Hatteras, North Carolina. This coast consists of an almost continuous chain of barrier islands that are interrupted only by the Santee River Delta and the Grand Strand, a short stretch of 80 miles (129 kilometers) from Winyah Bay, near Georgetown, South Carolina, to Cape Fear in North Carolina. Behind most of the barrier islands are very narrow lagoons that are rapidly filling in with salt marshes. The crescent-shaped Grand Strand is characterized by a stable 100,000 year old sand barrier formation that forms a nearly continuous beachfront broken only by a few isolated tidal inlets. A little farther away from the actual coast are freshwater swamps like the Okeefenokee Swamp in Georgia and the Dismal Swamp in North Carolina.

From Cape Hatteras, North Carolina, to the Virginia state line, the coastal landscape pattern changes slightly. In this region, the barrier islands are referred to as the 'Outer Banks' and they are separated from the mainland by relatively wide open-water lagoons and sounds. Most of the larger Piedmont rivers of North Carolina drain into these waters. Over time, the exact number of islands and inlets changes as new inlets are opened up, often during violent storms, and other inlets close, usually due to shifting sands. The Outer Banks are the most hurricane-prone area anywhere in the southeast north of Florida.

Figure 9-5: Map of the Outer Banks

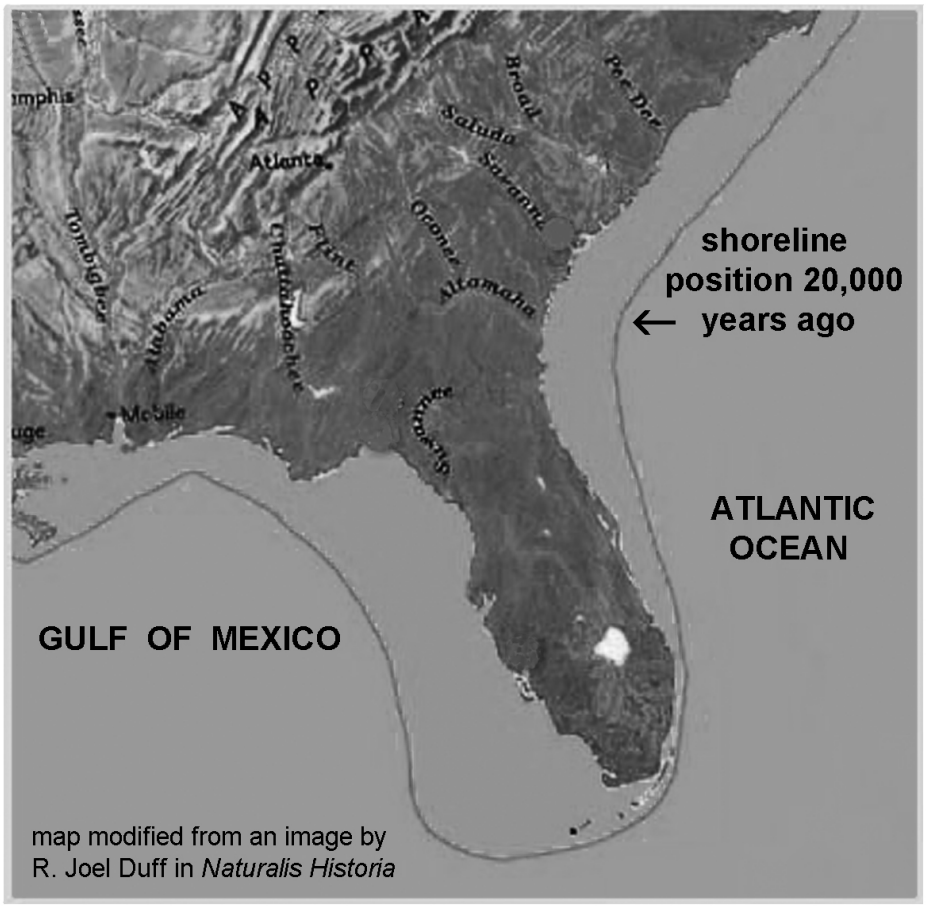


Rock Types and Geologic History

It is difficult to talk about rocks in the Coastal Zone because there are almost no situations where any rocks are visible at the surface. All of the most prominent coastal landforms are composed of modern sediments, mostly sand, silt, and clay, which have either been directly deposited or reworked by modern marine processes. However, the region does have a dynamic and interesting geological history.

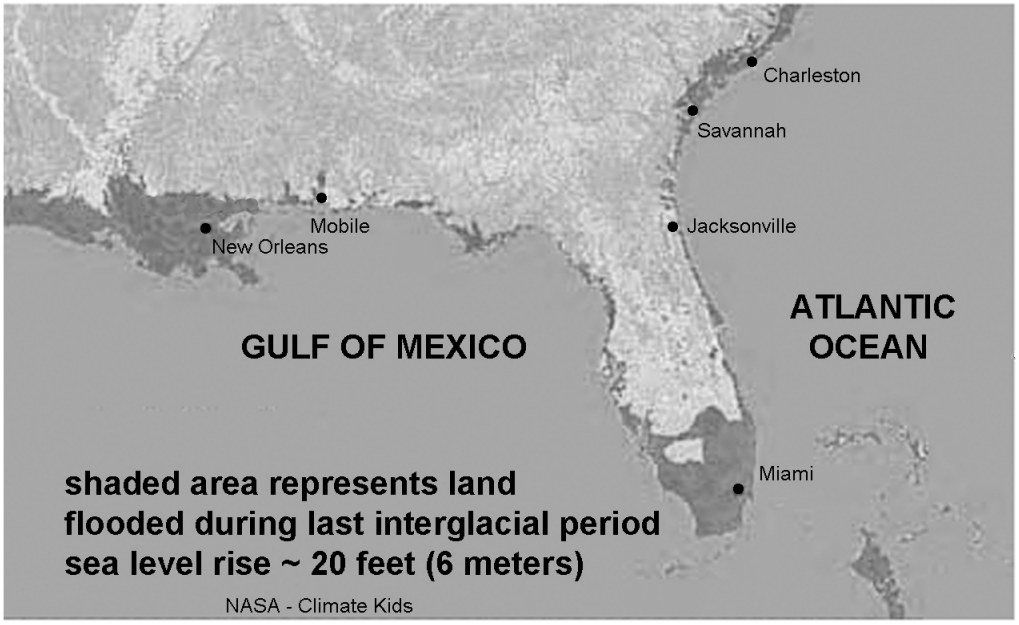
Over two hundred million years ago, there was no Atlantic Ocean or Gulf of Mexico, and the North American continent was joined with Europe, Africa, and South America in a supercontinent named Pangea. Tectonic activity then triggered sea-floor spreading and continental drift that soon opened an embryonic Atlantic Ocean that has been growing wider ever since. The Gulf of Mexico was originally part of an inland sea that covered most of the western states until regional uplift cut off its connection to the Pacific Ocean. Later subsidence in the Southeast opened up connections with the Atlantic and for the rest of the Cenozoic Era, the shorelines of both oceans fluctuated landward and seaward throughout the Coastal Plain region as sea levels rose and fell. The current Coastal Zone region simply occupies the most recent shoreline position in this long migration process.

Figure 9-6: Sea Level During the Last Ice Age



The features seen in the Coastal Zone today are primarily the result of sea-level fluctuations during the Pleistocene Ice Ages. There were actually four major ice advances that affected North America over the past 1.6 million years. Although the Southeast did not experience any actual ice cover, the climate shifts in the region were dramatic. During each of those cold periods, worldwide sea level dropped by as much as 400 feet (122 meters) and the position of the shoreline moved far out onto the continental shelf into areas that are now completely submerged beneath ocean waters. During warmer interglacial periods, worldwide sea level increased by about 20 feet (6 meters) and the shoreline moved inland, leaving many relict beach ridges behind that are now standing high and dry far from the ocean.

Figure 9-7: Sea Level During the Last Interglacial Period



Influence of Topography on Historical Events and Cultural Trends

Folklore

Ancient Native Americans who inhabited the seacoasts took advantage of the plentiful fish, game, and shellfish available in this region. Most of our information about their culture comes from archeological study of middens, essentially garbage dumps that were left behind when communities moved from a village. Along the coast, shell middens provide especially valuable data as some pottery, shells and charcoal can be analyzed by radiocarbon dating methods to establish exactly how long ago a village was occupied. The contents of a midden can also help archeologists reconstruct past human behaviors. In addition to containing artifacts that reveal how daily tasks were carried out, the items a person throws away are a reflection of what kinds of food they will eat and what they will not eat. Bones from food animals and pollen from plants also provide valuable data.

The Coastal Zone was settled in different places by different groups representing different European nations. The Louisiana Coast has been the center of French culture in the United States since the founding of New Orleans. One of the oldest folk tales in the region dates back to the time of the Louisiana Purchase in 1803. It is the story of the 'grunch', a monster said to be the size of a man, but with razor sharp teeth and the legs of a goat. It lurks in the tall grass along Grunch Road (which has since been renamed) waiting for someone to park a car there. This deformed being is said to feed on goats, livestock, and people. Some of the stories claim that the grunch was a man who had a curse put on him by the local Voodoo Queen, Marie Laveau.

Legend of the Grunch

--Traditional; excerpted from a version told on *witchesbrewtours.com*--

According to legend, when New Orleans was a relatively newly-established city, there was a road in the eastern section of the town. This road led deep into a seemingly abandoned wooded area, before eventually leading to a dead end. However, it wasn't abandoned. Deep in those woods, creatures that were half-human and half-beast lived. Nobody knew what they were, and considered them the devil's creations. They continued to breed, and their offspring became even less human, and more terrifying.

It wasn't long before livestock, mainly goats, began going missing from around New Orleans…. Was It The Grunch? Farmers would awake in the mornings to discover numbers of their goats missing or devoured in their fields. This became a frustrating inconvenience, and while people speculated it might be the fabled creatures on Grunch Road, they couldn't prove that it was more than a mere wolf or coyote. But then people began disappearing, one by one, and sightings of the horrifying creatures in the woods were becoming more frequent.

While nothing was ever done about the Grunch in the woods, mainly because of their ability to remain undetected and flee quickly, the disappearances haven't slowed. According to the stories told by locals, the Grunch will leave a wounded goat on the roadside to attract passers. Once the travelers depart from their vehicles, however, the Grunch show themselves, taking the people deep into the woods to be devoured. So, if you're traveling through New Orleans and see an injured goat on the roadside, heed this advice: think twice before you stop.

In Florida and Alabama, the Spanish first set up military outposts along the Gulf coast as centers for exploration efforts (Hernando De Soto launched his expeditions from the Appalachee Coast near Tallahassee, Florida and intended to return to an outpost on Mobile Bay in Alabama), but they are credited with founding the first permanent European settlement in North America at St. Augustine, Florida in 1565. Many local legends in Florida are told about boatmen and fishermen who have seen 'ghost ships' haunted by spirits who brought bloody mutinies, deathly plagues, and other unexplained occurrences upon unsuspecting sailors. Other accounts of ghostly appearances center on cemeteries, where spirits have been reported to roam the grounds among the live oak trees.

The English settlers who colonized the Carolinas and Georgia also brought their own ghost tales with them, but were even more focused on the activity of witches. Several popular stories referred to 'hags' (an old English term for witch) who terrorized people at night by sitting on a victim's chest to produce nightmares. The hag had to be gone before daylight or they would die. Such stories were often used to frighten children into being well behaved or going to sleep on time. There were many types of hags, some even inhabited streams and rivers and would drag children into the water if they ventured too close to the edge of the riverbank. Other stories of mythical creatures such as dragons, brownies, goblins, trolls, and unicorns also made the transition to the new world.

In the rice fields of South Carolina and Georgia, a creolized African-American folk culture developed as more and more slaves were brought to the region from West Africa. These enslaved Africans spoke diverse languages and were under great pressure to understand their white masters as well as to be able to communicate with each other. This situation forced the slaves to develop an alternate language called Gullah. This language, still spoken by some modern residents of the Sea Islands, is called a creole language because it is a blend of English and several languages used in West Africa, and is very similar to other creole languages that have developed along the West African Coast. A number of Gullah words have entered our everyday vocabulary: tote: 'to carry'; chigger: 'small flea'; goober: 'peanut'; and, nana: 'grandmother'. In addition to words and phrases, many interesting beliefs and practices, such as the examples that follow, were handed down in Gullah folklore.

Gullah Beliefs and Folklore

--Adapted from Reminiscences of Sea Island Heritage; Legacy of Freedmen on St. Helena Island, by Ronald Daise--

The palmetto branch was used to discern whether a person had spoken untruthfully about theft. With two palmetto leaves placed on either side of the accused's neck, the person performing the ritual would command the fronds to "Tie, palmetto, tie" if a lie had been told. According to lore, the green blades would entwine around a liar's neck, beginning to choke him.

Whenever a family member died, survivors would mourn the death for a year by dressing only in black when appearing in public. Some dressed in black even in their homes. If a deacon died, a black bow was affixed somewhere in the church.

The expression "let mornin' star greet you on yo' prayin' groun" began during slavery. Because they weren't allowed to worship openly, slaves sneaked to their "prayin' grounds" in the woods late at night. The morning star was their timepiece. When it started twinkling, slaves knew morning would soon follow. They then returned home before they were missed, to escape being whipped.

A fireplace at night was a common site for reliving local ghost tales. One favorite tale was about "the hag," which supposedly sat on people's faces at night as they slept, disorienting and terrorizing them.

Another popular belief among the Gullah peoples on St. Helena's Island is that the second belt a woman wore beneath her waist, to raise the level of her long skirts when working in the field, gave her extra strength.

Historical Events

In the 1700's, as many as twenty separate Native American Nations lived in the vicinity of the bays and sounds and along the coastal rivers. As a result, many towns, rivers and landforms in the region bear Native American place names. Clashes with the European colonists, disease, and slavery all worked to displace or eliminate almost all of the native inhabitants within a period of two hundred years. When Europeans arrived as explorers, they learned about Native American legends about gold and other riches available inland and began establishing settlements and forts along the coast from which they could launch expeditions.

The earliest permanent settlement along the Atlantic coast was St. Augustine, Florida, founded by the Spanish in 1565. However, earlier settlements had been attempted. In 1526, Lucas Vasquenz de Ayllon, along with 500 Spanish colonists, including men, women, and children, several slaves, and 89 horses, left Santo Domingo in six ships. They landed at the mouth of the Cape Fear River, North Carolina, which they called the River Jordan. From there the group traveled down the coast to settle near the mouth of the Pee Dee River in South Carolina. The settlers were threatened by disease, attacks from Native Americans, and a slave insurrection. Early in 1527, the colonists headed home for Spain with only 150 survivors.

In 1521, Spanish explorer Francisco Gordillo explored the area near Beaufort, South Carolina, which he named Santa Elena because his ships reached land on the feast day of that saint. The purpose of the Spanish settlement at Santa Elena was to protect the Spanish treasure ships which had to sail up the coast of North America before picking up the prevailing westerly winds to carry them back across the Atlantic Ocean to Spain. In 1576 the settlement at Santa Elena was destroyed in an attack by Native Americans, but the Spanish returned and rebuilt it in 1577. When the English captain Sir Francis Drake burned St. Augustine, Florida, in 1586, the Spanish royal government realized that its colonial resources were stretched too thin for proper protection. Therefore, in 1587, the settlement at Santa Elena was abandoned - the same year that the first English attempts at settlement were being made on Roanoke Island, North Carolina.

After two attempts at colonization on Roanoke Island, both unsuccessful, the English finally succeeded with a colony along nearby Albemarle Sound in 1653. Soon after, in 1670, approximately 150 colonists settled along the Ashley River in South Carolina and named the settlement Charles Towne. The first settlement in Georgia, at Savannah, did not take place until 1733. Meanwhile, the French were attempting to colonize the Gulf Coast. Biloxi, Mississippi was founded in 1699 and Mobile, Alabama was founded in 1711. Although many explorers had traveled up and down the Mississippi River for years, New Orleans, Louisiana, was not established until 1718. In the 1730's French Creoles were beginning to exploit the delta wetlands, but the most significant colonization effort occurred in 1755 when the French Acadians arrived from Canada.

In the Southeastern Coastal Zone, the Revolutionary War only involved the colonies of Georgia, South Carolina, and North Carolina. The British forces controlled

most of the coastal cities while the Patriot and Tory forces fought each other in the back-country. Most of the decisive battles in this war were fought in the upstate of the Carolinas. During the War of 1812, the final battle took place near New Orleans, a battle which the Americans won. Farther east, a two-day battle for the city of Pensacola, a coastal city in the Panhandle of Florida, ended in a Spanish surrender. The Civil War involved all of the Southeastern states and several coastal cities were major battle sites. The actual start of that war took place at Fort Sumter in the harbor of the coastal city of Charleston, South Carolina. And Sherman's infamous 'March to the Sea' through Georgia ended at the coastal port of Savannah.

After the Civil War, coastal cities fared much better than the rest of the South. As centers of trade and commerce, these places recovered economically much more quickly, but they also supported the racial segregation policies and 'Jim Crow' laws that kept Blacks relegated to second-class citizenship. However, one coastal community, near Beaufort, South Carolina became part of what was known as the Port Royal Experiment, an attempt to educate ex-slaves so they could be self-sufficient. Some of the freedmen were able to purchase small tracts of land, and General Sherman, in 1865, issued an order that set aside all the sea islands from Charleston to Port Royal, including all land within 30 miles from the coast, exclusively for newly freed slaves. However, President Andrew Johnson, during the Reconstruction Period, ordered this land to be restored to its original White owners, with the exception of a few islands in the Port Royal area. One enduring feature of the Port Royal Experiment is the Penn Center on St. Helena Island, which was established by Quaker missionaries from Pennsylvania to teach the local inhabitants basic skills in reading and writing. During the 1960s, the Penn Center facilities were used by civil rights organizations as a training center. Famous participants in these sessions included Dr. Martin Luther King, Jr., Andrew Young, John Lewis, and Jesse Jackson.

Influence of Topography on Commerce, Culture, and Tourism

For most of the port cities during the colonial period, trade was the economic engine that drove everything else. The colonies could provide items, like deerskins and naval stores, that their European rulers could not obtain easily at home. Certain agricultural products, like indigo, rice, and sea-island cotton did very well in the warm, moist environments of the Coastal Zone and these items became extremely valuable in trade. Eliza Lucas Pinckney is given credit for successfully introducing indigo as the first major cash crop in the colony of South Carolina. The leaves and stems of the indigo plant were processed to produce a dark blue dye. In 1741, at the age of nineteen, she produced her first successful indigo crop. She then gave indigo seeds to other planters. By 1747, more than 100,000 pounds of indigo per year were shipped from the colony. The expansion of indigo cultivation to the sea islands region led to the emergence of a plantation economy in the mid 1740's. The Revolutionary War ended the commercial growing of indigo due largely to the fact that the British government was no longer willing to pay Americans a bounty for its production, making it no longer profitable.

The Rice Plantation Era originated in South Carolina in the early 1700's when the river basins around Charleston and Georgetown became major tidewater rice cultivation

areas. Many historians believe that rice seeds were first brought to America by Africans from Madagascar, a large island off the east coast of Africa. Georgetown became the major port for exporting rice to England and the West Indies. Later, rice cultivation spread to the sea islands of Georgia, in particular the land on the Altamaha River Delta that provided perfect conditions for growing rice. The extremely labor intensive nature of rice production created a planter's aristocracy of great wealth and power, made possible by the hard work of thousands of slaves.

The search for a new cash crop to replace indigo led to the introduction of a particular type of cotton cultivation - so-called Sea Island cotton. The early variety of Sea Island cotton, called black seed cotton, produced a long staple fiber measuring 1.5 to 2.5 inches. It required a long growing season and drier conditions than some other varieties, which limited cultivation to the warmer portions of the Coastal Zone. Sea Island cotton bolls tended to rot in the moister inland areas, but thrived in the salt air along the coast. The plantation system, already in place with indigo and rice, provided the necessary labor.

By the late 1800's, a new economic model was required, both because labor could no longer be supplied by slaves, and because increased mechanization was rendering labor-intensive practices obsolete. After weathering a long period of economic doldrums (with some exceptions like port activities) the Coastal Zone has been reborn as a tourism and recreation mecca. Tourist destinations like Panama City Beach, Florida, Myrtle Beach, South Carolina, Nags Head, North Carolina, Tybee Island, Georgia, West Beach, Alabama, Gulfport Beach, Mississippi, and Grand Isle, Louisiana compete each year for the title of 'best beach in the South'. The charm of old cities like Charleston, South Carolina, Savannah, Georgia, St. Augustine, Florida, and New Orleans, Louisiana also attracts hordes of visitors. Part of the attraction of the coast to vacationers, convention planners, and other tourists is the availability of fresh seafood in markets and restaurants. Fishing is a multi-million dollar industry in every coastal state with shellfish accounting for about three quarters of that total. Other tourist activities commonly available at beach resorts include boating, scuba diving, parasailing, deep-sea fishing, and shell collecting. For tourists looking for a more back-to-nature experience, each state has designated certain beaches as protected areas set aside for wildlife preserves or parks.

Natural Resources, Land Use, and Environmental Concerns

Climate and Water Resources

Climate is fairly uniform across the Coastal Zone. Although the Atlantic Ocean coastline extends much farther north than the Gulf of Mexico coastline, ocean waters there are warmed by the Gulf Stream current and moist air masses that form over the Gulf of Mexico usually end up affecting the Atlantic coast as well. In the Gulf of Mexico, ocean temperatures can reach over 80°F (27°C) in the summer months and seldom drop below 60°F (16°C) in the winter. At most Atlantic Ocean beaches in North Carolina, summer ocean temperatures also can exceed 80°F (27°C), but winter temperatures often drop below 50°F (10°C).

The Coastal Zone is almost always cooler and more pleasant than neighboring areas even a few miles inland. The contrast between land and sea temperatures creates almost continual land or sea breezes, and causes many convection-current based thunderstorms to develop during the hot summer months. During the cooler months, fog sometimes envelopes shoreline areas and helps to distribute moisture. Rainfall is abundant and temperatures usually moderate. The entire area is prone to periodic damage from hurricanes and tropical storms that can cause extensive beach erosion, storm surges, washover deposits, and even create new tidal inlets through existing barrier islands.

Although it would seem that the Coastal Zone has more than enough water, most of it is either salty or brackish. One of the major issues facing coastal communities is how to acquire sufficient fresh water, for drinking and household use, to support the anticipated growth in both the resident population and in seasonal tourists. Coastal cities have traditionally handled this problem in one of two ways. Some have constructed aqueduct systems to bring in large quantities of fresh water from upstate rivers and reservoirs. However, most fresh water for coastal communities, especially in rural areas, comes from wells. Although groundwater is plentiful, in many sections of the coast it is being used at a faster rate than can be replenished through natural geologic recharge. The result has been salt water incursion into many wells. Because fresh water is less dense, it forms a floating lens on top of the denser salt water. When wells are pumped too quickly, the freshwater lens thins to the point where salt water can enter the base of the well and contaminate the water supply.

Soils and Agriculture

The soil on barrier islands is primarily just loose sand, but away from the beach enough organic material can accumulate to support scrub vegetation like sea oats and other grasses and a few species of trees like Red Cedars and Wax Myrtle. Salt marshes are populated primarily by Spartina grass. Further inland, from three to twenty-five miles from the seashore, the soils are extremely young, so there has not been enough time for distinctive soil layers to form. Some unusual soil types have developed in this region, including Spodosols, very acid soils that usually occur under coniferous forests in more northern climates, and Sulfaquents, the sulfurous rotten-egg smelling soils typical of the salt marshes. Soils formed in river delta deposits are less acidic and extremely fertile. Soil nutrients are replenished each time the river floods. Abandoned delta floodplains often form swampy wetlands that accumulate lots of organic material and can produce peat-like soils capable of supporting dense forests.

Although overall climate is favorable along the coast for agriculture, soils are the limiting factor in determining what can be grown. Closest to the coast, unweathered minerals, which make poor soil, are often found in surface layers of the soil. As one proceeds away from the coast, unweathered minerals are found at greater depth and the fertile topsoil thickness increases. In some areas, poor drainage limits suitability for agriculture, but pine forests do very well. The sea islands of Georgia and South Carolina have better drained **loamy** soils that support truck farming. Only four percent of the Coastal Zone Region is considered prime farmland and approximately nine percent of the

area is actually used for farming. Fifty percent of the area is in forest. In certain places along large estuaries, the soils are ideal for rice cultivation and the rise and fall of the tides provides the necessary flushing action to keep the rice fields productive. Sea-island cotton and sugar cane were other crops that flourished in the tidewater environment.

The tidewater ecosystem is a region of dynamic activity, constantly changing in response to tidal action and to the varying amounts of fresh water that are introduced into the system by seasonal and meteorological variations. Rivers, creeks, and smaller tributaries serve as arteries for transporting nutrient-rich material eroded from upstream. This material, along with nutrients brought in by the tides, nourishes many forms of marine life, especially the larval stages of invertebrate species that flourish in this protected environment. As a result, salt marshes are often referred to as the nurseries of the sea. In addition to fishing operations, crab, oyster, clam and shrimp harvesting is commercially feasible in many Coastal Zone locations.

Mining and Resource Extraction

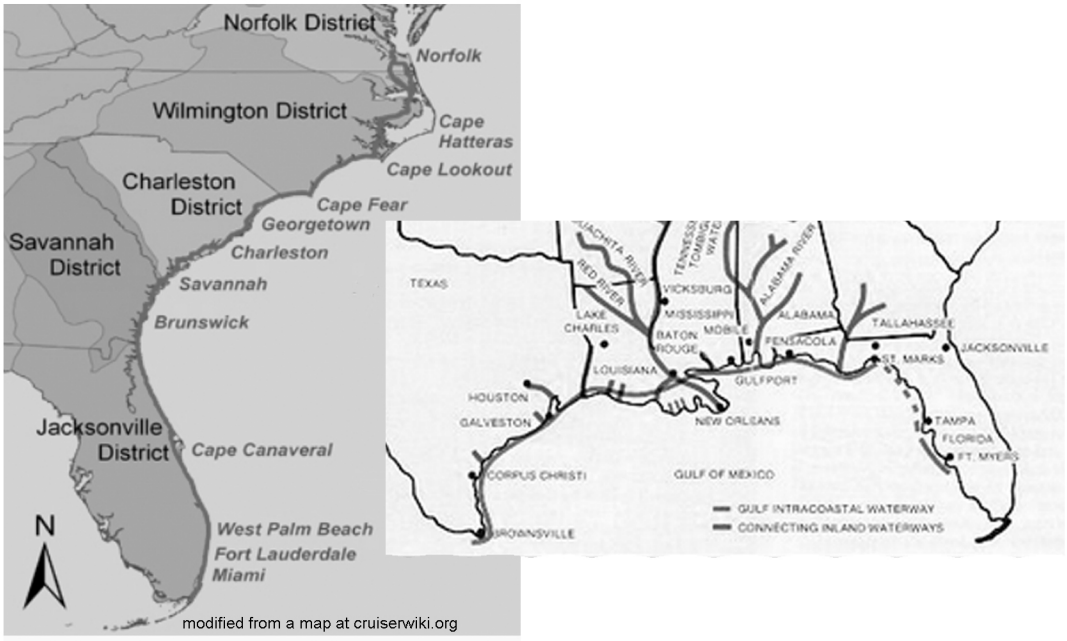
Very few resources other than sand are extracted from the land surface of the Coastal Zone. Phosphate deposits along some parts of the Florida Gulf coast were mined commercially in the past, but these operations are no longer economically feasible. The high water table level makes quarrying operations in this region nearly impossible. There are, however, extremely valuable oil and gas resources deep underground, both onshore and offshore along the Gulf of Mexico coastline. Offshore drilling platforms extend from Louisiana to Alabama and provide a major economic boost to those states. In addition to oil and gas, sulfur and salt deposits are also recovered from these wells and processed. Oil spills and pipeline leaks, particularly offshore, are the most significant environmental hazards associated with drilling operations.

The Coastal Zone provides an endless variety of habitats important to wildlife. Every state has designated areas preserved as publicly managed parks and reserves. Most of these sites include beaches, barrier islands, brackish and saltwater marshes, forested wetlands, and pine and hardwood upland areas. They also offer protection for such threatened and endangered species as the bald eagle, woodstork, osprey, loggerhead sea turtle and the shortnose sturgeon. Publicly managed lands serve to maintain and enhance the present habitat diversity while improving recreational and educational opportunities for both local citizens and visitors.

The Intracoastal Waterway is made up of a series of connected natural and constructed water passages along the Atlantic and Gulf coasts that provides a protected navigational route for all types of ships. It stretches nearly 3,000 miles from Boston, Massachusetts to Key West, Florida and westward to the Rio Grande River in Texas. Although there have been discussions and plans for developing a water passageway along the Atlantic seaboard since colonial times when George Washington surveyed the area, true enthusiasm for construction did not begin until the World War I era when the Army Corps of Engineers began designating certain navigable waters for military maneuvers. In 1936, the last section of the waterway, between Little River and Winyah Bay, in South

Carolina, was completed. The river-like characteristic of the Intracoastal Waterway offers a tremendous advantage to commercial, recreational, and military vessels which no longer have to venture into the Atlantic Ocean where open water conditions are much more likely to be stormy and dangerous. Today, the waterway is almost exclusively used for tourist travel and shellfish harvesting operations.

Figure 9-8: Route of the Intracoastal Waterway



Several environmental issues pose a great concern for coastal communities. A certain amount of tension exists between people who want to preserve the natural state of beaches and other natural coastal features and those who desire to profit economically from those beaches. The crowding and clutter characteristic of many famous tourist beaches is contrasted by the carefully managed development of a few upscale resorts that have tried to maintain as much of the natural beauty as possible. The loss of wetlands is also a major concern. In addition to being a nursery site for shellfish and other invertebrates, wetland ecosystems have a unique ability to remove certain non-point source pollutants. Some pollutants are chemically trapped by the abundant organic matter, while microorganisms break down others, such as nitrates, into harmless gases. Sea-level rise is another important concern to coastal cities, such as Jacksonville, Florida, Charleston, South Carolina, and Mobile, Alabama.

PLACES TO VISIT IN THE COASTAL ZONE

Barrier Island Environmental Education Program at St. Christopher Camp and Conference Center. 2810 Seabrook Island Road, Johns Island, SC 29455-6219. For more information call 843-768-1337 or search online at http://www.stchristopher.org/index.php?BI

Cape Hatteras National Seashore. 1401 National Park Drive, Manteo, NC 27954. For more information call 252-473-2111 or search online at http://www.nps.gov/caha/index.htm

Cape Lookout National Seashore. 131 Charles Street, Harkers Island, NC 28531. For information call 252-728-2250 or search online at http://www.nps.gov/calo/.

Cumberland Island National Seashore. 101 Wheeler Street Saint Marys, GA 31558. For information call 912-882-4336 or search online at http://www.nps.gov/cuis/.

Gulf Islands National Seashore. 1801 Gulf Breeze Parkway, Gulf Breeze, FL 32563-5000. For information call 850-934-2600 or search online at http://www.nps.gov/guis/.

Gulf Islands National Seashore. 3500 Park Road, Ocean Springs, MS 39564-9109. For information call 228-875-9057 or search online at http://www.nps.gov/guis/.

Jean Lafitte National Park/French Quarter Visitor and Folklife Center. 419 Decatur Street, New Orleans, LA 70130. For more information call 504-589-3882 or search online at https://www.nps.gov/jela/index.htm

Jekyll Island 4-H Center. 201 South Beachview Drive, Jekyll Island, GA 31527. For more information call 912-635-4117 or search online at http://www.jekyll4h.org/

Jockey's Ridge State Park. 300 W. Carolista Drive, Nags Head, NC 27959. For more information call (252) 441-7132 or search online at https://www.ncparks.gov/jockeys-ridge-state-park/home

Louisiana Children's Museum. 420 Julia Street New Orleans, LA 70130. For more information call 504-523-1357 or search online at http://www.lcm.org/

Myrtle Beach State Park. 4401 South Kings Hwy, Myrtle Beach, SC 29575. For more information call 843-238-5325 or online at https://southcarolinaparks.com/myrtle-beach

Tybee Island, Georgia. 20 miles east of Savannah, Georgia. For more information call the Tybee Island Visitor's Center at 800-868-2322 or search online at http://www.tybeevisit.com/index.php

Wright Brothers National Memorial. 1401 National Park Drive, Manteo, NC 27954. For more information call 252-473-2111 or search online at https://www.nps.gov/wrbr/index.htm

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Saxon, Lyle, Dreyer, Edward, and Talbot, Robert. (1991). *Gumbo Ya-Ya: Folktales of Louisiana*. Gretna LA: Pelican Publishing Company.

Smith, Julia Floyd (1991). *Slavery Rice Culture: Low Country Georgia, 1750-1860*. University Tennessee Press.

Sublette, Ned (2008). *The World That Made New Orleans: From Spanish Silver to Congo Square*. Lawrence Hill Books.

SELECTED INTERNET RESOURCES (all sites were functional and accessible in 2003)

http://www.frf.usace.army.mil/aboutUS.shtml
This site has information about the U.S. Army Corps of Engineers Field Research Facility in Duck, North Carolina on the Outer Banks. It offers a virtual tour.

http://search.eb.com/blackhistory/micro/129/80.html
This website goes in to a brief history of the Civil Rights Movement, naming important people, the laws that were in effect, the series of events, and organizations that were started during the movement. Video and audio clips can be accessed from this page.

http://www.cwc.lsu.edu/cwc/links/links12.htm
It provides links to various agriculture-based topics dealing with the South around the time of the Civil War. Some of the links include: When Rice was King, Cotton Culture.

http://www-class.unl.edu/geol101i/14b_coasts%20deposition.htm
This website describes shorelines. Also, it talks about various coastal formations (i.e. spits, bay mouth bars, islands, dunes, etc…etc). This site is not specific to coastlines.

http://www.pbs.org/wgbh/nova/teachers/programs/3015_wright.html
http://www.csmonitor.com/2003/1030/p25s01-stin.html
These websites deal with the history of the first flight of the Wright Brothers.

http://www.fao.org/rice2004/en/rice1.htm
This site discusses the relationship between rice and people and how it has inspired songs, paintings, stories and other modes of communication.

http://www.absoluteastronomy.com/topics/Beach_ridge
This site defines beach ridges and describes the formation process. In addition, examples and their locations worldwide are discussed.

http://www.ncsu.edu/coast/shell/index.html
This reference from North Carolina State University is actually a series of webpages. There are videos and pictures showing the movement of the inlet over a period of years.

http://web.bryant.edu/~dlm1/sc366/deltas/deltas.htm
This site defines deltas, describes where they occur, and classifies deltas based on three major factors affecting development: rivers, tides, and waves.

http://www.waterencyclopedia.com/Oc-Po/Ocean-Floor-Bathymetry.html
This site offers a very detailed explanation of seafloor bathymetry, including the techniques involved in measuring ocean depth. Additional references are listed.

http://soundwaves.usgs.gov/2009/03/
This site from the USGS discusses the field work involved when scientists map the sea floor and stratigraphy around Ship and Horn Islands, Northern Gulf of Mexico.

http://w.leeric.lsu.edu/crcl/crcl.htm
This site provides information from the Coalition to Restore Coastal Louisiana.

THE GREENVILLE NEWS

June 4, 2000

Timbers Could be Part of Blackbeard Flagship

Amy L. Royster [Cox news] **Beaufort, NC** - Timbers from the wreck believed to be Blackbeard's flagship waited 282 years to be lifted to the surface. Divers raised four deteriorated planks from the port side of the wreck to waiting research vessels. These timbers may resolve critical questions about Blackbeard's pirate career, including the origin of his ship, *Queen Anne's Revenge*.

Hurricane Floyd left the timbers vulnerable to assault by abrasive, sand-slinging currents and wood-eating mollusks. Project scientists covered the timbers with sand in October 1999 but were fearful that the 2000 hurricane season would uncover them again.

On Wednesday, divers approached the pile hand-over-hand along a carefully staked line until the shape of a large anchor emerged.

Jim Craig, a professor of geology at Virginia Tech, said the timbers may provide important scientific leads that help separate historical fact from pirate lore.

"One of the good things about these timbers, which is even better than the cannons already excavated, is that you can do radio-carbon age dating and tie it into the dendrochronology (tree-ring dating)," he said.

Archaeologists working on the project believe the question if the wreck site is in fact the *Queen Anne's Revenge* has been answered.

"I've been doing this for 20-some years, and we've investigated thousands of wrecks. I can count on one hand the number of those wrecks that we have the same kind of evidence as for *Queen Anne's Revenge*. I'm very convinced that it is what it is," Project Director Mark Wilde-Ramsing said.

While some artifacts are on exhibit in the North Carolina Maritime Museum in Beaufort, many pieces await further examination in labs at the Institute for Marine Sciences in Morehead City. There, in a warehouse near the waterfront, corroded cannons lie in freshwater tanks. Throughout the warehouse, buckets hold objects yet to be identified.

RATIONALE

The Outer Banks is comprised of a series of barrier islands, inlets, and sounds that line the North Carolina coastline for over 200 miles (320 kilometers). The exact number of islands and inlets changes over time as hurricanes and other storms move and redistribute vast amounts of sand along the shoreline, often requiring the relocation of lighthouses and other structures. This dynamic interaction of marine and terrestrial processes provides a textbook example of the geology along a submergent shoreline.

Shifting sands can create unpredictable navigational hazards and as a result this region has been the site of many shipwrecks. Pirates also took advantage of the many inlets and coves to evade capture. Several National Seashore Parks have been established in the area to preserve the natural environment in the face of hordes of tourists that arrive year-round.

Several famous historical sites are located in this area, including Roanoke Island, site of Raleigh's 'lost colony', and the Wright Brothers Monument, honoring the site of the first powered, controlled manned flight.

PERFORMANCE OBJECTIVES

1. Analyze shoreline changes through time.
2. Locate aids to navigation and explain why they are needed.
3. Describe geometry of ancient beach ridges and the processes that formed them.
4. Distinguish between beach sand and sand shoals on infrared aerial photographs.
5. Predict how long it will take to completely flood island using graphing techniques.
6. Calculate percentage of land area that has a particular land use.
7. Analyze societal benefits from preserving historical landmarks.
8. Evaluate suitability of choice of location for first English settlement.
9. Write limerick referring to historic event or people involved in that event.
10. Construct acrostic to paint 'word picture' of landscape feature.

SAMPLE ASSESSMENT RUBRICS

EXAMPLE #1 (relates to Performance Objective #2)

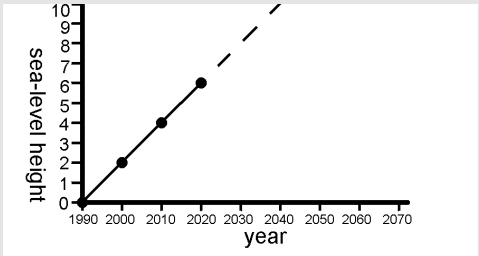
Ask students to name four different items that serve as navigation aids to ships sailing in the ocean, inlets, and sounds surrounding the Outer Banks and are typically marked on maps. [*possible answers include: lighthouse, channel marker, buoy, buoy light, light, shipwreck location*]

A (level 4) – Four correct responses given.
B (level 3) – Three correct responses given.
C (level 2) – Two correct responses given.
D (level 1) – One correct response given.
F (level 0) – No correct responses given.

EXAMPLE #2 (relates to Performance Objective #5)

PART A: Give students the data points listed below and ask them to construct a graph and place the ordered pair points on the graph correctly.

Sea-level = 0 feet above in the year 1990
Sea-level = 2 feet above in the year 2000
Sea-level = 4 feet above in the year 2010
Sea-level = 6 feet above in the year 2020



Answer should look something like this:

PART B: Use the information on the graph to predict in what year sea level will reach a flood level of 10 feet. [*Answer: year = 2040 +/- 2 years*]

A (level 4) – Points graphed correctly and prediction is correct.
B (level 3) – Points graphed correctly, but prediction is not correct.
C (level 2) – Points not all graphed correctly, but axes are correctly labeled.
D (level 1) – Points not all graphed correctly, but basic graph design is followed
F (level 0) – Points not graphed correctly and basic graph design is lacking.

Cartographic Product Information

MAP 9A: Outer Banks

TITLE: Outer Banks, NC (topographic map)
DATA SOURCE: Manteo and Currituck Sound USGS 1:250,000 Quadrangles
DATE: Manteo (1957 - photoreviserd 1969); Currituck Sound (1946 - photorevised 1980)
SCALE: 1:250,000 [1 inch ~ 3.2 miles] [1 cm ~ 2 kilometers]
OTHER IMPORTANT DATA:
- Currituck Sound Quadrangle (upper portion of map)
  There are no contour lines shown on this map; all elevations below 10 meters.
  Bathymetric (underwater) contour line interval is 2 meters.
- Manteo Quadrangle (lower portion of map)
  The contour interval is 25 feet but very few contour lines are shown on map.
  Bathymetric (underwater) contour line interval is 30 feet.

POINTS OF SPECIAL INTEREST:
- Wright Brothers National Memorial is located in center-top of map.
- Fort Raleigh (Roanoke Island) is located in upper-center of map.

OTHER FEATURES TO LOOK FOR:
- Oregon Inlet (east of Roanoke Island) & Cape Hatteras (lower-center) are on map

TITLE: Kitty Hawk, NC (topographic map)
DATA SOURCE: Kitty Hawk USGS 1:24,000 Quadrangle
DATE: 1982
SCALE: 1:24,000 [1 inch = 2,000 feet] [1 cm ~ 250 meters]
OTHER IMPORTANT DATA:
- All contours and elevations are marked in meters (contour interval = 2 meters).
- The 'tire-tread' pattern shown on this map is a publication error and is not real.

POINTS OF SPECIAL INTEREST:
- Wright Brothers National Memorial is located in the bottom-right corner of map.

OTHER FEATURES TO LOOK FOR:
- Several ancient beach ridges visible on left side of map (white strips with roads).

TITLE: Cape Hatteras, NC and Oregon Inlet, NC (topographic maps)
DATA SOURCE: Cape Hatteras: [Buxton, Cape Hatteras], USGS topographic maps
Oregon Inlet: [Pea Island, Oregon Inlet] USGS topographic maps
DATE: Buxton, Cape Hatteras: 1948 [photorevised 1983]
Pea Island: 1950 [photorevised 1983], Oregon Inlet: 1953 [photorevised 1983]
SCALE: 1:24,000 [1 inch = 2,000 feet] [1 cm ~ 250 meters]
OTHER IMPORTANT DATA:
- The contour interval of these maps is 5 feet.

POINTS OF SPECIAL INTEREST:
- Cape Hatteras lighthouse is located along shoreline (right edge of Hatteras map).

OTHER FEATURES TO LOOK FOR:
- Several shoal areas and channels are marked on Oregon Inlet map (left-center).

Cartographic Product Information

IMAGE 9A: Outer Banks

TITLE: Kitty Hawk, NC (NHAP [infrared aerial photograph])
DATA SOURCE: NHAP CIR Photographs 325-139, 325-141, and 325-143
DATE: 1982
SCALE: 1:40,000 [1 inch ~ 3,333 feet] [1 cm ~ .4 kilometers]
OTHER IMPORTANT DATA:
- This image is a false-color infrared photograph, so all true colors are shifted.
- This is a summer photo, so leaves are on trees and forested areas show up in red.
- Water with sediment shows up as milky-blue; clear water shows up as black.

POINTS OF SPECIAL INTEREST:
- Kitty Hawk located in upper-left corner of photograph.
- Roanoke Island located in lower-center of photograph (Ft. Raleigh at north end).

OTHER FEATURES TO LOOK FOR:
- Several ancient beach ridges visible in upper left corner (white strips with roads).

TITLE: Oregon Inlet, NC (NHAP [infrared aerial photograph])
DATA SOURCE: NHAP CIR Photograph 721-20
DATE: 1983
SCALE: 1:31,000 [1 inch ~ 2,666 feet] [1 cm ~ .32 kilometers]
OTHER IMPORTANT DATA:
- This image is a false-color infrared photograph, so all true colors are shifted.
- This is a summer photo, so leaves are on trees and forested areas show up in red.
- Water with sediment shows up as milky-blue; clear water shows up as black.

POINTS OF SPECIAL INTEREST:
- Pea Island National Wildlife Refuge is at extreme bottom-right of photograph.

OTHER FEATURES TO LOOK FOR:
- Several sand shoals visible on ocean side of Oregon Inlet (white markings).

TITLE: Cape Hatteras, NC (NHAP [infrared aerial photograph])
DATA SOURCE: NHAP CIR Photograph 721-36
DATE: 1983
SCALE: 1:31,000 [1 inch ~ 2,666 feet] [1 cm ~ .32 kilometers]
OTHER IMPORTANT DATA:
- This image is a false-color infrared photograph, so all true colors are shifted.
- This is a summer photo, so leaves are on trees and forested areas show up in red.
- Water with sediment shows up as milky-blue; clear water shows up as black.

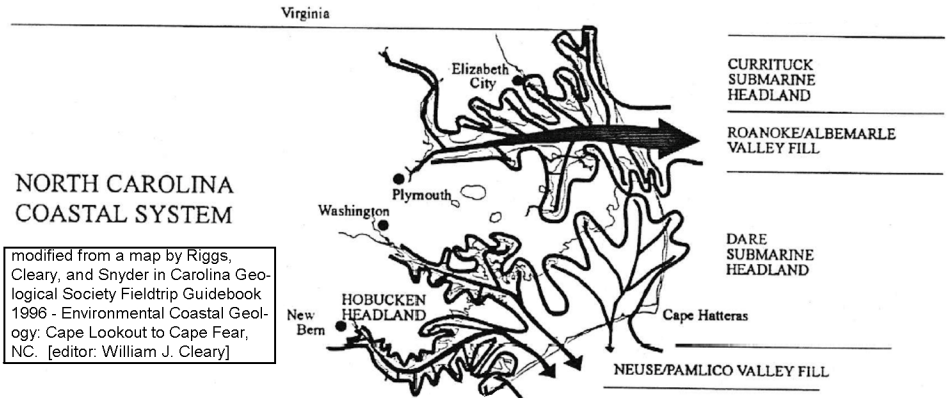
POINTS OF SPECIAL INTEREST:
- The actual cape (Cape Hatteras) is located in lower-right portion of photograph.

OTHER FEATURES TO LOOK FOR:
- There is a long sand spit growing southward from point of Cape Hatteras.

Barrier Islands and Shoreline Migration

Barrier islands form the eastern-most lands of North Carolina. They are among the most dynamic geological environments on earth. Like other interfaces between land and ocean, barrier islands react to the changing conditions of wind, tides and currents. They generally form along submergent coastlines where the land is slowly subsiding either from tectonic forces or a rise in ocean sea level. The original shoreline of North Carolina was a highly irregular terrain, dissected by Coastal Plain rivers and interrupted at random intervals by bays and estuaries. The rising sea level now impacting this region flooded the original Coastal Plain landscape, filled in the ancient river channels, and left higher elevation areas behind as isolated islands, surrounded by seawater. Much of the sand now being supplied to the barrier islands was originally deposited in the ocean by ancient rivers and was later brought onshore by wave action, especially during major storm events. Since 1985, over 24 named hurricanes have either made landfall along the Outer Banks or otherwise severely impacted the region.

Figure 9A-1: Ancient River Courses in Eastern North Carolina

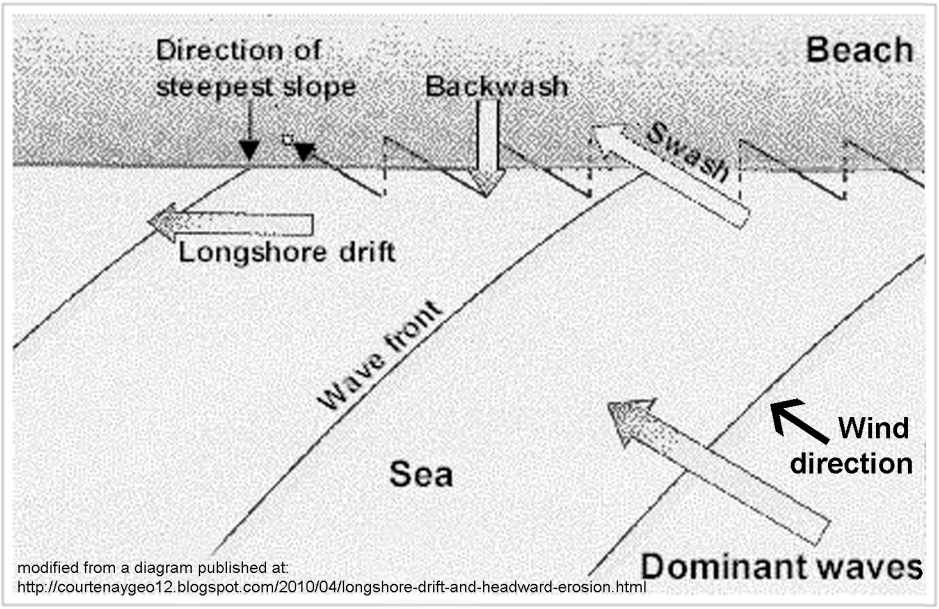


During the Pleistocene Epoch four major ice ages affected North America. Although the ice itself did not reach the North Carolina coast, the resulting changes in sea level had a major impact on the landscape. During periods of ice advance, and lower sea level, rivers flowed across the exposed sea floor on the continental shelf to supply sand to a string of ancient beaches. These rivers cut deep channels that were later flooded and became estuaries as sea level slowly returned to normal. Remnants of those ancient shorelines still exist as submarine sand ridges and shoals. During interglacial warm periods, sea level rose high enough to flood parts of the Coastal Plain and form temporary beach ridges that now stand high and dry far landward of the current shoreline. The most recent rise in sea level began about 20,000 years ago when the shoreline was located near the outer edge of the continental shelf, about 300 feet (100 meters) below current levels.

There were no barrier islands here initially, but they began to form as wave action eroded the high points on land that were former drainage divides. Longshore currents

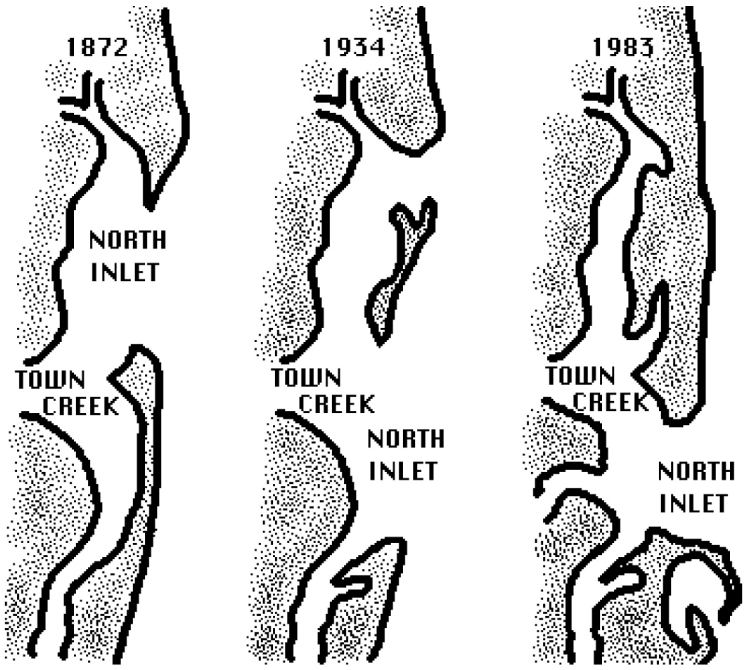
later moved the sediment eroded from these headlands along the shore to form long spits and sand bars. These spits and bars eventually joined to form barrier islands. Waves seldom strike the beach from directly offshore; rather they usually come in at an angle. This angled approach helps to develop a current moving parallel to the coast that is familiar to anyone who has played in the surf for a while and noticed that they have been gradually moved relative to the beach, sometimes for as much as several hundred yards. The initial wave moves sand up onto the beach at an angle, then the backwash pushes the sand back down the beach in the direction of the steepest slope. This creates a continual zig-zag movement of sediment along the coastline. Seasonal differences in wave direction and wave strength can affect beaches also. In general, winter storms tend to move sand offshore, while more gentle summer waves tend to return the sand from offshore sand bars and build up and widen the beach face.

Figure 9A-2: Mechanism of Longshore Drift of Sand



During the past 4,000 years, the rate of sea-level rise has slowed significantly, but winds, waves, and tidal currents are continuing to re-shape and re-form the barrier islands of the Outer Banks. Like the rest of the Coastal Zone, the Outer Banks are influenced by the rise and fall of the tides, an effect that extends approximately ten miles inland. Inlets form, migrate, and later close; islands form and then later disappear; storm washover events move sand from the seaward to the landward side of islands; tidal deltas, both ebb-tide and flood-tide, create shifting sand shoals; and beaches migrate landward. Prevailing winds not only direct longshore currents, but also blow a significant amount of beach sand into a distinctive dune line, which helps protect the inner portions of the barrier island from storm erosion. Sea oats and other beach front grasses take root there and provide more wind-breaks for further sand accumulation and greater dune stabilization. Major hurricanes are able to affect and change the geometry of barrier islands and their surroundings in a very short period of time. At the same time, the bathymetry of the ocean floor is also being re-shaped by these same processes.

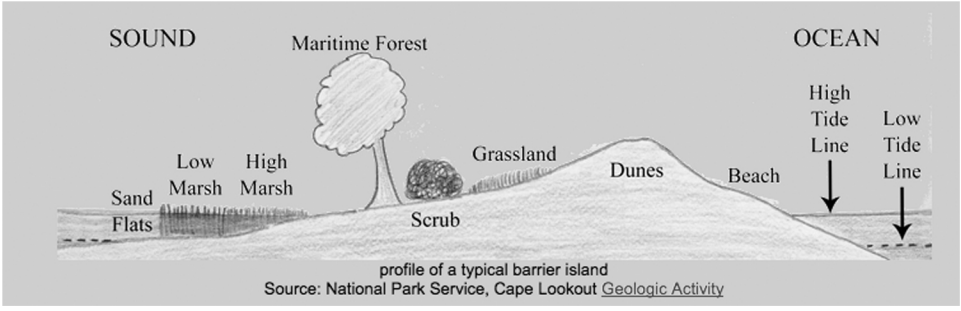
Figure 9A-3: Shoreline Changes Over Time at North Island



Navigation and Land Use

Older beaches and dune ridges have become vegetated by mature **maritime forests**, but younger sand ridges closer to the beach front are dominated by sea oats and other salt-tolerant shrubs and grasses. The numerous bays, inlets, salt marshes, and estuaries are a different, but perhaps even more vibrant part of the barrier island system. They are the breeding and feeding grounds for many sea creatures and much bird life, and, historically, these mixing grounds of fresh and salt water have also provided the means of earning a living for numerous people through fishing and shellfish harvesting.

Figure 9A-4: Cross-Section Through Typical Barrier Island



The National Park Service has tried to conserve as much of the fragile natural environment of the Outer Banks as possible by establishing restricted areas such as the Cape Hatteras National Seashore and the Pea Island National Wildlife Refuge. Migrating birds and waterfowl are abundant in the area. As one of the leading tourist destinations in the country, over-development and commercialization of the area is a major concern. Fishing and surfing locations in the Outer Banks are considered by many to be the best on

the Atlantic coast. Vacation communities have overwhelmed many of the small towns. In areas outside of the parks, most of the development is confined to the beach itself and to a series of older, mostly parallel beach ridges that rise high enough above the adjacent tidal flats and marshes to allow the construction of permanent buildings. Because of their high sand content, such beach ridges do not hold moisture well and can become very dry, supporting plant communities that are more typical of desert ecosystems.

The ever-shifting sands and the resulting opening and closing of inlets have created a navigational nightmare for sailors and fishermen cruising the Outer Banks. Nautical charts routinely become out-of-date soon after they are published. The Coast Guard has installed a series of lighted buoys and channel markers to help steer sailors away from sand shoals, shipwrecks, and reefs that would endanger boat traffic. The Cape Hatteras area in particular has earned the title "Graveyard of the Atlantic" because of its treacherous currents, sand shoals, and frequent storms. Debris from shipwrecks as old as the 1600s and as recent as the 1940s have been discovered washed up on local beaches. In earlier days, primarily in the 1600s and 1700s, pirates roamed these isolated waters preying on merchant ships and then sailed into the shallow sounds and tidal marshlands to hide. The famous pirate, Blackbeard, had his home base on Ocracoke Island, just to the south of Cape Hatteras. Stede Bonnet, the "Gentleman Pirate," joined forces with Blackbeard for a while to blockade the port of Charleston, SC for over a week.

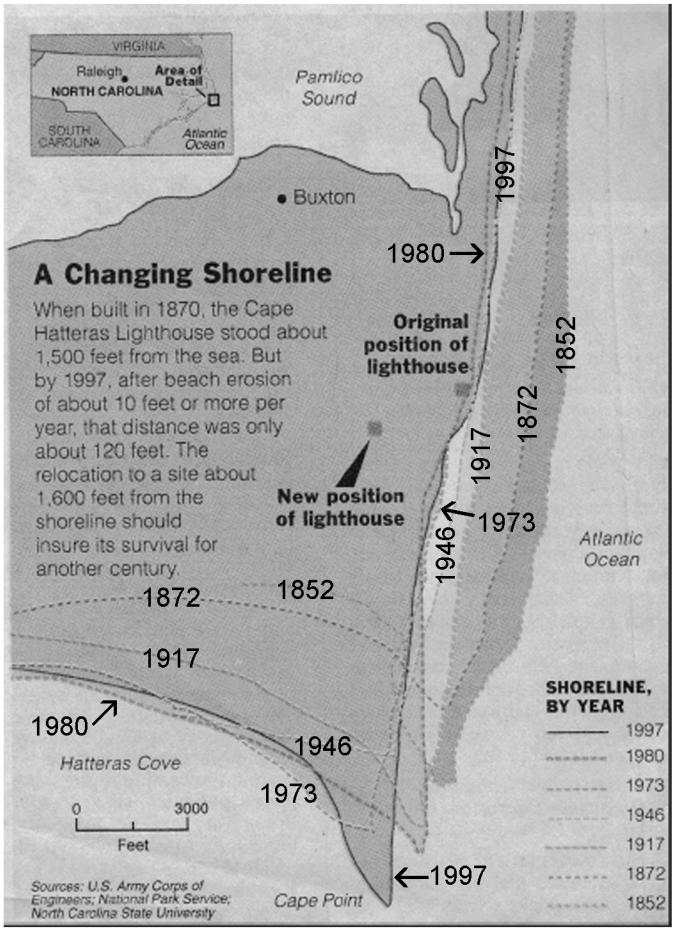
A Short Biography of Blackbeard the Pirate

--excerpted from the North Carolina Office of Archives and History--

The Outer Banks of North Carolina was an inviting spot for pirates of the eighteenth century. One of the most famous, Blackbeard, started his reign of terror here. When he first began pirating in 1713 with Benjamin Hornigold, he was known as Edward Teach. Soon after, Teach was given command of his own ship. They later seized another ship, the *Concord,* and renamed it *Queen Anne's Revenge*. When Hornigold retired, *Queen Anne's Revenge* became Teach's flagship. He soon earned a most terrifying reputation and was referred to as "Blackbeard" because of the thick black beard that grew about his face, covering it almost entirely. Along the way, four ships manned by more than 300 other pirates joined Blackbeard as he captured and looted various vessels they encountered. Blackbeard was known for burning ships, stealing treasures, and at times, killing those he encountered if they did not cooperate. But this partnership came to an end when *Queen Anne's Revenge* became stranded in an inlet. Blackbeard took all the treasures he had acquired and boarded another ship in his command (the *Revenge*), leaving most of his crew behind. Blackbeard renamed his new ship the *Royal James* and set off to continue pirating. Later on, Blackbeard went to North Carolina's capital where he was pardoned for piracy. However, he continued to terrorize the East Coast and seized still more ships. The Royal Navy was sent to North Carolina where they finally found Blackbeard. On November 22, 1718, Blackbeard was killed, after receiving over twenty sword slashes and five musket-ball wounds.

One of the most famous landmarks in the Outer Banks is the Cape Hatteras Lighthouse. Built in 1870, this structure is the world's tallest brick lighthouse rising to a height of 199 feet (61 meters). When it was built, the site was located inland about 1,500 feet (457 meters) from the shoreline. But by the year 1980, the beach had migrated to within 50 feet (15 meters) of the lighthouse. And by 1999, the shoreline had shifted far enough that waves were lapping at the base of the structure and its destruction seemed imminent. After much deliberation and debate, the decision was made to move the 4,800 ton (4,354 metric tons) lighthouse further inland; a massive engineering effort that took 25 days and required the clearing and leveling of a wide pathway through the maritime forest. The new site sits about 6 feet (2 meters) higher than the original site and lies about 1,500 feet (457 meters) from the current surf zone. Engineers predict that the move should ensure the lighthouse's continued survival through the next century.

Figure 9A-5: Changing Shorelines at Cape Hatteras



In the long run, both subtle changes and sudden dramatic storm events have been important factors in shaping the landscapes of the Outer Banks. In recent times, however, the most dramatic changes have occurred as the result of human engineering. Far more than natural processes, the shapes and characteristics of shorelines have been affected by the building of dams on local rivers which has reduced the sediment load transported reaching the ocean, effectively shutting down longshore drift and starving the beaches. Other engineering projects, including the draining and filling of marshes,

increased shoreline development, **beach renourishment** projects, and the construction of **jetties**, **groins**, and sea walls have made it much more difficult for this ecosystem to continue to thrive. By stopping the natural flow of sand along the beach, such measures often destroy adjacent beaches and remove the protective dune line. The threat of rising sea level doesn't just impact those living along the beach; in a worst-case scenario, the barrier islands will be washed away faster than their sand can be replenished and the sounds and rivers will become salt-water estuaries.

Historic Milestones

The Outer Banks have been the site of many historic 'firsts' over the past 500 years. Some historians believe that the Italian explorer Amerigo Vespucci first set foot on the continent later named for him somewhere along Hatteras Island in 1497. Others believe that Vespucci's accounts of this first voyage are forgeries, because all of his verified later travels involved explorations of only the Caribbean Sea and the South American coast. Later French and Spanish explorers also landed here between 1524 and 1588 in search of gold and other riches.

In 1584, England decided that it needed to establish a permanent settlement in North America to counter the Spanish presence in the New World. Queen Elizabeth I issued a charter to Sir Walter Raleigh to establish a colony in North Carolina. Raleigh dispatched a reconnaissance fleet of two ships to locate a suitable place for settlement, which turned out to be on Roanoke Island just west of Oregon Inlet. Captains Philip Amadas and Arthur Barlowe established friendly relations with the Algonquian Indians who inhabited the island and even took two of the Native Americans with them when they returned to England.

In 1585, Raleigh dispatched seven ships carrying over 600 people, under the command of Sir Richard Grenville, to occupy the land for England, find precious metals, and establish a base from which to raid Spanish ships. After an earthen fort was constructed, Grenville left for England, promising to return with more supplies. Things did not go well for these first colonists, relations with the natives deteriorated rapidly, and when a fleet of ships commanded by Sir Francis Drake stopped by, the colonists accepted his offer to take them back to England. When Captain Grenville finally returned to the deserted fort, he left 15 men behind to maintain an English presence on the continent.

One more colonization attempt was made in 1587. This time, the group of 117 settlers included women and children. They repaired the fort and dwellings left behind by the previous group and shortly thereafter Virginia Dare became the first English baby to be born in America. Unfortunately, hostilities with some of the Native Americans on the island had worsened and supplies were running low. The colony's leader, Governor John White, decided to sail back to England for more supplies, but he was unable to return to Roanoke Island until 1590. When White finally arrived, he found the settlement completely deserted and only a single clue, the letters "CROATOAN" carved into a post. The ultimate fate of the colonists remains a mystery, and as with many mysteries, a number of stories and legends were devised to explain the rest of the story. Here is one.

Legend of The White Doe: The Fate of Virginia Dare

--summary excerpted from a narrative poem by Sallie Southall Cotten--

According to Ms. Cotten's story and later variations of the legend, Virginia Dare grew up in the tribe of the friendly Indian Manteo. She became known as Winona-Ska and grew into a beautiful young woman whom everyone loved. Okisko was a handsome young Indian chieftain who wished to marry her. However, an old witch doctor, Chico, also wanted to win Winona-Ska. Chico was very jealous of Okisko. In spite of his efforts to win her love, Chico was turned down by Winona-Ska. Enraged, he used his evil magic to turn her into a white doe. If she wouldn't be his, no other man could have her, either.

Okisko was determined to undo the evil magic. He found a kindly magician, Wenokan, and they made a magic arrow with a pearl tip. Wenokan said that if the white doe was shot with this arrow, the evil spell would break, and Winona-Ska would become human again.

At this time another warrior, Wanchese, decided he would seek fame and glory by killing the charmed white doe. He knew that only a silver arrow could kill this special doe. Queen Elizabeth I had given such a silver arrow to his father. Now the son would use it to kill the white doe.

One day Okisko saw the white doe near the ruins of Fort Raleigh on Roanoke Island. Nervously, he raised his bow and shot his magic pearl arrow, but at exactly the same time, Wanchese shot his silver arrow from another direction. Both arrows pierced the white doe's heart. Magically, Okisko's pearl arrow turned her back into a beautiful young woman, but Wanchese's silver arrow pierced her human heart. Okisko rushed to her, but Winona-Ska died in his arms. Later, when he returned to the place where she had died, he found no sign of Winona-Ska. But the white doe appeared in the distance and looked at Okisko with her soft eyes. Then she ran into the woods. To this day many people report seeing a ghostly white doe near the area where the Lost Colony first settled on Roanoke Island.

The Outer Banks' only claim to fame in the 1700s was its connection to piracy. European sailing ships loaded with trade goods from several Caribbean islands had to sail northward along the Atlantic coast to the Outer Banks to catch the favorable winds that would take them back across the Atlantic Ocean to Europe. Pirates such as Blackbeard would lie in wait in the protected inlets and sounds until the merchant ships came into range. During the Civil War, Union forces easily captured Fort Hatteras and Roanoke Island. In 1862, a severe storm off of Cape Hatteras sank the first Union ironclad ship, Monitor, which had previously engaged the Confederate ship, Merrimack in the Battle of Hampton Roads, the first recorded military encounter of ironclad ships.

Perhaps the most famous 'first' that can be claimed by the Outer Banks is the first successful power-driven airplane flight at Kill Devil Hills near the remote fishing village of Kitty Hawk. In 1903, brothers Wilbur and Orville Wright designed and built a homemade airplane that flew for 12 seconds and covered a distance of 121 feet (37

meters). In 1904, the brothers built a second airplane that remained in the air for five minutes; and in 1905 yet another flight lasted for thirty-eight minutes. A later version of their airplane reached speeds approaching 40 miles per hour (64 kilometers per hour) and was able to stay in flight for over an hour. The Wright brothers are credited with designing, building, and flying the first power-driven, heavier-than-air machine in which humans made free, controlled, and sustained flight and were able to land safely at a pre-determined location at least as high as the site from which it had taken off. The Kitty Hawk location was selected because it was known for its year-round windy conditions and because its remote location provided the privacy they needed to work on their new invention without interference.

A Wright Brothers Limerick

--author unknown: *www.alysion.org/ryan/poems/Limericks.htm*--

[A limerick is a humorous poem consisting of five lines. The first, second, and fifth lines must have seven to ten syllables while rhyming and having the same verbal rhythm. The third and fourth lines should only have five to seven syllables; they too must rhyme with each other and have the same rhythm.]

Two brothers devised what at sight
Seemed a bicycle crossed with a kite.
They predicted - rash pair!
It would fly through the air!
And what do you know? They were Wright!

During World War I, the Outer Banks was a frequent target for German submarines patrolling the North Atlantic Ocean. In August 1918, the Diamond Shoals Lightship was sunk by a German sub. In that same month, a British tanker, The Mirlo, was sunk off the coast of Rodanthe by another German sub, but the crew was rescued by members of the Chicamacomico Lifesaving Station. During World War II, German submarines again patrolled the coastal North Carolina waters with similar results. The British ship San Delfino was sunk north of Diamond Shoals. Bodies recovered from that encounter are buried in the British Cemetery on Ocracoke Island.

POWER THINKING EXERCISE - "Rescue Routes"

The Outer Banks are often hit hard by hurricanes because the land sticks out so far into the Atlantic Ocean. When a major hurricane makes landfall here, the resulting storm surge may reach 10 to 15 feet above normal sea level and will probably cover almost all of the barrier islands as well as low-lying coastal areas. As a weather monitor with the United States Weather Service office for eastern North Carolina, it is your responsibility to issue evacuation orders for the coastal islands in North Carolina whenever you think a major hurricane is headed towards your area. You are also required to designate certain highways as official evacuation routes so the residents of the barrier islands will know which way to go when they leave.

Weather forecasters have just informed you that a Category Three hurricane is expected to strike Cape Hatteras in exactly 20 hours. They are predicting a maximum storm surge of 12 feet above normal sea level. You need to decide which highways to use for evacuation routes and how many hours before landfall to begin the evacuation process. The hurricane is currently heading due north towards Cape Hatteras and is expected to continue on that same course heading until it leaves the state completely.

Examine the Outer Banks topographic map on MAP 9A, OUTER BANKS and trace your proposed evacuation route for Cape Hatteras with a wipe-off pen. Discuss in your group how quickly the residents would be able to evacuate Cape Hatteras, using this route, once the order is given. Use information on the map to determine approximately how many people need to be evacuated. Look carefully at the elevation data for the barrier islands and predict how much of the islands would be under water when the hurricane passes? Refer to the Cape Hatteras and Oregon Inlet topographic maps on MAP 9A for more detailed information. Discuss potential problems that would tend to slow down the evacuation process. Based on all this information, how many hours before landfall do you issue the evacuation order? Be prepared to defend your decision against angry homeowners who don't want to leave that soon, or who don't want to leave at all.

Materials
MAP 9A, OUTER BANKS
IMAGE 9A, OUTER BANKS
Figure 9A-5: "Changing Shorelines at Cape Hatteras"
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Analyze shoreline changes through time.** ✈
   Topographic maps are often updated through aerial photographic analysis rather than by conducting a completely new ground survey. Such photorevised maps use the color purple to indicate features that either were not present at the time of the original topographic survey, or have moved or changed shape since that time. Both the Cape

Hatteras and Oregon Inlet topographic maps on MAP 9A, OUTER BANKS were ground surveyed around 1950 and then photorevised in 1983. The Cape Hatteras and Oregon Inlet NHAP infrared aerial photographs on IMAGE 9A, OUTER BANKS were taken in that same year.

Half of the class groups should focus on Cape Hatteras; the other half should focus on Oregon Inlet. Examine both your assigned map and corresponding aerial photograph to identify and mark, with a wipe-off pen, any features that are different or which have changed between 1950 and 1983. Which changes would you consider to have major impacts? Defend your answer. Do more changes occur on the ocean side of the barrier islands or the bay side? Give at least two reasons. Are there certain specific areas on your map that are more likely to experience major changes? Name them and explain why you picked them.

2. **Analyze surf zone position in Oregon Inlet.** ☼

Examine the ocean front side of the barrier islands shown on the Oregon Inlet NHAP infrared aerial photograph on IMAGE 9A, OUTER BANKS, and locate the surf zone where waves are breaking in the water just off the beach front. Why do both the beach sand and the surf zone show up as white on the false-color infrared photograph? How can you tell the difference between these two features if they are the same color?

Locate Oregon Inlet on the aerial photograph. Mark with a wipe-off pen the location of the surf zone around this inlet. Why is the surf zone so far away from the beach front at this location? What conclusions can you make about the water depth in Oregon Inlet? Explain your answers.

3. **Predict year that Cape Hatteras lighthouse must be moved again.** 💻

Locate the Cape Hatteras lighthouse on the Cape Hatteras topographic map on MAP 9A, OUTER BANKS. In 1999, facing wave damage and possible collapse from a rapidly eroding beach, the lighthouse was moved about 1,600 feet to a new location that away from the shoreline. Use information from figure 9A-5, "Changing Shorelines at Cape Hatteras" to estimate the position of the new location and mark this spot on the topographic map with a wipe-off pen.

Use the data in Figure 9A-5 to construct a graph relating time (in years) to width of land lost to beach erosion (in feet). Your origin point should be labeled with the coordinates (1850, 0); your grid interval along the x-axis should be labeled every 20 years; and your grid interval along the y-axis should be labeled every 500 feet. When making a data table, you will have to estimate the width of land lost to erosion (y-coordinate) for each time value (x-coordinate). Plot all of the ordered pairs in your data table onto your graph, then use a ruler to draw a straight line that represents the 'best fit' through the point distribution. Note that your line may not intersect every data point that you placed on the graph. Use a ruler to extend your line far enough to reach the y-axis value that is equal to the current distance from the lighthouse to the ocean. The x-axis value that corresponds to that point gives you the year that the lighthouse will once again be threatened by waves and must be moved again.

4. **Evaluate decision to move lighthouse.** 🕮
   Locate the Cape Hatteras lighthouse on the Cape Hatteras topographic map on MAP 9A, OUTER BANKS. Also consult Figure 9A-5, "Changing Shorelines at Cape Hatteras" to find the new location to which the lighthouse was moved. The move took a long time and cost a lot of money, and was very controversial. The plan to move this historic landmark was adopted only after a lot of other options were considered and rejected. Within your group, discuss other options to save the lighthouse that you think might have been suggested. For each option, list one "pro" and one "con" statement. Why do you think so many people thought it was important to save the lighthouse? What benefits do 'historic landmarks' provide to society?

5. **Construct acrostic to provide 'word picture' of Outer Banks.** ✍
   An acrostic is a literary device used to produce a 'word picture' of a person, place, or object. The first letter of each line spells out a word or message when read vertically. Here is an example that spells out the word "B E A C H". The first word used in each line should be a noun that describes or relates to the acrostic word selected.

   B **B**arrier Islands are shaped by ocean waves

   E **E**grets fly around in the sky

   A **A**nchors keep ships from getting stuck on sandbars

   C **C**rabs crawl around in the sand

   H **H**eat from the sun makes the sand too hot to walk on

   Construct your own acrostic by selecting any geographic location on the Outer Banks topographic map on MAP 9A, OUTER BANKS and using the letters that spell out that word as the first letter of each line. The nouns that start each line can include plant and animal names as well as inanimate objects. If your group is really good at constructing acrostics, try to write a poetic acrostic, where lines rhyme.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Plot paths of major hurricanes that impacted Outer Banks.** ✈
   Use local library or internet resources to research the hurricane history of the Outer Banks. Use a wipe-off pen to mark the paths of each storm on the Outer Banks topographic map on MAP 9A, OUTER BANKS. Do some areas get hit more often?

2. **Predict impact of climate change on Outer Banks.** ☼
   Use local library or internet resources to research estimates of sea-level rise in the next hundred years. Consider both 'best case' and 'worst case' scenarios. Predict how much of the Outer Banks barrier island system will be underwater if those estimates are accurate. Where will all the sand go? Be prepared to justify your prediction.

Activity 9A-2: Navigation and Land Use

POWER THINKING EXERCISE - "Pirate Pursuit"

You are part of a pirate crew that has just attacked and robbed a merchant ship in the Atlantic Ocean along the Outer Banks five miles east of Oregon Inlet. Locate Oregon Inlet on the Outer Banks topographic map on MAP 9A, OUTER BANKS. Along with necessary items, such as food and clothing, you have stolen a large collection of coins and jewelry that you have brought back to your ship in a large treasure chest. You must hide the treasure chest quickly before you are discovered by naval patrols. Use your map reading skills to locate a secret hiding place, and leave directions so your crew can find it again, once your pursuers give up chasing you and you can safely return to retrieve it.

The pirate captain has given you three maps of the region to work with, the Cape Hatteras, Oregon Inlet, and Kitty Hawk topographic maps, all on MAP 9A. You must bury the treasure at a location that is shown on one of those maps. You may also refer to the Cape Hatteras, Oregon Inlet, and Kitty Hawk NHAP photographs on IMAGE 9A, OUTER BANKS for additional information. Discuss in your group how to determine the physical and other characteristics of the best burial site. Mark on one topographic map, with a wipe-off pen, the spot at which you think the treasure should be buried. Be prepared to justify your selection.

A buried treasure is no good unless you know how to find it again. But you don't want to draw directions directly onto the map because it would be too easy for other pirates to steal the map and get to your treasure first. Instead, write up a set of directions that will get your crew from Oregon Inlet to the secret hiding place using written and pictorial references to physical landmarks, distances, shoreline features, and compass directions. Remember that pirates generally did not want just anyone to be able to use their directions to find their hidden treasure; so use references that have hidden meanings. For example, if you needed to refer to Duck Island, northwest of Oregon Inlet, you might draw a webbed foot, or a picture of a duck. When you have completed your set of directions, exchange them with another group and see if you can follow their directions to find their treasure.

Materials
MAP 9A, OUTER BANKS
IMAGE 9A, OUTER BANKS
Transparent Plastic Grid
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Locate and explain aids to navigation.** ✈
   Refer to the Outer Banks topographic map on MAP 9A, OUTER BANKS and examine closely the chain of barrier islands that separates Pamlico Sound from the Atlantic Ocean. Mark on this map with a wipe-off pen every occurrence of a buoy

light, a lighthouse, a coast guard station, a reef, and a shipwreck (indicated by a small symbol of a sinking ship). Which of these features occur primarily on the ocean side of the islands? Which occur primarily on the Pamlico Sound side? Explain this distribution. Why is it important for ships to know where these features are located?

Describe the geometric shape of the bathymetric contour lines offshore from Cape Hatteras. What is happening on the ocean floor in this area to cause these lines to look the way they do? Why do you think there is a buoy light located so far offshore from Cape Hatteras (lower right-hand corner of map)?

2. **Analyze geometry and land use of ancient beach ridges.** ☼

Ancient beach ridges are old sand dune deposits formed when the shoreline was in a different location than it is today. These higher elevation areas are characterized by an abundance of trees and shrubs and are usually the places where highways and other human structures are located. Locate and identify several examples of ancient beach ridges on the Cape Hatteras and Kitty Hawk topographic maps on MAP 9A, OUTER BANKS. Locate the same features on the Cape Hatteras and Kitty Hawk NHAP photographs on IMAGE 9A, OUTER BANKS. Describe the geometry of an ancient beach ridge. Briefly describe the landscape features that occur between adjacent beach ridges. Why do people preferentially build structures on the ridges instead of between them? Are all of the ancient beach ridges exactly parallel to the modern beach? Explain any difference you see. In general, how is an ancient beach ridge different in appearance from the sand dune ridge on the modern beachfront? Explain your answer.

3. **Estimate number of ducks that will fit in pond.** 💻

Locate the Pea Island National Wildlife Refuge (just south of Oregon Inlet) on the Outer Banks topographic map on MAP 9A, OUTER BANKS. Find the large pond, about five miles south of Oregon Inlet, which is maintained for waterfowl. Locate this same pond on the Oregon Inlet topographic map on MAP 9A and on the Oregon Inlet NHAP photo on IMAGE 9A, OUTER BANKS. Place the TRANSPARENT PLASTIC GRID over the NHAP photo to estimate the surface area of this pond. Be prepared to explain how you calculated the surface area using the grid.

Assume that each duck landing in this pond needs a three-foot diameter circle of open water to feel safe. How many ducks could fit into this pond at one time? Explain mathematically how you arrived at your answer. How likely is it that this many ducks would all fly to the same pond at the same time? Why do you think the pond was constructed to be so large?

4. **Summarize land use in National Seashore.** 🕮

Locate and trace, with a wipe-off pen, the boundaries of the Cape Hatteras National Seashore on the Outer Banks topographic map on MAP 9A, OUTER BANKS. Trace with a wipe-off pen these same boundaries onto the Cape Hatteras and Oregon Inlet topographic maps on MAP 9A. Also transfer these boundary lines, with a wipe-off pen, to the Cape Hatteras and Oregon Inlet NHAP photographs on IMAGE 9A, OUTER BANKS. Carefully investigate the land use differences inside and outside the

park boundaries. Make one list of all land uses or structures you find outside the National Seashore and make another list of features inside the park. Circle any land use or structure that seems out of place. Display your data in a Venn Diagram that shows land uses or structures that are common to both regions.

5. **Investigate and explain pirate nicknames.** ✍
   Throughout the ages, pirates and other outlaws have seldom been known by their legal names. The famous pirate "Blackbeard" was actually named Edward Teach. The famous bank robber "Billie the Kid" was actually named William H. Bonney. Even in comic books, heroes like "Batman" get into fights with outlaws like "The Joker," "The Riddler," and "Mr. Freeze." None of these villains uses their real name. Why do you think pirates and other outlaws preferred nicknames? What effect did these nicknames have on ordinary people? Explain your answer.

   Assume you are a new pirate just starting out. You have selected the Outer Banks area of North Carolina as your territory. Your first raid on a merchant ship takes place in Hatteras Inlet between Ocracoke and Hatteras Islands. Locate this inlet on the Outer Banks topographic map on MAP 9A, OUTER BANKS. During the raid, the merchant captain demands to know your name. What do you tell him? Explain to your crew why you picked that nickname.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Research information on pirates.** 🕮
   Use local library or internet resources to research information about famous pirates that operated along the eastern coast of North America in the 1700s. Collect stories that tell of the pirate's exploits on board ship or on land. What do all these stories have in common? Note any specific battle sites or hideaways the pirate used that are referred to in the stories and are in or near the Outer Banks. Why do you think that so many pirates spent so much time in and around the Outer Banks?

2. **Explain causes of shipwrecks.** ✈
   Sites of several shipwrecks are shown on the Outer Banks topographic map on MAP 9A, OUTER BANKS (look for small symbol of sinking ship). What do all of these shipwreck areas have in common? What do you think caused the wrecks? Research one or more shipwreck events that occurred in this area, using library and/or internet resources, to find out why the Outer Banks is such a notorious location for shipwrecks.

Activity 9A-3: Historic Milestones

POWER THINKING EXERCISE - "Colonial Controversy"

Your group has been asked to participate in a conference of historians debating the fate of the "Lost Colony" on Roanoke Island, which disappeared without a trace in the year 1587. Everyone agrees on the location of the colony, and the initial settlement layout, but there are lots of different theories about what went wrong and what might have happened to the colonists. Historians generally agree that all successful colonies have to be able to provide food, clothing, and shelter to the inhabitants, and provide for defense against both natural and human enemies. In the case of the failed Fort Raleigh settlement, one or more of these necessities must have been lacking.

Locate Roanoke Island on the Outer Banks topographic map on MAP 9A, OUTER BANKS. Use this map as a reference to help locate Roanoke Island on the Kitty Hawk NHAP photo on IMAGE 9A, OUTER BANKS. Fort Raleigh was located on the northern end of the island. Mark its position as closely as possible with a wipe-off pen. Your group will be assigned one of the four critical needs to research. Use the information on the map and photo to determine how your assigned need could be met on Roanoke Island. Identify potential problems affecting your assigned need and suggest ways to solve them. Prepare a short presentation to the class explaining why you think that particular need was or was not responsible for the disappearance of the colony. Remember that these map products are modern, the roads and buildings were not there in 1587.

Need I – FOOD
Need II – CLOTHING
Need III – SHELTER
Need IV – DEFENSE

Materials
MAP 9A, OUTER BANKS
IMAGE 9A, OUTER BANKS
story: "A Wright Brothers Limerick" on page 9A-12
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Analyze terrain at Wright Brothers monument. ✈**
   Locate and circle with a wipe-off pen the site of the Wright Brothers National Memorial on Bodie Island on the upper center portion of the Outer Banks topographic map on MAP 9A, OUTER BANKS. Also locate and circle with a wipe-off pen this same site on the lower right corner of the Kitty Hawk topographic map on MAP 9A. Finally, locate the site on the Kitty Hawk aerial photograph on IMAGE 9A, OUTER BANKS. Circle with a wipe-off pen Kill Devil Hill, West Hill, and the First Flight Airport runway on both the map and the photo. What is the elevation of Kill Devil Hill? of West Hill? of the airport runway?

Describe the land cover at each of these sites. Why do you think the runway is located so far inland from the beach? Why do you think it was important for the runway to be flat (instead of starting at the top of Kill Devil Hill)?

2. **Explain influence of landscape on development.** ☼

Refer to the Kitty Hawk topographic map on MAP 9A, OUTER BANKS to locate the communities of Kill Devil Hills and Kitty Hawk, and also the developed area on Colington Island. Use wipe-off pens to sketch onto the map the approximate limits of the developed area in each community. Locate the corresponding areas on the Kitty Hawk NHAP photo on IMAGE 9A, OUTER BANKS, and draw in the same boundaries with the same color wipe-off pens.

Fill in the following chart with information on both landscape characteristics and developmental patterns. Study the landscape carefully on both the map and photo. Describe the street pattern in your own words. For each community, count the number of houses (small black squares) within the nearest large grid square printed on the Kitty Hawk map. Each of these large grid squares covers one square kilometer of surface area. Explain briefly how the underlying landscape characteristics influenced the development pattern in each community.

Community	Street Pattern	Houses per square km	Landscape Description
Kitty Hawk			
Kill Devil Hills			
Colington Is.			

3. **Calculate percentage of community with waterfront property.** 💻

Refer to the Kitty Hawk topographic map on MAP 9A, OUTER BANKS to locate the communities of Kill Devil Hills and Kitty Hawk, and also the developed area on Colington Island. In different color wipe-off pens, sketch on the map the approximate limits of the developed land area in each community. Locate the corresponding areas on the Kitty Hawk NHAP photo on IMAGE 9A, OUTER BANKS, and draw in the same boundaries with the same color wipe-off pens. Use the TRANSPARENT PLASTIC GRID overlay and the map scale to calculate the surface area of each town that lies inside of the boundary lines you drew.

Each of these communities has some waterfront property that homeowners find very valuable. Use a string and the scale bar to measure the total length of waterfront within your marked boundary for each community. Divide the value for waterfront length by the value for surface area for each community, then fill out the chart.

Community	Surface Area	Length of waterfront	Ratio of Waterfront to Area
Kitty Hawk			
Kill Devil Hills			
Colington Is.			

Which community has the highest ratio of waterfront to surface area? What changes had to be made to the landscape in order to accomplish this high ratio? Why do you think other communities like Kill Devil Hills and Kitty Hawk don't do the same thing? Which community do you think contains more affluent homeowners? Explain your answers.

4. **Evaluate selection of Fort Raleigh harbor for settlement.** 🕮

Locate Fort Raleigh National Historic Site on Roanoke Island on the Outer Banks topographic map on MAP 9A, OUTER BANKS. Use this map as a reference to help you locate Fort Raleigh on the Kitty Hawk NHAP photo on IMAGE 9A, OUTER BANKS. Mark on IMAGE 9A, with a wipe-off pen, where you think ships docked when they loaded and unloaded supplies for the colony. Why did you select this particular docking location? Explain your answer. Why do you think the colony was placed at the north end of Roanoke Island? Discuss within your group the landscape features that make certain areas good harbors for ships. List your criteria and rank them in order from most important at the top to least important at the bottom. How many of these criteria does the Fort Raleigh site meet? Explain your answer with references to the NHAP image.

5. **Write limerick about historical site in Outer Banks.** ✍

Read the story entitled "A Wright Brothers Limerick" on page 9A-12. Limericks can be defined as five-line poems in which the last words of the first, second, and fifth lines rhyme with each other, and the last words of the shorter third and fourth lines rhyme with each other. Limericks are usually funny and sometimes even outrageous. They are almost never serious. The last line often contains the "punch line" to complete a joke.

Locate the Wright Brothers National Memorial site on Bodie Island and Fort Raleigh on Roanoke Island on the Outer Banks topographic map on MAP 9A, OUTER BANKS. Select either the famous airplane flight pilots or the first settlers (perhaps Virginia Dare) in the lost colony as your subject and write a limerick about their adventures. Use the same style (word cadence) as the sample limerick provided on page 9A-12. Share your limericks by reading them aloud to the class or by binding them together in a notebook for others to read.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Research reasons for preserving historical sites. 🕮**
   Select either the Wright Brothers National Memorial or the Fort Raleigh National Historic Site. Locate your chosen site on the Outer Banks topographic map on MAP 9A, OUTER BANKS. Use library and/or internet resources to find out all you can about what the original site was like, and how closely the modern site resembles the original. Find out why, when, and how the site was given status as a National Historic Site. Share your findings in a report or power point presentation to the class.

2. **Compare dimensions of historic runway to modern airports. ✈**
   Locate the Wright Brothers National Memorial site on Bodie Island on the Outer Banks topographic map on MAP 9A, OUTER BANKS and use this information to locate the Memorial site on the Kitty Hawk topographic map also on MAP 9A. Measure the length of the original Wright Brothers' runway. Contact your local airport to get specifications on the runway lengths needed for modern planes to take off and land. Determine how size and weight of airplane and the speed of the plane at take-off influence how long a runway needs to be to accommodate that plane.

THE GREENVILLE NEWS

September 10, 1989

Myrtle Beach vs. the Sea

By Jenny Munro

A rising Ocean is eating away at Myrtle Beach, where coastal development could literally go under during the next century if plans are not made to move it back.

By the year 2025 the ocean could be 39 to 89 feet farther inland if sea level continues increasing at the expected rate, said Jim London, associate professor of planning at Clemson University. By 2100, the shoreline could be anywhere from 182 to 960 feet farther inland. That would place the water between Ocean Boulevard and U. S. 17 in some areas. But "Myrtle Beach will still exist if they adjust to the sea rise and adopt some flexible land use policies," London said.

Although the magnitude of the increase is uncertain, "scientists have come close to a consensus that the greenhouse effect is upon us," London said. As the earth warms, the polar ice caps will begin melting, causing a rise in sea level, and the ocean water will warm up and expand.

London said, "The options are to fortify the beach with sea walls or to make a gradual retreat." Different areas will require different decisions. In Myrtle Beach, where the main attraction is the beach, London said retreating is probably the best answer. Sea walls would cause problems. "Eventually, what happens is you lose the public beach," he said. "We're going to have to build a little smarter. But the planning will not be easy", said London. "The public probably does not yet realize sea level is rising."

Myrtle beach officials already have begun building smarter, according to Jack Walker, planning director. The city has a mandatory construction setback from the ocean front, based on a 50-year erosion rate. Also, the city has no sea walls. "Basically, sand is about the only thing we can use in that zone," Walker said.

"We pushed the ocean away from the city by renourishing the beach with sand," he said. If the city has to fight a rising sea as well as erosion, "we will not only extend the beach out but raise the beach up."

RATIONALE

The Grand Strand of South Carolina forms an unusually continuous stretch of the coastline featuring long, wide beaches interrupted by very few inlets, tidal flats, or salt marshes. To the south the wide beach ridge transitions into a more typical barrier island coast that is interrupted only by the Santee Delta. Myrtle Beach and surrounding communities are a popular travel destination for tourists from all over the eastern United States and as far away as Canada. Although beaches have always been attractive to tourists, more and more visitors are looking for additional attractions such as amusement parks, theaters, golf courses, shows, and convention facilities. Offshore fishing provides an important economic resource that is controlled by offshore topography and enhanced by the emplacement of artificial reefs. Technologies such as side-scan sonar offer new ways of viewing the continental shelf. Even though the Grand Strand is located on an ancient beach ridge, the area is still susceptible to sea-level changes and other features of a rapidly changing coastline such as beach erosion.

PERFORMANCE OBJECTIVES

1. Compare and contrast landscapes and landforms from deltas, estuaries, and beaches.
2. Predict future shoreline positions based on assumed continued sea level rise.
3. Explain patterns of sediment distribution along coast and how this changes with time.
4. Use latitude/longitude data to locate positions of shipwrecks and artificial reefs.
5. Estimate dimensions of sunken features based on side-scan sonar images.
6. Interpret seafloor topography from bathymetric data and side-scan sonar mosaic.
7. Recognize and label tourist related land uses on topographic maps and aerial photos.
8. Describe and evaluate impact of sources of non-point source pollution.
9. Describe and explain the typical behavior patterns of tourists (non-native visitors).
10. Infer the impact on and benefits to tourism of opening a railroad line to Myrtle Beach.

SAMPLE ASSESSMENT RUBRICS

EXAMPLE #1 (relates to Performance Objective #6)

Give students a copy of MAP 9B (use Grand Strand Bathymetry map portion) and ask them to calculate the approximate slope of the continental shelf off the coast of the Grand Strand. Provide students with rulers and ask them to use metric units. Tell students they must show/explain all their calculations as well as provide the correct answer in both meters per kilometer and a percentage for full credit.

A (level 4) – Answer is somewhere between .075% (15 meter drop in 20 kilometers distance) and .05% (15 meter drop in 30 kilometers); and all work is shown correctly in meters per kilometer and as a percentage.

B (level 3) – Answer is somewhere between 15 meter drop in 20 kilometers distance and 15 meter drop in 30 kilometers; and all work is shown correctly in meters per kilometer but not as a percentage.

C (level 2) – Answer is somewhere between 15 meter drop in 20 kilometers distance and 15 meter drop in 30 kilometers; but work is not shown correctly or explained properly.

D (level 1) –Answer is not within prescribed limits but work/explanation shows some understanding of procedures needed to calculate answer.

F (level 0) – Answer is not within prescribed limits and work/explanation shows little or no understanding of procedures needed; or no answer is given.

EXAMPLE #2 (relates to Performance Objective #7)

Give students a copy of IMAGE 9B (Myrtle Beach, SC NAPP) and ask them to identify the land use in the marked area. Mark the map ahead of time by outlining the go-cart tracks at Springmaid Beach (locate this feature on MAP 9B) between the south end of the airport runway and the Springmaid Beach ocean pier.

A (level 4) – Student identifies tracks correctly or gives a similar land use.
B (level 3) – Student identifies tracks incorrectly, but answer is reasonable.
C (level 2) – Student identifies tracks incorrectly; answer possible but unrealistic.
D (level 1) – Student identifies tracks incorrectly; answer generally unrealistic.
F (level 0) – Student answer is nonsense, or no answer is given.

Cartographic Product Information

MAP 9B: Grand Strand

TITLE: Grand Strand Bathymetry, SC (topographic map)
DATA SOURCE: Compiled by Dr. Scott Harris, Coastal Carolina University, Conway SC; contour data overlain on USGS 1:24,000 base map mosaic
DATE: 1998
SCALE: approximately 1:100,000 [1 inch ~ 1.6 miles] [1 cm ~ 1 kilometer]
OTHER IMPORTANT DATA:

- Bathymetric contour lines are measured in meters and shown in various colors of blue and purple (see legend for details). Land elevation contours are measured in feet; the green line represents sea level, the yellow line represents the 25 foot contour line, and the orange line represents the 50 foot contour line.
- The black and white ocean floor image seen along coastline of Myrtle Beach is the same side-scan sonar image as the enlarged version shown on IMAGE 9B.
- The straight bathymetric lines to the left of the 'legend' are printing errors generated by computer malfunctions. The vertical line break at longitude 79 00 06 is also a computer generated error caused by the joining of two maps.

POINTS OF SPECIAL INTEREST:

- Winyah Bay, in the lower left corner of the map, is an estuary - a drowned river valley - that shows a deep narrow channel (dark blue bathymetric lines) that was eroded by the river on land during times of lower sea level long ago.

OTHER FEATURES TO LOOK FOR:

- Parallel beach ridges are visible in the lower left portion of the map to the west of Winyah Bay. Ridges are marked by contour lines and color patterns.
- Bathymetric contour lines at tidal inlets show a wide, shallow underwater shelf.

TITLE: Myrtle Beach, SC (topographic map)
DATA SOURCE: Myrtle Beach and Ocean Forest USGS 7.5 minute topographic map Series - provisional edition
DATE: 1984
SCALE: 1:24,000 [1 inch = 2,000 feet] [1 cm ~ 240 meters]
OTHER IMPORTANT DATA:

- The contour interval of this map is 2 **meters**.
- A 'provisional edition' does not use all of the standard topographic map symbols
- Within the shaded areas (with high population density) only major buildings are shown. Outside of the shaded area, all houses and other buildings are shown.

POINTS OF SPECIAL INTEREST:

- The Intracoastal Waterway runs from left to right in the upper left corner of map
- Myrtle Beach State Park is located in the lower left corner of the map between "Long Bay Estates" and "Springmaid Beach".

OTHER FEATURES TO LOOK FOR:

- There are several 'seawall' on the beach between 'Springmaid Beach Pier' and the 'Myrtle Beach Pier'.

IMAGE 9B: Grand Strand

TITLE: Myrtle Beach, SC (NAPP [infrared aerial photograph])
DATA SOURCE: NAPP CIR Photograph 7440-96
DATE: 1994
SCALE: 1:24,000 [1 inch = 2,000 feet] [1 cm ~ 240 meters]
OTHER IMPORTANT DATA:
- The image is an infrared aerial photograph, so all true colors have been shifted.
- This is a summer image, with leaves on trees, so forested areas appear red.
- Water with high sediment load appears milky-blue; clear water appears black.

POINTS OF SPECIAL INTEREST:
- The intracoastal waterway runs diagonally across upper left corner of photo.
- The Myrtle Beach Air Force Base is the large cleared area on the left side.

OTHER FEATURES TO LOOK FOR:
- Golf courses have distinctive 'sausage-link' pattern (one is to right of airport).

TITLE: Myrtle Beach, SC (side-scan sonar image)
DATA SOURCE: Dr. Scott Harris, Coastal Carolina University, Conway, SC
DATE: 1998
SCALE: 1:24,000 [1 inch = 2,000 feet] [1 cm ~ 240 meters]
OTHER IMPORTANT DATA:
- The side-scan sonar mosaic is made up of parallel strips of data laid next to each other to show the 'big picture' of the sea floor. Some of the data is missing right along the shoreline and elsewhere (indicated by empty light-gray strips).
- The mosaic areas of lighter tone represent hardbottom (shelly and rocky) areas; while areas of darker tone represent soft sediment (mud and sand) areas.
- Bathymetric contour lines are measured in meters and shown in various colors of blue (see legend for details). Land elevation contours are measured in feet; the green line represents sea level, the yellow line represents the 25 foot contour line, and the orange line represents the 50 foot contour line.
- The six-digit numerals along the bottom and right side of the map are grid coordinates. The degree and minute numerals indicate latitude and longitude.

TITLE: Grand Strand, SC (NALC [infrared satellite image])
DATA SOURCE: EPA and USGS NALC Pathfinder, WRS2 Path 15 Row 37
DATE: 1991
SCALE: 1:170,000 [1 inch ~ 2.7 miles] [1 cm = 1.7 kilometers]
OTHER IMPORTANT DATA:
- This is a false-color satellite image in which red tones denote areas of healthy vegetation and darker tones denote wetter areas. White areas are bare soil.

POINTS OF SPECIAL INTEREST:
- The intracoastal waterway can be traced along the entire length of the image.

OTHER FEATURES TO LOOK FOR:
- Ancient beach ridges visible on both sides of Winyah Bay (lower-left of image).

A Changing Coastline

The long crescent-shaped beach (sometimes called an arcuate strand) stretching from the North Carolina border southward to Winyah Bay near Georgetown is often referred to as the Myrtle Beach Grand Strand or South Carolina Grand Strand. The Strand is anchored by a 100,000 year old sand barrier formation which separates the Waccamaw River from the ocean for a distance of more than 60 miles (96 kilometers). Only a few **tidal inlets** interrupt this barrier, namely Murrell's Inlet, Pawleys Island Inlet, and North Inlet. Winyah Bay itself is an old river valley that has been flooded by recent rising sea level to form a wide **estuary** surrounded by marshy wetlands. Just south of Winyah Bay is the Santee Delta. This cuspate delta is the largest on the Atlantic coast of the eastern United States. The Santee River and its tributaries drain a large portion of the state of South Carolina as well as western North Carolina and bring enough sediment to the coast that the river has been able to keep pace with rising sea level and maintain its sizeable delta.

Viewed in geologic time, the Grand Strand region developed slowly as a result of deposition of sediment eroded from the Appalachian Mountains and carried to the sea by ancient rivers. These sediments gradually built out into the ocean and have been reworked and sculpted by wave and tide activity into the landform structures visible today. During the Pleistocene ice ages, sea level rose and fell several times, causing shoreline features to advance and recede back and forth across the region. Sand dune remnants far inland from the ocean and a series of accompanying **escarpments** and **terraces** are evidence that sea level was once higher. These ridges can easily be seen along many portions of the Coastal Zone, particularly on aerial photographs and satellite images. These dune ridges were once active barrier islands typical of the South Carolina coast and the tide-dominated Coastal Zone in general. Older dune ridges have become vegetated with mature **maritime forests**, but younger sand ridges closer to the beach front are dominated by sea oats and other salt-tolerant shrubs and grasses.

In the offshore direction, portions of drowned terraces are still visible on the Continental Shelf, showing that sea level was once lower than it is today. Some ridges can be traced from land out into the ocean, indicating that shoreline positions of the past were not always exactly parallel to present positions. The underwater landforms have the same basic geometry as the landforms above sea level except that wave action has smoothed them out and in some cases has eroded them away completely. After the most recent ice age, from 20,000 years until about 10,000 years ago, the world's glaciers were melting rapidly, causing the sea level to rise at the rate of several feet per century, for a total rise of more than 350 feet (107 meters). Beaches migrated inland to near their present position to keep pace with the rising sea. South Carolina's present-day barrier islands and beaches began to grow, and the wetlands and estuaries behind the outer beaches were able to develop their modern geometry when sea level finally stabilized near its current position. River sediments, a mixture of sand, silt, and clay, began to

accumulate on the bottoms of the drowned river valleys, however the type of sediment deposited at any particular location depended primarily on the intensity of wave and current energies at work in that particular location. High energy levels caused sands to be deposited along beaches, while finer silts and clays were able to settle in marshes and as offshore mud deposits because of the lower energy of these environments.

Scuba diver Jackie Epperson of Murrells Inlet was exploring off the coast of South Carolina in 1994 with three other divers when he discovered the remnants of an ancient forest under 55 feet (17 meters) of water about 15 miles (24 kilometers) off shore from Myrtle Beach. The site contained eight stumps from cypress trees that Paul T. Gaves, geologist from Coastal Carolina University, says are about 10,000 years old, based on the results of radiocarbon dating analysis. Gaves also reported that the sediment from the old forest floor is very similar to the sediment found in salt marshes, but the presence of peat and pollen grains indicates that freshwater vegetation also flourished at the site. Even though the erosion rate has slowed over the last 6,000 years, Gaves estimates that the Grand Strand beaches are still losing beachfront property at the rate of a foot a year.

In addition to the long-term shoreline changes caused by rising sea level, there are other landscape changes along the coast that occur much more rapidly due to the actions of waves and tides. Most waves strike the coast at an angle, generating a water current running parallel to the coast. Sand grains on the beach are also transported in a similar direction by the energy of the waves in a process called **longshore drift**. Seasonal differences in wind direction and wave strength can move sand from offshore sandbars into the surf zone while large storms can erode large amounts of sand from beaches or even break entirely through a beach leaving a new inlet. Storm debris left on the beach can trap sand and help establish a protective barrier of sand dunes. When sea oats and other beach front grasses take root on these sand dunes, the dune line becomes stabilized and is better able to shield the beach from further erosion.

In the long run, both subtle long-term changes and sudden dramatic storm events have been important factors in shaping the coastal landscape. In recent times, however, the most dramatic shoreline changes have occurred as the result of human engineering. The building of dams and reservoirs along major coastal rivers has trapped sediment that used to travel to the ocean and has actually starved beaches of the sand they need to grow and maintain their position. Other coastal projects, including the draining and filling of marshes and other wetlands, the building of jetties, groins, and sea walls, and the destruction of sand dunes, has altered the natural flow of sand and water through the system, destroying the balance necessary for long-term stability.

South Carolina passed a Coastal Zone Management Act (CZMA) in 1976 in order to regulate and control development in areas like the Grand Strand. The Act regulates what can be built along the coast, where it can be built, and what environmental engineering specifications must be met by builders. Another South Carolina law, the Coastal Barriers Resource Act, was passed in 1983. It removed previous subsidies and

other incentives for commercial growth and set aside certain areas where further development was not to be permitted.

One of the most controversial issues facing Coastal Zone policy managers is the question of **beach renourishment**. Supporters stress the importance of wide, attractive beaches to the tourism industry and maintain that the cost will be recouped through increased revenue from vacationers and convention attendees. Detractors claim that beach renourishment is only a temporary solution and that in a few years, the procedure will have to be repeated at even greater expense. Most sand used for beach renourishment comes from offshore sand bars. Engineers look for offshore deposits that closely match the original sediment characteristics of the beach to be renourished.

Ocean Floor Topography

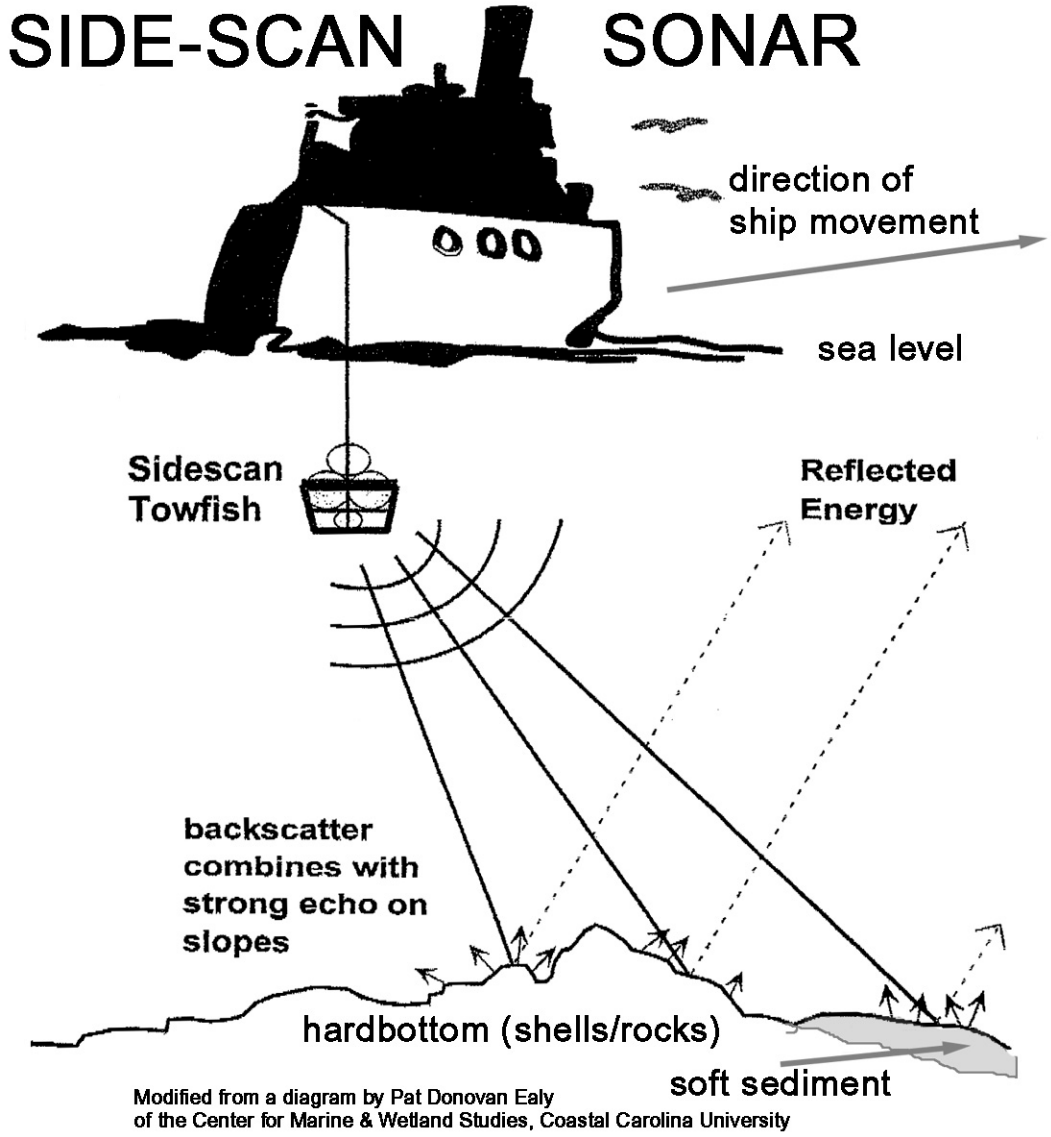
Many people think that the ocean floor is just a flat, featureless expanse of sand, but especially near the coastline, the sea bottom shows many of the same features that are found on dry land. In the Grand Strand area, the ocean floor is part of a wide, shallow **continental shelf** that is basically an underwater extension of the Atlantic Coastal Plain. During the ice ages, when sea level was much lower, large areas of the continental shelf were exposed to the air and experienced both erosion and deposition forming hills, ridges, basins, and river valleys. Some of these landforms can still be traced from the land all the way out to their underwater extensions in the ocean.

The continental shelf off the coast of the Grand Strand slopes very gently seaward until it reaches a fairly steep drop-off at the margin of the continental slope about 80 miles (128 kilometers) offshore. The water depth at the far edge of the shelf approaches 700 feet (200 meters). Irregularities on the sea-floor surface can be mapped with contour lines in exactly the same way that topographic maps are drawn for land areas. The only difference is that the line numbers under water get larger with greater depth and the lines are called **bathymetric** contour lines. Sometimes water depth is expressed in units called 'fathoms' and 'leagues'. A **fathom** is equal to six feet and a **league** equals three nautical miles. A **nautical mile** is equal to 1.151 land miles, a distance that represents the length of one minute of longitude at the earth's equator. The speed of ships or water currents is sometimes given in knots. A **knot** is equal to a speed of one nautical mile per hour.

Both geologists and physical oceanographers are interested in getting detailed information about the sea floor, especially close to the coastline. One way to get a detailed picture of bottom features is to use a remote sensing method called **side-scan sonar**. High frequency sound waves are released from a transmitter called a **towfish** that is usually dragged through the water behind a moving boat. The sound waves travel down through the water and bounce off of the bottom surface and are reflected back towards the water surface where a microphone on the towfish records the intensity of the reflected sound. Because more energy is lost the farther away the towfish is from the seafloor, there is a practical limit of about 500 feet (150 meters) on either side of the ship's line of forward motion that can be scanned with acceptable precision. For this

reason, the boat must travel back and forth many times to cover a study area and side scan sonar surveys are said to be "mowing" the ocean in much the same way as we would mow the grass in our front yard. These data pathways can be patched together by a computer to create a mosaic image of the entire area of seafloor that was scanned.

Figure 9B-1: Side-Scan Sonar Procedure



As the sound waves travel through the water, they bounce off everything in their path, and depending on the hardness and shape of the seabed surface, the returning sound is recorded as either strong (bright reflection) or weak (dark reflection). Areas where solid rock is exposed, or where lots of shells or coarse sand has accumulated, are known as **hardbottoms**. Hardbottoms typically generate bright signatures on sonar images. Areas covered with finer grained sediment are usually smoother and softer and so fewer sound waves are reflected back to the towfish, causing darker signatures to be recorded

on sonar images. By analyzing the light/dark pattern on side-scan sonar images, scientists can make predictions about what type of seabed material is there. When sound encounters objects standing above the bottom or suspended in the water column (like large rocks on the bottom or large fish) the sound cannot penetrate all the way to the bottom and instead casts a clear shadow on the image (like a flashlight would).

When characterizing bottom sediment, it is important to know the thickness of the layer as well as something about the grainsize and the mineralogy. The use of a **vibracore** to drill through the sediment can provide this information. The vibracore will penetrate the seafloor until it reaches a layer too hard to drill through. The depth at which the drill stops is called the **refusal depth**. In hardbottom areas, the refusal depth may be right at the seafloor surface. In other places it may be much deeper. The sediment retrieved by the vibracore can be examined to obtain grain size and mineral information.

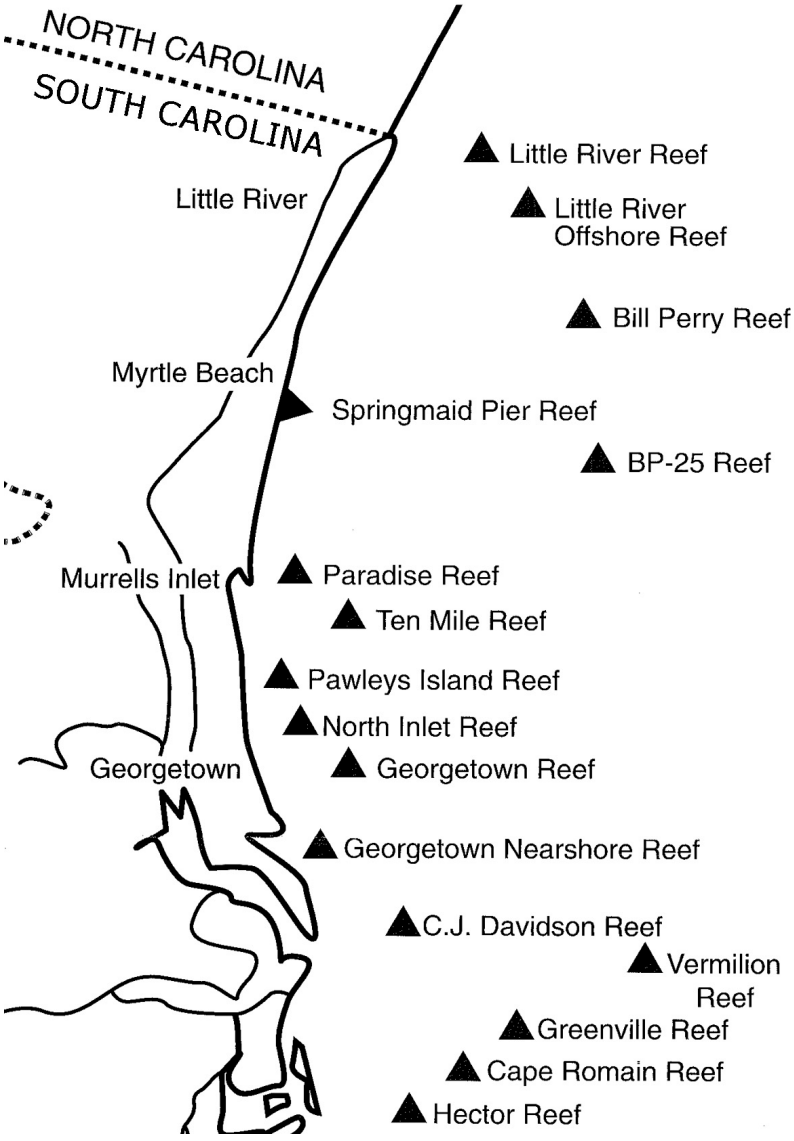
Many valuable and some not so valuable objects have been lost from boats over the centuries, especially along the waterfront and in nearby tidal creeks and estuaries. In some cases, entire vessels have been shipwrecked by storms, pirates, or other causes. Such boats and miscellaneous objects usually end up either on the bottom of the ocean or buried in sediment. The location, retrieval, and identification of such objects are the primary goals of underwater **archeology**. Most archeological diving in the Myrtle Beach area takes place within 3 miles (4.8 kilometers) off shore or in the Winyah Bay estuary. A large number of 19th century rice plantation boats have been discovered in the Waccamaw River and surrounding areas by sport divers. These sunken boats range up to 40 feet (12 meters) in length and usually lie in less than 30 feet (9 meters) of water. A unique law in South Carolina enables divers to collect and keep artifacts and fossils as long as they submit reports of the location, type and quantity of their finds.

A number of technologies are available to help scuba divers and archeologists locate features of interest. In addition to side-scan sonar, which is especially useful in locating wooden structures on the bottom, two other remote mapping techniques are typically used in local underwater archeology exploration. **Magnetometers** measure the local strength of the earth's magnetic field and can detect variations in this field caused by the interference of metallic structures or debris (like iron objects from ships). **Seismic profiling** uses low frequency sound waves to penetrate the bottom sediments and rocks and return a picture of the layering of the sea floor sediments. Seismic profiling can even detect objects that are buried deeply under ocean floor sediment. For each of these procedures the energy waves are generated from a source carried on a boat and the return signals are received by extremely sensitive "listening" devices also onboard the vessel.

The Grand Strand area boasts a significant sport and commercial fishing industry. Commercial fishing techniques are quite elaborate, use more expensive equipment, and the fish are usually sold on the open market. Recreational or sport fishing on the other hand is done on a much smaller scale, uses less expensive equipment, and the fish are usually kept for personal consumption or thrown back. Tourists and locals alike take advantage of the fresh seafood that abounds in both the nearshore and offshore waters. "Nearshore" fishing is defined as that which takes place less than 25 miles from shore

and includes such species as snapper and grouper. There is a large tourist "party boat" industry in Myrtle Beach that caters to this type of fishing. "Offshore" fishing takes place in the "blue water" of the Gulf Stream which location can vary seasonally from 20 to 75 miles offshore. The warmer, tropical waters of the Gulf Stream yield such species as Marlin, Yellowfin Tuna, Mahi Mahi (Dolphin fish) and Barracuda. Fishing from beaches, bridges, piers and groins is considered "inshore" fishing and a typical catch includes trout, flounder, red drum, spot, and sheepshead.

Figure 9B-2: Location of Artificial Reefs Along Grand Strand



Saltwater fishermen have realized for many years that fish tend to congregate around solid structures in the water. In tropical areas, coral reefs provide a rocky substrate that attracts large numbers of fish. In temperate climates, like the Grand Strand of South Carolina, corals are much less common, but rocky sections of the sea floor serve the same function. Many benthic organisms, or those living on or near the ocean floor,

aggregate on these hardbottom surfaces and they attract larger organisms that in turn feed upon them, and so on up the food web all the way to the sport fish that are the target of both commercial and recreational fishermen. For hundreds of years, coastal fishermen have experimented with dumping a variety of solid materials into the ocean to try and increase the quantity of solid structures on the sea floor. In recent times, the South Carolina Department of Natural Resources has coordinated and monitored the placement of actual **artificial reefs** in waters from 3 to 20 miles (4.8 to 32 kilometers) offshore. The materials used have included parts of automobile bodies, school buses, steel-hulled boats, large household appliances, and hundreds of thousands of used automobile and truck tires. In 2001, New York City contributed 300 rusting, rattling, and no longer usable subway cars to South Carolina's artificial reef program. The 40 ton cars were stripped of their wheels, motors, seats, and windows before a barge carried them out into the ocean and a bulldozer pushed them overboard into about 70 feet (21.5 meters) of water about 15 miles (24 kilometers) offshore.

Tourism and Land Use

The Grand Strand is best known for spectacular white, sandy, tourist beaches, the most famous of which is Myrtle Beach, and the host of accompanying restaurants, theaters, shopping malls, and other tourist oriented establishments that crowd the beachfront area. But this region also contains some other unique points of interest. Brookgreen Gardens, near Murrell's Inlet, is the preserved plantation site of Joshua John Ward, one of the original rice planters in the Georgetown District. Hobcaw Barony, on Winyah Bay was the summer home of noted financier Bernard Baruch, and the unique Atalaya Mansion at Huntington Beach was the home of artist Anne Hyatt Huntington. Lately, the Grand Strand has evolved into a highly acclaimed convention center and has acquired the nickname "the Golf Coast" because of the proliferation of golf courses associated with neighboring condominiums and gated residential communities.

Two hundred years ago, the Grand Strand was known to local inhabitants as the Long Beach and was separated from the dense pine forests only by sand dunes, sea oats, scrub oaks, and evergreen myrtle bushes. The area's first high profile tourist was President George Washington who traveled through the South Carolina coastal region in 1791. Washington entered the state on the King's Highway (now US Hwy. 17), which was little more than a widened Native American path at the time, and visited with many influential and prominent families living in the area. At Little River, he dined with James Cochran and went on to lodge at Jeremiah Vereen's house near Long Beach. He gave the beach at Windy Hill its name, because his hat was blown off as he walked along the ocean. From there, he was piloted across Singleton's Swash by Mr. Vereen, dined at George Pawley's house just north of present-day Myrtle Beach, and spent the night at Dr. Henry Collins Flagg's Brookgreen Plantation. President Washington later crossed Winyah Bay on his way to Georgetown, where he was welcomed by a salute of cannons by the local infantry dressed in their most handsome uniforms.

As recently as 1901, the Grand Strand still saw very few tourists and most of these were local and tended to congregate at Pawley's Island. Franklin G. Burroughs, a

Conway businessman, was the first to visualize the potential for these beaches to become a major resort area. His company, Burroughs and Collins, acquired a vast amount of timberland that included most of the beachfront all the way from Murrells Inlet to Little River. Shortly afterwards, his company began construction of a railroad line to transport tourists from Conway to the ocean. They used an old locomotive called the "Black Maria" which was originally designed to pull logs out of the swamp, and built a drawbridge over the Waccamaw River. The railroad tracks extended to within four blocks of the ocean, ending at present-day 9th Avenue. Once the railroad opened, in 1904, the company built its first resort hotel, the Sea Side Inn, and later sponsored a contest to select a name for its new resort. A popular suggestion was "Edgewater"; however, the name "Myrtle Beach" won the contest mainly because of the local abundance of the evergreen aromatic plant called wax myrtle (*Myricaceae cerifera*).

Travel on the wood-burning Black Maria train with its shrill whistle and smoke streaming out from the engine must have been quite an adventure. Sparks from the smokestack often set the neighboring woods on fire. When this happened the engineer would stop the train so the crew could jump off to put out the fire. Also, cattle and hogs usually had free run of the countryside, and when the animals became frightened by the smoke and noise, they would often charge the train. After the cows became used to the noise, they would lay down on the warm sandy track beds. If the train killed the animals, a six dollar per animal fee was charged. To avoid this fine, the engineer would stop the train long enough to shoo the cattle off the tracks. Later, cowcatchers were added to the front of the engine. A top speed of twenty-five miles per hour made passengers feel like they were riding in the wind. After serving beachgoers for four years, the Black Maria was replaced with a coal-burning engine that eliminated most of the cinders and sparks.

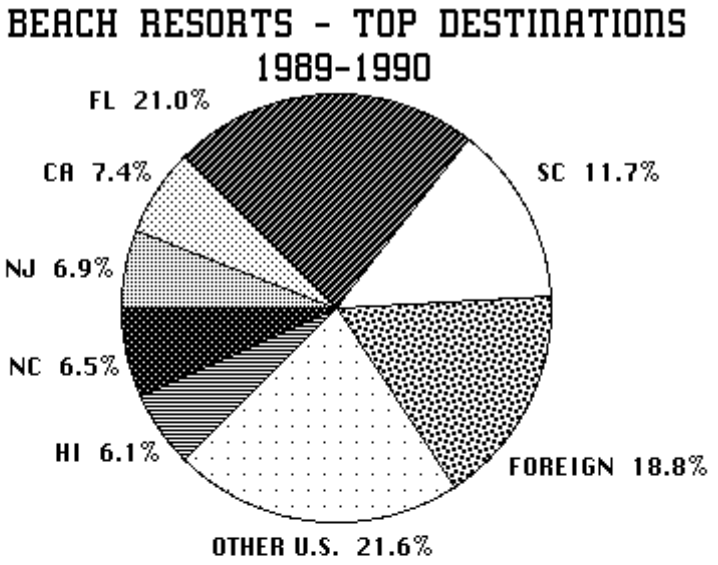
Another important spur to economic development in the Grand Strand region was the building of the **intracoastal waterway**, a protected water route, using both natural and constructed channels, that stretches along the Atlantic and Gulf of Mexico coast from Boston, Massachusetts to Key West, Florida, and westward to the Rio Grande River in Texas. The final section, between Winyah Bay and the North Carolina state line, was completed in 1936. The original idea behind the waterway was to provide a route for military and commercial boats to travel along the coast without having to venture into the open Atlantic Ocean where water conditions were much more likely to be dangerous. During World War II, the waterway was used to ship war materials up and down the coast, but today, about 95% of boat traffic is recreational and only about 5% is commercial. The U.S. Army Corps of Engineers maintains the waterway at a minimum low-tide depth of 12 feet (3.6 meters) and a minimum width of 90 feet (27.5 meters) by periodic dredging. Any bridges that cross the intracoastal waterway are required to be at least 65 feet (20 meters) above the mean high tide level. The waterway is a great location for fishing, crabbing, water skiing, and swimming and is used heavily by both local residents and vacationers.

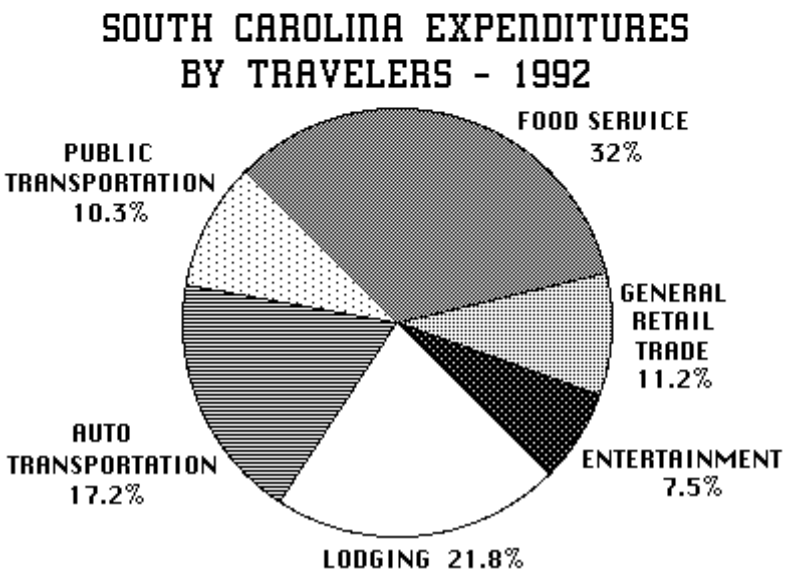
For a long time, in the segregated South, a large percentage of the population, the Black residents of South Carolina, were not permitted to use the beaches in the town of Myrtle Beach. The Atlantic Beach Company, located about 16 miles (25 kilometers)

north of Myrtle Beach, saw an opportunity to boost their own economy and set aside a portion of their oceanfront property for the exclusive use of Black Americans, and in later years, this beach was owned and operated by African Americans. However, the expected influx of tourists never fully materialized, probably because of the onset of Civil Rights legislation. Once court-ordered integration opened public beaches to all citizens, African Americans had many more choices and were no longer limited to one particular resort.

The entire Grand Strand is crowded each summer with tourists and their vehicles, heading to and from the many beach houses, golf courses, hotels, condominiums, shops, and restaurants that have developed in the area. Such a large concentration of people in a small area can put huge stresses on environmental quality, especially in the areas of sewage treatment, water and air pollution.

Figure 9B-3: Tourism Statistics for Grand Strand





Where obvious pollution sources exist it is possible to deal with environmental issues at the point of the problem. With non-point source pollution, such as car exhaust, dripping fluids from automobiles, lawn chemicals, and septic system effluent, small amounts of pollutants are contributed by multiple sources over a wide area and control is more difficult. However, a more serious problem, beach erosion, threatens the long-term future of the tourist industry at Myrtle Beach. Since the late 1970's, when the city first began to study the problem, it has been determined that the ocean encroaches the shoreline at Myrtle Beach by approximately a foot per year due to normal erosion (not including additional damage caused by storms). To combat this problem, South Carolina has carried out several expensive beach renourishment projects where sand was added to beaches and dunes. These projects do not halt beach erosion but do slow the effects. Beach erosion will continue as a threat to coastal development and tourism and will also continue to generate public debate on how to maintain and protect coastal development.

Local residents sometimes tend to stereotype tourists and often brand out-of-town visitors with nicknames such as "Touroid" or "Gringo". Not all touroids are equally well received by the local population or by law enforcement. Large crowds sometimes create lots of noise and traffic, which can disturb residential areas of the city and generate lots of trash. Conflicts can arise between vacationers who are looking for a good time and tend to stay up late, and residents who have to go about their normal workday tasks and have to get up early the next day. Even though residents may complain and make up funny stories about Touroids, they still look forward to their arrival because of the strong boost they provide to the economy of the region. No single characteristic absolutely identifies a Touroid, but one or more of the following signs suggests a sighting.

Signs of a Touroid Sighting

--excerpted from Peter Meyer's book, Nature Guide to the Carolina Coast--

Walking with towels, beach umbrellas, cookers, chairs, balls, buckets, etc.

Letting beach towels get soaked by waves as tide rises.

Spending endless hours walking the beach, collecting worthless shells.

Wearing loud Hawaiian print shirts, funky shorts, and weird hats.

Wearing socks with sandals, or socks with any type shoes during summer.

Talking with a foreign-sounding accent; unable to understand local dialect.

Buying or sending multiple sets of postcards.

Asking directions for the fourth time to the same destination.

Driving down one-way streets the wrong way.

Driving 10 MPH in a 35 MPH zone, gawking at the sights.

Buying shells, trinkets, and souvenirs in tourist-trap shops.

Invariably ordering seafood platters in local restaurants.

Appearing on the street in the evening with a lobster-red sunburn.

Tourism contributes both directly and indirectly to the state economy, with about fifty percent of tourist dollars spent on food service and about twenty percent on lodging. The remainder generates employment in various service related industries, including transportation, recreation, entertainment, and retail trade. Almost forty percent of all tourist dollars generated in South Carolina come from the Myrtle Beach area. And almost one-fifth of all State Park visits are recorded at Myrtle Beach State Park. This tourist region is growing so fast that the city will soon have to make a decision whether to try and maintain a small town family atmosphere, or become a more impersonal convention resort. There are benefits and drawbacks associated with each option.

Activity 9B-1: A Changing Coastline

POWER THINKING EXERCISE - "Turtle Trot"

Along the Grand Strand of South Carolina live two beach turtles, Tasha and Tanya, who are cousins. Tasha lives under the boardwalk in Crescent Beach, about 13 miles (20 km) north of Myrtle Beach, and loves to watch the crowds of people and listen to loud beach music. Tanya lives on the southernmost tip of North Island, where Winyah Bay enters the Atlantic Ocean, and loves to watch horseshoe crabs crawl along the quiet beaches and listen to the lonely sounds of seagulls and other shore birds.

One year, Tasha and Tanya decide they want to see each other again, but the only time they can schedule this is over the Fourth of July holiday weekend. They agree to begin walking towards each other, in opposite directions along the shoreline, until they meet. Their favorite food is seeds from the sea oats that grow on sand dunes along the beach, so they want to travel along the beach sand as much as possible. Tasha and Tanya are land turtles, and cannot swim, so they have to be very careful not to cross any salt water that is over their heads. They also need to stay out of salt-marshes, to avoid getting stuck in the mud or being eaten.

Examine the Grand Strand NALC segment of IMAGE 9B: GRAND STRAND and determine the position of the shoreline and the color pattern that represents beach sand. Mark on the map, with a wipe-off pen, where each turtle will start her journey. Refer to the Grand Strand Bathymetry map on MAP 9B: GRAND STRAND if you need help locating the turtles' homes. Make a quick, but intelligent prediction about where the two turtles will meet, assuming that they both walk at the same speed for the same number of hours. Mark your predicted meeting spot with a wet-erase marker on the NALC image.

Next discuss within your group a strategy to determine a more accurate location for Tasha and Tanya's final meeting point. Carry out your strategy, mark this new location on the map with a different color wet-erase marker, and compare it to your original prediction. Was your original prediction close? Why or why not? Which turtle would be more at-home with the land use along the beach at the meeting point?

Materials
MAP 9B, GRAND STRAND
IMAGE 9B, GRAND STRAND
Newspaper Article, "Myrtle Beach vs. the Sea" on page 9B-1
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Examine coastline variations. ✈**
   Randomly assign class groups to study one of the three shoreline types listed below. Each group will use the Grand Strand Bathymetry map on MAP 9B: GRAND STRAND and the Grand Strand NALC inset on IMAGE 9B: GRAND STRAND.

Group I Grand Strand Area (from Garden City Beach to Crescent Beach)
Carefully examine the Grand Strand and surrounding areas along this shoreline. What is the general shape of the shoreline? How many rivers empty into the ocean along this section of the coast? What percentage of the Grand Strand area is high ground (modern sand and ancient beach ridges)? What percentage is low ground (salt marsh or tidal flat mud)? How can you distinguish between those different environments on the topographic map? How can you distinguish between them on the NALC image? Locate the route of the Intracoastal Waterway on your portion of the coast. Does the route follow natural passages, or has the channel been dug out? Explain how the placement of the Intracoastal Waterway was influenced by the landscape. Be prepared to present all of your findings to the rest of the class.

Group II Barrier Island Coast (from Winyah Bay to Garden City)
Carefully examine the barrier islands and surrounding areas along this shoreline. What is the general shape of the shoreline? How many rivers empty into the ocean along this section of the coast? What percentage of the barrier island coast area is high ground (modern sand and ancient beach ridges)? What percentage is low ground (salt marsh or tidal flat mud)? How can you distinguish between those different environments on the topographic map? How can you distinguish between them on the NALC image? Locate the route of the Intracoastal Waterway on your portion of the coast. Does the route follow natural passages, or has the channel been dug out? Explain how the placement of the Intracoastal Waterway was influenced by the landscape. Be prepared to present all of your findings to the rest of the class.

Group III Santee Delta (South of Winyah Bay)
Carefully examine the Santee Delta and surrounding areas along this shoreline. Locate the Santee River system. Trace all possible courses of Santee River water as it passes through the delta area on its way to the ocean. What percentage of the Santee Delta area is high ground (modern sand and ancient beach ridges)? What percentage is low ground (salt marsh or tidal flat mud)? How can you distinguish between those different environments on the topographic map? How can you distinguish between them on the NALC image? Locate the route of the Intracoastal Waterway on your portion of the coast. Does the route follow natural passages, or has the channel been dug out? Explain how the placement of the Intracoastal Waterway was influenced by the landscape. Be prepared to present all of your findings to the rest of the class.

2. **Examine sediment distribution along coast. ☼**
Locate Winyah Bay at the lower end of the Grand Strand NALC inset on IMAGE 9B: GRAND STRAND. Examine the light blue color pattern near to where Winyah Bay empties into the Atlantic Ocean. Contrast this color with the very dark violet (almost black) color associated with the open ocean. Locate the three tidal inlets on the coastline north of Winyah Bay and note the similar light blue coloration. What water condition do you think the light blue color represents? Why is this condition found here? Is this same water color found anywhere else on the NALC image? Explain your answer. What is the 'real life' color of this water? Explain your answer.

Refer to the Grand Strand Bathymetry map on MAP 9B: GRAND STRAND. Mark with a wipe-off pen all areas on this map that correspond to the locations of light blue coloration on the NALC image. Based on the bathymetric data, what conditions do all of these regions have in common? Explain your answer in detail.

3. **Analyze future shoreline position along Grand Strand.** 💻

Consult the newspaper article, "Myrtle Beach vs. the Sea" on page 9B-1 to review the data on current rates of shoreline migration in the Grand Strand region. Note that the predicted shoreline migration values are not given as single numbers, but rather as a range of possibilities, from minimum values to maximum values. Show this prediction visually by creating a graph on which the x-axis represents time in years and the y-axis represents the projected shoreline migration in feet. The origin point on your graph should represent the ordered pair (0 feet, 1989 years) that describes the situation at the time the news article was written - the year 1989. Plot the two data points on your graph as ordered pairs and draw two lines representing the maximum and minimum predicted shoreline migration. Each line should pass through (as closely as possible) its two data points and the origin point. Label each line with an appropriate title. Are your lines straight or curved? Explain why the shape of the lines is important to the prediction. Use the information in your graph to calculate the maximum predicted rate of shoreline migration (in feet per year) and the minimum rate of shoreline migration (in feet per year). Which rate do you think is most likely to actually occur in the future, the maximum, the minimum, or some average value in the middle of the projected range? Explain your reasoning.

It is easy to confuse shoreline migration with sea-level rise. Explain the difference between these two concepts. Locate the present shoreline on the Myrtle Beach topographic map on MAP 9B: GRAND STRAND. Use the scale bar for reference to draw in, with different color wipe-off pens, the approximate position of the two lines representing the maximum and minimum predicted shoreline migration positions for the year 2100. Examine the contour lines and/or other map information to determine a typical elevation value that corresponds to the position of the maximum and minimum shoreline migration positions. Record these elevation values and label them "maximum predicted sea-level rise" and "minimum predicted sea-level rise" for the year 2100. Note that contour lines and elevations on this map are given in meters. You must convert these numbers from meters to feet before continuing. If the maximum sea-level rise actually took place between now and the year 2100, what would the new shoreline of Myrtle Beach really look like? Trace your prediction onto the Myrtle Beach topographic map with a different color wipe-off pen. Is your predicted shoreline a straight line? Does it run parallel to the current shoreline?

4. **Locate historical sites along Waccamaw River.** 🕮

Lucas Vasquenz de Ayllon may have established the first European settlement in the United States at the mouth of the Pee Dee River (known then as the Gualdape River) along the eastern shore of Winyah Bay in 1526. He had followed the coastline southward from North Carolina to Winyah Bay and then sailed up the Waccamaw River. Examine the Grand Strand Bathymetry map on MAP 9B: GRAND STRAND

and trace with a wipe-off pen de Ayllon's probable route to the mouth of the Pee Dee River. Where do you think he might have founded his settlement? Explain your reasoning. Nearby Sandy Island contains well preserved pottery fragments and other artifacts of earlier Native American settlements. Locate Sandy Island on the Grand Strand Bathymetry map. List some geographic features that made Winyah Bay a better location than Myrtle Beach for both Spanish and Native American settlements.

5. **Analyze impact of newspaper article.** ✍
   Read the newspaper article on page 9B-1, "Myrtle Beach vs. the Sea." Examine the Myrtle Beach topographic map on MAP 9B: GRAND STRAND and identify the shoreline the article is talking about, as well as the places and events named in the story. Also locate as many of these features as possible on the Myrtle Beach NAPP photograph on IMAGE 9B: GRAND STRAND. Explain why the publisher thought this story might be of interest to newspaper readers. The article talks about events that could cause a major problem for Myrtle Beach. How well does the story convey the future danger of the situation? Does the article excite and scare people about the problem? Explain your answers. What type of writing style could make the story more dramatic so that readers will be more concerned and worried after reading the article. Using the same references and setting, write another newspaper article related to the same situation, but in a more dynamic fashion. Choose another title (headline) and draw an appropriate picture to illustrate your main point. Are there dangers in using very dramatic stories in newspaper articles? Explain your answer.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Research early settlements in Grand Strand area.** 🕮 ✍
   The Winyah Bay area has seen a variety of Spanish, English, and Native American settlements at different times throughout recorded history. Select one of these three cultures and research, through library and/or internet resources, the history of their settlements in this geographic area. Make special note of landscape features that influenced their choice of site. In a class presentation, describe where the settlers came from, where they were going, and their purpose in making the trip. Also explain what happened to the settlement and whether any remains of it can be seen today.

2. **Research beach renourishment project.** ✈
   Coastal cities often encounter problems with shoreline erosion resulting in the severe loss of sand and beachfront. Many have attempted to stabilize beaches by carrying out massive renourishment projects in which sand is taken from inland or offshore areas and pumped onto the beach. Find one example of a beach renourishment project in Myrtle Beach or other community along the Grand Strand of South Carolina and gather detailed information about it from library and/or internet resources. When did the project occur? Where was the sand taken from? How long did the project take to complete? How long did the renourished beach last? What were the political impacts of the project? What was the total cost? List the benefits and problems generated by the project. In your opinion, was the result worth the cost? Explain your answer.

Activity 9B-2: Ocean Floor Topography

POWER THINKING EXERCISE - "Contour Confusion"

You are the new owner of a small business in Murrell's Inlet that rents fishing boats to tourists. It is very important for the success of your business to ensure that these fishermen catch lots of fish, so your company will gain a good reputation and attract more customers. You have heard from other fishermen in town that certain fish species tend to inhabit particular types of ocean bottom environments, and that different kinds of fish travel in schools at different water depths. You and your partners figure that you would be able to find fish for the fishermen more effectively if you knew the topography of the ocean floor off the coastline of the Murrell's Inlet. So, on a tip from a friend, you purchase a bathymetric map from the nearby Coastal Carolina University in Conway, South Carolina.

When you open up the map, it looks just like the Grand Strand Bathymetry map on MAP 9B: GRAND STRAND. You remember from science class that contour lines can be used to represent water depths as well as land elevations, but you don't ever remember seeing contour line patterns this complicated before. Study the legend of this map carefully, then try to figure out exactly what the ocean bottom looks like offshore from the Grand Strand. [A note enclosed with the map explains that the straight-line contours to the left of the legend box are a computer error and should be ignored.]

Locate and mark on the map, with a wet-erase marker, at least three different places where deeper water is found very close to the shoreline. Then locate and mark, with a different color wipe-off pen, at least three different places where shallower water is found far away from the shoreline. Compare the pattern of contour bathymetry lines close to shore with those further out in the ocean. In which region are the lines more regular (simpler to interpret)? Why do you think there is a difference in the contour line pattern? How is the ocean floor topography (bathymetry) different from the topography on land? Explain your answers.

Materials
MAP 9B, GRAND STRAND
IMAGE 9B, GRAND STRAND
Figure 9B-2: "Location of Artificial Reefs Along Grand Strand"
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Plot locations of artificial reefs. ✈**
   Consult Figure 9B-2, "Location of Artificial Reefs Along Grand Strand," and find each artificial reef mentioned in the table below. Plot the exact positions (as closely as you can) on the Grand Strand Bathymetry map on MAP 9B: GRAND STRAND. Mark and label reef sites with a wipe-off pen. The latitude/longitude reference line values are labeled along the lower and right-hand margins of the map.

Artificial Reef Name	Structure	Latitude	Longitude
#5 - PARADISE	Reef Buoy	33º 31.071´	078º 58.140´
	Small Object	33º 30.930´	078º 57.999´
	Concrete Reef Balls	33º 30.959´	078º 58.051´
#6 - TEN MILE	Northern Buoy	33º 25.303´	078º 51.497´
	Southern Buoy	33º 26.261´	078º 52.706´
	Tugboat & Barge	33º 25.389´	078º 51.609´
	200' Ship	33º 26.407´	078º 52.807´
	Concrete Reef Balls	33º 26.081´	078º 52.239´
	Concrete Reef Balls	33º 26.092´	078º 52.201´
#8 - PAWLEY'S ISLAND	Reef Buoy	33º 25.993´	079º 00.718´
	Landing Craft	33º 26.082´	079º 00.686´
	Landing Craft	33º 26.100´	079º 00.749´
#9 - NORTH INLET	Reef Buoy	33º 20.530´	079º 00.910´
	Steel Pup Tents	33º 20.608´	079º 00.922´
	Concrete Reef Balls	33º 20.619´	079º 00.894´
#10 - GEORGETOWN	Reef Buoy	33º 14.332´	079º 00.152´
	100' Ship	33º 14.237´	079º 00.025´
	Barge	33º 14.547´	079º 00.136´
	Landing Craft	33º 14.341´	079º 00.217´
#11 - GEORGETOWN NEARSHORE	Reef Buoy	33º 12.716´	079º 00.306´
	130' Deck Barge	33º 12.727´	079º 00.313´
	62' Lash Barge	33º 12.760´	079º 00.346´
	62' Lash Barge	33º 12.730´	079º 00.205´

Refer to the bathymetric contour lines and the legend box on the map to determine the approximate water depth at each artificial reef. Are the reefs all at the same depth or does the water depth vary at each reef? List all the different materials used to construct artificial reefs. What do all of these materials have in common? Speculate on the purpose of the 'reef buoy'? Why do you think the Ten Mile Reef needs two buoys? Justify your answer. Why do you think they placed the artificial reefs in these particular locations? Locate a good spot to place the next artificial reef in this area and mark it with a wipe-off pen. Explain your selection process to the class and defend your reasoning.

2. **Interpret sea floor topography from sonar imagery.** ☼

Examine the contrasting patterns of light and dark on the Myrtle Beach Side Scan Sonar image on IMAGE 9B: GRAND STRAND. The brightest reflections usually come from rocky or shelly hardbottom areas. Soft mud and fine sand reflect poorly and show up as nearly black. Identify several hardbottom areas on the image. Is there any correlation between water depth, as expressed by the bathymetric contour lines, and the location of hardbottom areas? Explain your answer.

The side-scan sonar image is actually composed of strips of data gathered as a ship moves parallel to the shoreline. How many data strips were used to create the Myrtle Beach sonar mosaic? Explain how you determined your answer. What do you think caused the gaps in the image where no data is shown? Are these gaps severe enough to prevent you from understanding the basic sea floor topography? Why or why not? Do any of the bathymetric features continue onto land? Justify your answer.

3. **Estimate size of sunken features using sonar.** 💻
   Compare the four Side Scan Sonar insets on IMAGE 9B: GRAND STRAND. The red parallel lines on each image represent a way to calibrate distances under water. The thick red line running down the center of the image represents the path of the boat that is carrying the sonar technology. That line can be considered to have a value of 0. Other red lines are spaced 5 meters apart and increase in value away from the center line. Use the red-line information to estimate the width of the bridge, the width of the dock, and the lengths of the two sunken boats. Ignore the extra red line that appears on the left side of the centerline in each of the sonar insets.

4. **Locate and identify sunken features using sonar.** 🕮
   Read the title of each Side-Scan Sonar inset on IMAGE 9B: GRAND STRAND. Each refers to a particular underwater feature that shows up on that sonar image. Locate and identify each of the items. Remember that bright reflections indicate a surface that is hard or tilted towards the sonar source. A dark area represents soft sediment or surfaces that are tilted away from the sonar source. Objects that stick up out of the ocean will usually appear bright themselves, but will cast a dark shadow just behind them. Explain how you were able to recognize each feature. Which ones could you have identified without knowing the image title? Why is it important for archeologists to know what is on the bottom of the ocean, especially this close to land? What historical information about a location do you think you can you get by gathering side-scan sonar data in rivers, harbors, or shallow ocean areas? Explain your answer.

5. **Describe familiar setting using side-scan sonar terminology.** ✍
   We see the world of sonar as consisting totally of black and white images, which give information about how well objects reflect sound waves. Strong reflectors appear white, weak reflectors appear dark. Sonar images look strange to us because they describe objects in a way that we are not used to seeing them. To get an idea how this process works, write a short description of your room at home or your classroom as if you were 'seeing' it with side scan sonar. Pretend you are walking through the room picking up information about what is on the floor. Use word pictures to describe what you see, and sketch a picture, using only black, white, and various shades of gray, to represent what you see. Refer to the Side Scan Sonar insets on IMAGE 9B: GRAND STRAND for ideas on how to sketch your picture. Exchange your paragraphs and/or pictures with other class groups and see if you can reconstruct and interpret the actual objects on the floor that were represented in the sonar description.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Research shipwreck discovered using side-scan sonar. 🕮**
   Locate other sources of side-scan sonar data and select an image to study that contains a known shipwreck. Use library and/or internet resources to research the history of that particular boat up until the time it was sunk. How much of this historical information can you get directly from the side scan sonar image? Explain your answer. Compare your chosen image with the sunken ships on the side scan sonar insets on IMAGE 9B: GRAND STRAND. Put together a list of characteristics by which someone could distinguish a sunken ship from other buried debris.

2. **Explain strange pattern of bathymetric lines. ☼**
   Contact your school district computer specialist, or other expert, to find out how bathymetric data is put into a digital format and then printed on a base map in the proper location. Invite that person to your class to demonstrate the process of digitizing data and placing it in a computer file. Examine the strange contour line pattern just to the left of the legend box on the Grand Strand Bathymetry map on MAP 9B: GRAND STRAND. This data does not accurately represent the true ocean floor topography in this area. Speculate about how the original data could be corrupted to produce such a bizarre result. How do you think it is possible to distinguish computer errors from normal bathymetric data on this map? Explain your answer.

Activity 9B-3: Tourism and Land Use

POWER THINKING EXERCISE - "Tourist Trap"

The Myrtle Beach Air Force Base closed in 1996 because of budget cuts in the United States Department of Defense, but the runways are still used as part of the Myrtle Beach International Jetport. The civic leaders of Myrtle Beach want to take over the remainder of the former Air Force base property to promote more tourism in the area and generate more tax revenue. They have asked your group to recommend a land-use plan that will bring the greatest number of new tourists into the Myrtle Beach area.

Locate the Myrtle Beach Air Force Base on the Myrtle Beach topographic map on MAP 9B: GRAND STRAND. The base covers nearly a fourth of the map area and consists of the airfield as well as a large portion of the surrounding land, especially towards the west. A dashed black line marks the boundaries of this facility. The boundary connects a series of gates that allow access onto the base. Trace this boundary on the map with a wipe-off pen. What community facilities, buildings and other features are located on the base property besides the airfield?

Discuss within your group what land use (or uses) you think would attract the greatest number of new tourists. Identify which existing structures or facilities you would keep and which you would replace. Once you have made your decision, draw your plans on the map with a wet-erase marker. Use the same type of symbols and labels that are standard for topographic maps. Present your land-use plan to the class and be prepared to explain and justify your recommendations using map references.

Materials
MAP 9B, GRAND STRAND
IMAGE 9B, GRAND STRAND
story: "Signs of a Touroid Sighting" on page 9B-14
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Identify tourist oriented features in Myrtle Beach. ✈**
   Myrtle Beach is one of the most popular tourist destinations in the southeast. Examine the Myrtle Beach topographic map on MAP 9B: GRAND STRAND and locate every feature you can find that is obviously a tourist attraction or that could be used to support the tourism industry in some way. List these items in alphabetical order. Also try to locate each of these same features on the Myrtle Beach NAPP photo on IMAGE 9B: GRAND STRAND. Which features on the photo could you identify as tourist related without referring to the labels on the topographic map? Make a list of other tourist features, also in alphabetical order, which you think probably do exist in Myrtle Beach, but that you can not find on either the topographic map or photograph. Why do you think these other features are so hard to recognize?

2. **Evaluate causes of non-point source pollution.** ☼

As more and more people visit the Myrtle Beach area, air and water pollution problems are getting worse, particularly along the beach front. Most of the danger comes from non-point source pollution, which cannot be traced to a single industry or hazardous site. Class groups should select one of the listed causes of pollution and evaluate its impact on the total pollution problem of Myrtle Beach. Each group should carry out the following procedures, present their results to the class, and then rank the categories, as to greatest danger, during a class discussion.

- locate and mark with a wipe-off pen an area on the Myrtle Beach topographic map on MAP 9B: GRAND STRAND in which you think this particular problem would be significant;
- locate and mark with a wipe-off pen the corresponding area on the Myrtle Beach NAPP photo on IMAGE 9B: GRAND STRAND;
- predict whether this pollutant would create any problems on the beach front;
- determine how serious a health threat you think this problem might really be;
- make a list of suggestions on how to reduce or prevent this type of pollution;

GROUP I – automobile and truck exhaust
GROUP II – runoff from streets and parking lots
GROUP III – runoff from agricultural fields
GROUP IV – litter (garbage and trash)
GROUP V – runoff from golf courses
GROUP VI – runoff from airport runways

3. **Estimate lodging capacity for tourists.** 💻

Locate Ocean Boulevard (parallel to the beach front) on the Myrtle Beach topographic map on MAP 9B: GRAND STRAND. Also locate this road on the Myrtle Beach NAPP photo on IMAGE 9B: GRAND STRAND. Choose a one-mile section of Ocean Boulevard anywhere between Midway Swash and Withers Swash and trace this road segment on the photo with a wipe-off pen. Count all of the buildings that are visible along that segment between Ocean Boulevard and the beach. You can assume that 90% of these buildings are either hotels or motels. If the average number of rooms per hotel is 100, and an average of three people stay in each room, estimate the total number of tourists vacationing within your chosen area at any one time. Where do you think all of these tourists are going to park? Explain your answer in mathematical terms.

4. **Analyze impact of Myrtle Beach railroad line.** 🕮

The railroad line that used to bring vacationers to Myrtle Beach from all over the country can be seen (labeled 'SEABOARD') running along the northern side of U.S. Highway 501, on both the Myrtle Beach topographic map on MAP 9B: GRAND STRAND and the Myrtle Beach NAPP photo on IMAGE 9B: GRAND STRAND. How close to the ocean could you get if you traveled to Myrtle Beach by train? Why do you think the train station was not located right on the beach? Locate the turnaround track near the intersection of Harlem Street and 8th Avenue North. Railroad workers call this track configuration a "wye" (pronounced like the letter "Y").

How do you think it got that name (Hint: look carefully at the shape of the track)? What impact do you think the railroad had on turning Myrtle Beach into a prime tourist destination? If passenger rail service to Myrtle Beach was to start up again, how many people do you think would use it on an average summer weekend? What are some advantages of traveling to the beach by train? What are some disadvantages?

5. **Develop list of touroid characteristics.** ✍
   Read Peter Meyer's "Signs of a Touroid Sighting" on page 9B-14 and discuss the examples given in that writing. Then expand his list of Touroid characteristics. Make posters illustrating some of the new characteristics and share them with the rest of the class. Relate familiar wise sayings such as "When in Rome do as the Romans do" and "One man's trash is another man's treasure" to the behavior of tourists. Develop a list of helpful hints for Touroids visiting either the Grand Strand or the tourist town nearest your school. Develop a dictionary of local lingo for tourists to use. Examine the Myrtle Beach NALC photo on IMAGE 9B: GRAND STRAND and locate a particular spot where you are most likely to observe Touroids. Mark this spot on the photo with a wipe-off pen and explain to the class why you chose that site. Tell a story to your group about a time when you behaved as a Touroid or sighted a Touroid in your neighborhood.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Rank Myrtle Beach area in terms of tourism.** 💻
   Consult an almanac or other similar reference to gather data on the number of tourists that visit various vacation spots in the southeastern United States. Also research the amount of money they spend on food, lodging, and entertainment. Where does Myrtle Beach rank in tourism according to these sources? Estimate the area of the city of Myrtle Beach on the Grand Strand NALC satellite image on IMAGE 9B: GRAND STRAND. Look up the areas of other tourist centers and compare the population density. Which of these other cities is the most overwhelmingly tourist oriented?

2. **Design brochure for Myrtle Beach resort.** ✍
   Find a vacant lot somewhere on the Myrtle Beach NAPP photo on IMAGE 9B: GRAND STRAND where your group would like to construct a tourist business, such as a hotel, restaurant, amusement park, etc. Also locate this site on the Myrtle Beach topographic map on MAP 9B: GRAND STRAND. Design and produce a brochure to advertise your business. Display your results on a bulletin board. First, name your facility and write an exciting description of the facility that will make tourists want to visit. Then draw a simple map and write easy to understand directions so tourists will know how to get there and where to park their vehicles. Finally, organize all the parts into an attractive format and add the necessary artwork to make your brochure one that people will notice, pick up, and read.

THE DAILY MESSENGER

February 2, 2002

Sea Turtle Preservation may Dim the Lights in Brunswick

BRUNSWICK, GA (A.P.) – Civic pride has clashed with sea turtle preservation in a debate over whether to hang decorative lights on what will be Georgia's tallest bridge. The 480-foot Sidney Lanier Bridge is expected to open in July and some wildlife officials are concerned that bright decorative lights would affect young sea turtles leaving their nests.

Woody Woodside, the president of the local Chamber of Commerce, said he has asked his legislative delegation to make sure the lights are installed. They could be added before or after the bridge opens, said Lisa Sikes, the construction engineer on the project.

"Down here people had no idea that it wasn't going to be included." Woodside said. "The Chamber is very interested in seeing the superstructure in Brunswick illuminated. In fact, it should be since it's the tallest bridge in Georgia."

When the US Fish and Wildlife Service expressed concerns that the lighting plan could affect young sea turtles, the cable and tower lighting was dropped from the building contract. Greg Masson, an assistant field supervisor with the service, said when sea turtles emerge from their nest along the Atlantic Ocean, they head out to sea toward the light-colored water The lights could affect the turtles' sense of direction and cause them to come towards the coast, he said. Masson said "turtle friendly" bulbs can be used on the bridge: they're already going to be installed in street lights on the north approach span of the bridge.

The 7,776-foot cable-suspension bridge spans the Brunswick River to the Jekyll Island Causeway. It will replace a 43-year-old drawbridge the Coast Guard has declared to be a navigation hazard. If the lights are installed, the most likely source for paying the monthly bill would be Glynn County. "As much as we would like to have lights on the bridge, we can't light neighborhoods," said County Commissioner Fred Tullos.

RATIONALE

The Georgia Coastal Corridor is a mix of thriving port cities, undeveloped barrier island seacoasts, and an agricultural history that goes back to the times of Native Americans. The cities of Savannah and Brunswick are major shipping centers with a historic past while the Gullah culture of the Sea Islands preserves a unique African American heritage. The Okeefenokee Swamp is a peat-filled wetland that is known as the largest blackwater swamp in North America and is home to an amazing variety of wildlife. Cumberland Island is one of the world's largest undeveloped barrier islands, providing habitat for sea turtles and alligators.

The area around Darien and the Altamaha River was ideal for rice cultivation and was the center of the coast's plantation economy until the Civil War. The Altamaha River flows through some of the South's last remaining bottomland hardwood forests, cypress swamps, and tidal marshes containing over a hundred species of rare plants and animals. Several historic forts along the Georgia coast have been restored.

PERFORMANCE OBJECTIVES

1. Cross reference features on topographic map with same features on photos and images.
2. Analyze reasons for locating forts along Georgia coastline.
3. Interpret meaning of colors on infrared aerial photographs and satellite images.
4. Describe impact of ancient beach ridges on coastal drainage patterns.
5. Use dimensions specified in city plans to calculate dimensions of residential lots.
6. Determine distance using scale bar information on maps.
7. Explain advantages of using a grid pattern for city streets.
8. Explain why port cities are not located right on the coastline.
9. Create new Porquoi Tales using rice-field landscape as a backdrop.
10. Write poem incorporating word pictures of swamp land.

SAMPLE ASSESSMENT RUBRICS

EXAMPLE #1 (relates to Performance Objective #3)

Give students a copy of the ERTS satellite image on MAP 9C and ask them to identify three different landscape features that are part of a typical barrier-island complex and record the false-color that is used to identify each feature. Answers may include:

Beach or dune line = [white]
Salt Marsh or Tidal Flat = [dark purple]
Deep ocean water = [black]
Maritime forest = [red]
Tidal Inlet = [milky blue]
Agricultural fields = [gray-white]

A (level 4) – Three features are named and color assignment is correct for each.
B (level 3) – Three features are named but only two color assignments are correct.
C (level 2) – Three features are named but only one color assignment is correct; or two features are named both with correct color assignments.
D (level 1) – Two features are named but with only one correct color assignment; or one feature named with correct color assignment.
F (level 0) – One feature named with incorrect color assignment; or no features named, or no answer given.

EXAMPLE #2 (relates to Performance Objective #10)

Ask students to write a four line poem that describes the Okeefenokee Swamp. *Answers will vary widely, but a quality answer should follow the major rules of poetic composition and make at least two references to objects or features typically found in a swamp. An simple example might look like this:*

Shrouded in mist; the dark trees hover, Bears and alligators duck for cover
I see the moon rise over the river; The cold wind blows, I start to shiver.

A (level 4) – Follows rules of poetic composition and includes 2 swamp references
B (level 3) – Follows rules of poetic composition and includes 1 swamp reference; Or only marginally follows poetic rules, but includes 2 references.
C (level 2) – Marginally follows poetic rules, but includes only 1 swamp reference; or generally follows poetic rules, but swamp references are lacking.
D (level 1) – Marginally follows poetic rules, but includes no swamp references; or Includes one swamp reference but composition is not poetic.
F (level 0) – Composition not poetic and no swamp references given.

Cartographic Product Information

MAP 9C: Georgia Coastal Corridor

TITLE: Georgia Sea Islands, GA-FL (topographic map)
DATA SOURCE: Valdosta, Brunswick, Savannah, Jacksonville, Macon, Waycross USGS 1:250,000 Quadrangles
DATE: Valdosta: 1954 (photorevised 1965); Brunswick: 1956 (photorevised 1977); Savannah: 1957 (photorevised 1978); Jacksonville, Macon, and Waycross: 1988
SCALE: 1:365,000 [1 inch ~ 6.15 miles] [1 cm ~ 3.9 kilometers]
OTHER IMPORTANT DATA:
- The contour interval of this map is 25 feet.
- The bathymetric contour interval (underwater contours) is 2 meters.
- Because this image is a mosaic, you can see where segments have been joined (not all roads, contour lines and other fixtures will line up perfectly here).

POINTS OF SPECIAL INTEREST:
- The cities of Brunswick (right-center) and Savannah (top-right) show up clearly.
- The Darien rice-growing region is along the Altamaha River north of Brunswick.
- The Okeefenokee Swamp is in the bottom-left region of the map.
- The Cumberland Island National Seashore is in the lower-right area of map.

OTHER FEATURES TO LOOK FOR:
- Several ancient beach ridges are visible west of the city of Brunswick.
-- Barrier islands line nearly the entire coastline of Georgia.

TITLE: Georgia Sea Islands, GA-FL (ERTS [satellite image mosaic])
DATA SOURCE: USGS and NASA Landsat 1 (ERTS)
DATE: 1973, 1974
SCALE: 1:365,000 [1 inch ~ 6.15 miles] [1 cm ~ 3.9 kilometers]
OTHER IMPORTANT DATA:
- This image is a false-color infrared image, so all true colors are shifted.
- Red colors indicate forested areas, light gray colors indicate more populated areas
- Water with lots of sediment will appear lighter blue; clear water will appear black
- Wiggly broken white lines at top-right and bottom-right are state boundary lines.

POINTS OF SPECIAL INTEREST:
- The Altamaha River valley crosses the center of the image from left to right.
- The Okeefenokee Swamp is the strange looking area in lower left-center of image
- Cumberland Island is the barrier island on coast just north of the GA/FL state line
- City of Savannah is shown in upper-right corner of image.
- City of Brunswick is located just south of where Altamaha River enters ocean.

OTHER FEATURES TO LOOK FOR:
- Interstate Highway 95 is visible (thin white line) on right side of image near coast
- Ancient beach ridges are visible west of the city of Brunswick.
- Salt marsh areas appear behind barrier islands as very dark areas.

Cartographic Product Information

IMAGE 9C: Georgia Coastal Corridor

TITLE: AVHRR Altamaha River Wetlands, GA (orthophotoquad mosaic [photo & map])
DATA SOURCE: Altamaha Sound, Darien, Doboy Sound, and Ridgeville USGS 1:24,000 Orthophotoquads
DATE: 1979
SCALE: 1:28,000 [1 inch ~ 2,424 feet] [1 cm ~ .3 kilometers]
OTHER IMPORTANT DATA:
- Contour interval of this map - 1.5 meters; bathymetric contour interval - .5 meters
- Colors represent true colors [green = vegetation; blue = water; orange = sand].
- Because this image is a mosaic, you can see where segments have been joined

POINTS OF SPECIAL INTEREST:
- The Altamaha River and its distributary channels run across map left to right.
- The town of Darien is located in the top left-center of the map.
- The Hofwyl-Broadfield rice plantation historic site is in bottom left side of map.

OTHER FEATURES TO LOOK FOR:
- Rice fields are concentrated on islands between rivers at far-left side of map.

TITLE: Savannah, GA (NALC [infrared satellite image])
DATA SOURCE: EPA & USGS NALC Pathfinder WRS2 Path 16 Row 38
DATE: 1991
SCALE: 1:143,000 [1 inch ~ 2.3 miles] [1 cm ~ 1.5 kilometers]
OTHER IMPORTANT DATA:
- This image is a false-color infrared image so all true colors have been shifted.
- Bright red = forests; dark areas = salt marsh/tidal flat; black = clear water.
- Blue-gray color = urban & bare fields; milky-blue = water with lots of sediment.

POINTS OF SPECIAL INTEREST:
- The city of Savannah is in top-center portion of image.

OTHER FEATURES TO LOOK FOR:
- Numerous tidal channels show up in salt-marsh areas.

TITLE: Savannah, GA (black & white photo [oblique view]) and historical sketch map
DATA SOURCE: Black & White photograph: Georgia GIS Clearinghouse
Historic map: Historic Urban Plans, Ithaca, NY (sketch by Peter Gordon)
DATE: 1998 (Black & White photo); 1734 (historical sketch map)
SCALE: B&W photo: approximately 1:30,000 [1 inch ~ .5 miles] [1 cm ~ .3 kilometers]
Historic sketch map: approximately 1:1.000 [1 inch ~ 80 feet] [1 cm ~ 23 meters]
OTHER IMPORTANT DATA:
- Both the photo and the sketch are oblique views, so scale changes with distance.

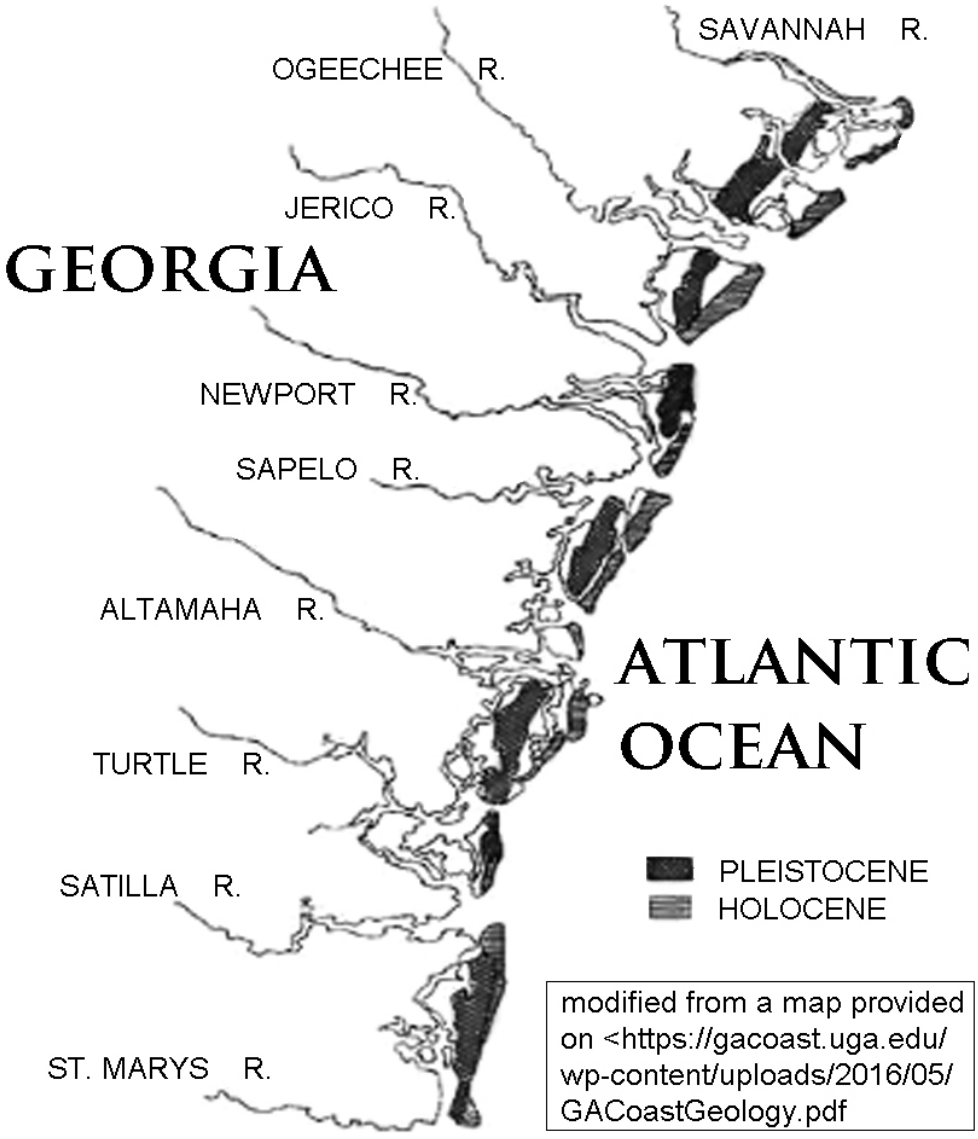
POINTS OF SPECIAL INTEREST:
- On photograph, roofs and concrete reflect light; rivers do not and appear dark

OTHER FEATURES TO LOOK FOR:
- Note that city is built on high ground while island in river is very low elevation.

Coastal Geology of the Sea Islands

At first glance, the Georgia Sea Islands appear to be part of a typical barrier-island dominated transgressive coastline, complete with migrating tidal inlets, estuaries, and extensive tidal flats and salt marshes. However, geologic studies have discovered that the Georgia coast actually contains two separate sets of barrier islands of different ages. The inner (landward) band of islands formed between 35,000 and 40,000 years ago during the Pleistocene Epoch and the barrier islands fronting the Atlantic Ocean date only between 4,000 and 5,000 years ago, during the Holocene Epoch.

Figure 9C-1: Ages of Barrier Islands Along Georgia Coast



The older islands are the remains of beaches that existed along the coast when sea level was about 6 feet (1.8 meters) higher than present. During the final phase of the most recent ice age the vast northern continental ice sheet trapped enough water on land to lower sea level over 300 feet (91 meters). About 18,000 years ago the ice began to melt and sea level began to rise at a rate estimated at about 5 inches (13 cm) per century. As the ocean rose to cover previously exposed stretches of river-deposited sediment, the combination of waves and tidal currents reshaped that sediment into a series of barrier islands. With continued sea-level rise, the shoreline kept migrating progressively westward as sand was eroded from the eastward facing beaches and deposited into the lagoons and marshlands behind the islands. At the current time, sea level continues to rise in this area at a rate of over 12 inches (30 cm) per century and the locations of the Holocene barrier islands are rapidly approaching the former shoreline position marked by the Pleistocene barrier islands.

Where major rivers empty into the ocean, enough sand is being added to the coastal supply to slow down the beach erosion process. As a result, barrier islands south of the Savannah River, near Savannah, and the Altamaha River, near Brunswick, have not yet caught up to the older barrier islands and the separation is still clearly visible on maps and aerial photographs. However, Holocene barrier islands fed by smaller rivers lack this source of new sand and in many cases have come close to or have already merged with the Pleistocene barriers to form a single wide island.

Because longshore current (and therefore longshore drift) runs from north to south along the Georgia coast, sand is typically eroded from the north end of the barrier island and deposited as sand spits or shoals along the south end of the island. Over time, unless additional sand is added, this pattern can produce islands that are very narrow at one end and very wide at the other end, a geometry sometimes referred to as the ‘chicken drumstick’ pattern. The migration of sand also can close some tidal inlets and cause others to migrate far from their original position. Storms often open new inlets that cut the barrier island in two and start the same process all over again.

Ancient beach ridges, much older than the Pleistocene Epoch, occur farther westward away from the ocean and represent different shorelines that existed at several different times of higher sea level during the Cenozoic Era. These ridges are significantly higher than the surrounding landscape and, although erosion has modified some of their features, they can often be recognized by their linear geometry, their elevation, and their distinctive soil types. Many of the highways and railroads running north to south through the Georgia Coastal Corridor take advantage of these ridges to avoid the flooding issues common in the lower elevation wetland areas. Also, several river courses in coastal Georgia appear to have been diverted around such old terrace features. One excellent example is the Satilla River. The Okeefenokee Swamp, in the southeastern part of the state, is a vast freshwater wetland that has been impounded by one of these ridges. The swamp features a variety of islands, lakes, jungles, ancient cypress forests, and prairies that provide habitat for black bears, alligators, a variety of wading birds such as the Sandhill Crane, and the Gopher Tortoise.

Most Georgia rivers enter the ocean through estuaries, which represent former river channels that have been flooded because sea level has gradually risen. Most pre-existing **landforms** are hidden below the water line, leaving only shallow marshy areas visible along the boundary of the estuary. They are essential wetland areas, where fresh water from inland sources joins incoming salt water from the oceans. They develop extremely dynamic ecosystems that are constantly changing in response to tidal action and to the varying amounts of fresh water, governed by seasonal and meteorological changes. Rivers, creeks, and smaller tributaries serve as arteries for transporting nutrient-rich material eroded from upstream. This material, along with nutrients brought in by the tides, nourishes many forms of marine life, especially the larval stages of invertebrate species that flourish in this protected environment.

Tidal flats are mostly flat, low-lying areas flooded by seawater part of the time and exposed to the air part of the time. The total amount of land flooded depends on the tidal range and the effects of storms. In many ways tidal flats are similar to river **floodplains**. Tidal channels drain the higher portions of the mostly featureless plains covered with marsh grass. The channels **meander** widely across muddier areas forming occasional **tidal channel levees** and sandy **point bar deposits**. The channels often interconnect, especially near the **tidal inlet**, which provides access to the open ocean. Some systems are dominated by very strong incoming tidal currents. Sediments are pushed landward by these currents to form flood tidal **deltas**. If the outgoing tidal current is stronger, sediments will often be carried out into the open ocean, through the tidal inlet, to form ebb tidal deltas. The relative amount of erosion and deposition on any portion of the tidal flat depends on its height above or below average sea level (mean sea level).

Coastal vegetation can be grouped into four zones - fresh marshes, maritime forests, salt marshes, and sand dunes. Fresh marshes are inundated by fresh water and are protected from saltwater intrusion by old beach ridges or other natural barriers. They support a marsh-type vegetation dominated by rushes, and in contrast to swamps, contain no trees or shrubs. The vegetation is composed primarily of bulrush, cattail, and black needlerush. The ancient beach ridges themselves were once active sand dunes that are now separated from the shore and have a distinct maritime forest vegetation. Maritime forests are dominated by trees and shrubs that are tolerant of sea winds and salt spray. The live oak and the palmetto palm are particularly tolerant of these conditions. Other trees and shrubs of the maritime forest include the slash pine, magnolia, holly, waxmyrtle, and wild olive. The active sand dunes, along the modern shoreline, are dominated and anchored by sea oats. Also common on the fore dune is the marsh elder and on the dune's protected backslope the pennyworth and sandspurs are found. In the depressions behind the fore dune is an area protected from salt spray. It is here that yaupon, waxmyrtle, dwarfed live oak, Spanish bayonet, and other similar plants thrive.

Closer to the ocean and inundated at high tide are the salt marshes. With ample sunlight, plentiful nutrients provided by inland rivers, and periodic tidal flushing, the salt marsh provides an ideal environment for plant production. However, the high salinity of the water limits plant life to one dominant species called cord grass, or **spartina**. This single species dominates the entire salt marsh, growing tall along creek banks, and

somewhat shorter on the expansive flats. As spartina growth slows during the winter months, wave action and bacteria break down the stalks to form a rich mix called **detritus** which provides a source of energy for zooplankton (microscopic aquatic animals) and phytoplankton (microscopic aquatic plants).

Few animals can survive the sudden and drastic environmental changes of the twice daily tides which alternately flood and drain much of the salt marsh. Marine animals, such as fiddler crabs, periwinkle snails, ribbed muscles, oysters, and clams, are especially adapted to deal with such rapid change by burrowing into the soft mud, called pluff mud, or closing their shells to provide protection from predators and desiccation when tides are low. The only vertebrates that live year round in the salt marsh are diamond back terrapins, clapper rails, and a few small fishes. Many species of vertebrates and invertebrates, however, visit the salt marsh with the rising tide to prey on resident animals and on each other. Life in the salt marsh is therefore intimately connected to life inland and even the open ocean.

The food web includes grazers such as the salt marsh grasshopper and marsh periwinkle, while animals like shrimp, fiddler crabs, and mullet feed directly on detritus. Less mobile organisms such as oysters, clams, and mussels filter nutrients directly from the murky water, and scavenging crabs clean up dead organic matter. Predators at the top of the food chain include such birds as clapper rails, oystercatchers, pelicans, herons, and egrets, as well as many species of fish, notably red drum, spotted seatrout, and flounder.

Three-quarters of all recreational and commercially important fish and shellfish spend all or part of their lives in estuarine waters in and around salt marshes. Many species of shrimp, crabs, and fish utilize the marsh's narrow, shallow creeks as nurseries for their early larval stages. In addition to providing food and shelter for so many marine organisms, the salt marsh also filters pollutants and silt from coastal waters, and buffers adjacent highlands from wind and waves. Recent development activities, however, pose an ever-increasing threat to the well being of these unique features. Destruction of wetlands by housing and recreational developments, water quality changes due to pollution from industries, and overuse of natural resources are three major threats to this ecosystem. Many of the Georgia sea islands have avoided such development in the past, but increased tourism has created new pressures to protect and preserve these sites. Cumberland Island is one of the largest undisturbed barrier islands in the world and has been designated a National Seashore wilderness area. It provides habitat for loggerhead sea turtles, American alligators, and more than 300 species of birds.

Coastal Agriculture and Forestry

The city of Darien was the center of the region’s timber and rice culture for many years. The Altamaha River floodplain contains extensive tracts of bottomland hardwoods and cypress swamps that were extensively logged during the 1800s. The surrounding longleaf pine forests also supplied lots of timber that was rafted down the river to Darien where it was cut by steam driven sawmills and loaded onto freighter ships for distribution all over the world. Once railroads reached the port of Brunswick, the industry prospered

even more and the number of sawmills increased greatly. By the 1920s, however, this industry was headed into decline due to the over-cutting of the forests. Today, the main forest product is wood pulp, used in the production of paper products.

Evidence indicates that rice seeds were first brought to America by African slaves from Madagascar, a large island off the east coast of Africa. The Rice Plantation Era in the South began in the early 1700's. The extremely labor intensive cultivation of rice created a planter's aristocracy of great wealth and power, made possible by the hard work of thousands of slaves. The earliest rice crops were grown in open fields, but keeping the weeds from choking the young plants, and insects from devouring the crop, were major problems. However, early in the eighteenth century it was discovered that tidewater cultivation of rice, on reclaimed swamp lands, solved most of these problems. In the tidewater model, rice plantations were located just above the level of the incursion of salt water and just below the upper limit of the tidal effect. In the brackish-water estuaries or marshes, strategically placed gates, dikes, ditches, and canals allowed the rice planters to make use of the rising and falling tides, which provided the energy to move water back and forth between the rice field and the canal or river. This tidal flushing action provided the proper agricultural conditions for rice cultivation. Although other rivers were used for rice cultivation, it was the Altamaha River wetlands near Darien that became the major rice producing region in Georgia and one of the largest in the world. In 1860, Georgia produced 38,950,691 pounds of rice, second only to South Carolina in the South.

Figure 9C-2: Hofwyl-Broadfield Plantation Layout

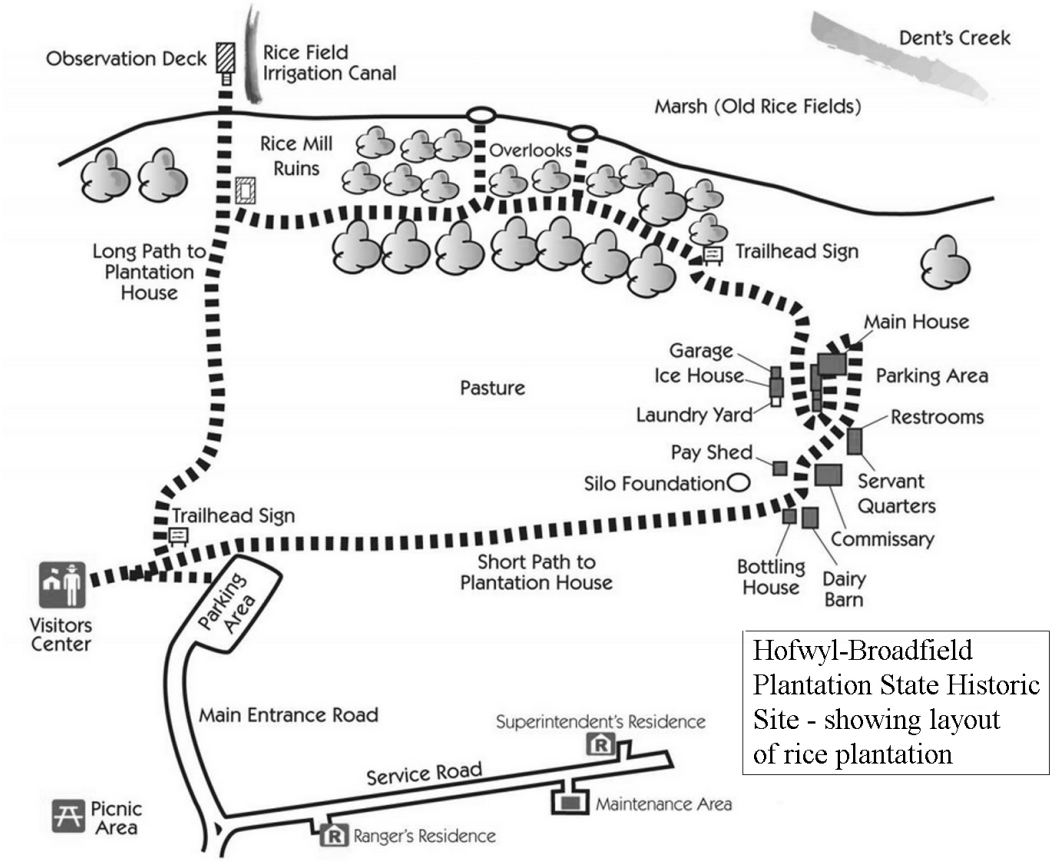
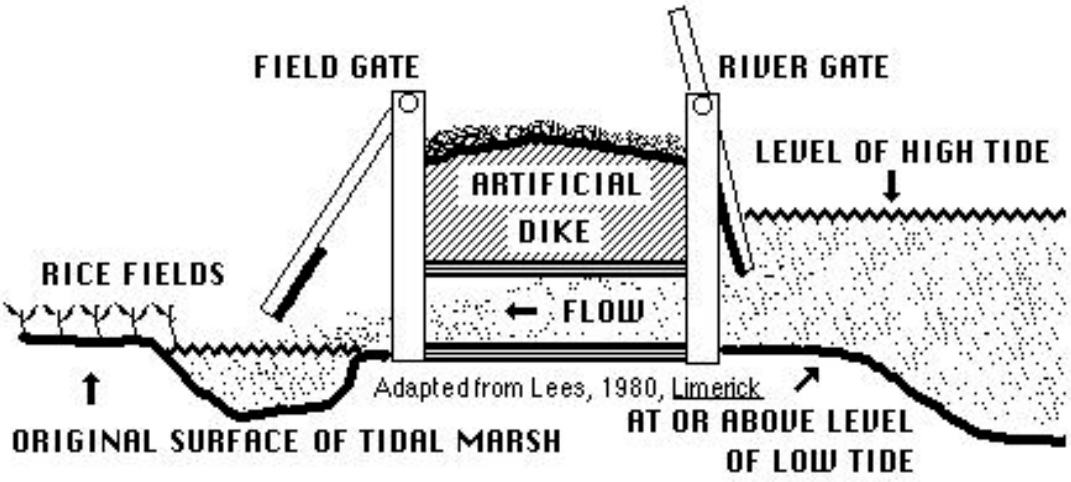


Figure 9C-3: Cross-Section of Typical Rice Trunk Gate



It was slave labor that cleared the cypress swamps and constructed dikes with sluice gates to flood and drain the fields, but slaves also provided much of the knowledge necessary for the cultivation of rice, since none of the Europeans had much experience with rice cultivation. In fact, rice planters preferred to import slaves from Sierra Leone, along the West African coast, where Africans had years of experience with rice cultivation. During the Plantation Era, slaves continued to use the traditional African methods of planting, hoeing, winnowing, and threshing rice. Slaves on rice plantations worked in what was called the "Task System." Each slave had a specified task that was based on the worker's age, ability, and physical condition. Categories of tasks were "full," "three-quarter," "half," and "quarter." Owners defined a task as "as much work as the meanest hand can do in nine hours working industriously." Slaves were given their task assignments in early morning. Once the work was complete, the slave could pursue personal interests. Slaves often worked together to help each other complete tasks, a tradition carried over from their original African culture. The singing of songs while working was another African custom which made the work seem to go faster and easier.

Many slaves were able to maintain and transmit some of their African heritage through development of the Gullah language, crafts, and folk tales. For example, in many rice-growing regions, basketry flourished and found practical application in the production of baskets for both storage and the winnowing of rice. These baskets used distinctive West African construction techniques, although they utilized local materials, traditionally coils of sweetgrass stitched together with dried palmetto fronds (leaves). The Africans also brought with them a heritage of trickster tales. The major animal trickster spoken about on the rice plantations of Georgia was Brer Rabbit, who would appear in a variety of different roles. Common to all the trickster tales was the theme of a smaller, weaker animal or person defeating a larger more powerful animal or person by using his wits. The title "Brer" can be translated as "Brother," and along with the title "Sister," was commonly used in addressing others of similar social status. Many of the Brer Rabbit tales also qualify as Pourquoi Tales (taken from the French word for "why"), a literary style which uses encounters between animals and natural events to explain how the world came to be the way it is.

How the Alligator Got its Bumpy Skin

--excerpted from Afro-American Folktales, edited by Roger Abrahams--

One time, Brer Alligator's back used to be smooth and white as a catfish skin. When he came out of the water and lay down to sleep in the hot sun, he shined like a piece of silver. He was mighty proud of that hide, and all 'round stuck up and pleased with himself in every way. He and his wife and his family lived down in the river at the edge of a rice field down near Darien. And they were so satisfied with themselves that they thought that there wasn't anybody quite like them in the entire county. And they had no notion how true that was!

Well, one hot day in the fall, Brer Gator was resting himself upon a rice field bank, when along came Brer Rabbit. Now Brer Rabbit had no love for Brer Gator, but he stopped all the same to pass the time. He said "Howdy, Brer Alligator. How is Sister Alligator, and all the young alligators making out?" Brer Gator answered; "They're getting on just fine. But it's no wonder that those children are smart and pretty and raised right, because they live right here in the river. I swear to God, I can't see how you others get by living up on top of that dry, drafty land."

Brer Rabbit got really angry with Brer Gator for being so set in his notion and so superior in his manners. But you know how, even when he's angry, he can hide it, so Brer Rabbit just stayed calm and pretended that Brer Gator is a wise man and sighs and says, "Maybe so. We sure have been seeing a lot of trouble up here lately." "I tell you, Brer Rabbit, I ain't never known nothing about this here Trouble," says Brer Gator. "What does Trouble look like?"

Brer Rabbit is mischievous and scheming and he takes his chance to teach Brer Alligator a lesson. "I don't know that I can tell you exactly what Trouble looks like. But maybe you'd like to see him?" So next Saturday Brer Alligator and Sister Alligator and all the alligator children met Brer Rabbit on the rice-field bank. Brer Rabbit led them up through a patch of woods until he got to a field grown over with broomgrass and briar! When they got to the middle of the field he stopped and cupped his ear and pretended to be listening for something. He smelled the wind and looked which way it was blowing. Then he pulled a handful of that long, dry broomgrass down, pulled a match from his pocket, struck it and lit the broomstraw blowing on it till the grass caught fire good. Then he ran along the edge of the field and set the field ablaze all around. When he was finished, he got up on a safe high stump where he could see good and he sat down. Finally the wind caught the fire and the fire flared high and the sparks and flames flew way up in the sky. One of the little alligators saw that and he hollered, "Oh look! That must be Trouble! Trouble is pretty!

Just then one of the sparks landed on the little alligator and he cried "Trouble hurts!" Then the sparks began to burn the whole bunch and they were so mixed up they didn't know what to do. They tried to get away, but everywhere they turned was fire. They hollered and hollered, "Brer Rabbit,

where are you? We don't want to see no more Trouble! Come for us!" And very soon the fire got so close to those gators that they couldn't hold their ground any longer. They stopped calling Brer Rabbit, and got ready to get through the fire the best they could. They didn't have any notion left in their head but, Get Home! They went right through the scorching flames right past Brer Rabbit. "Wait, Brer Alligator!" he shouted, "I guess you have seen Trouble now! Get back in the water where you belong. And don't ever hunt Trouble again." And they didn't stop either 'til they got to the rice field bank and jumped in the river with a "Swiish-ss-sh." When they finally got a chance to look at each other they found that their white skin was just as black and crinkly as a burned log of wood, and as rough as live oak bark. From that day to this, alligators have had a horny hide.

Rice never recovered its role as the major export staple of the coastal area after the Civil War. The plantation system required a stable, disciplined labor force. After the war, there was major unrest among Black rice workers. The full-scale renewal of rice production would have required a vast amount of capital, money not available in Georgia after the Civil War. Also, more productive lands farther west in Louisiana, Texas, and Arkansas were being opened to large-scale rice cultivation. The last of the commercial rice planters gave up after 1906 and turned to other crops. Afterwards, many of the old rice plantations were purchased by wealthy northern industrialists who turned the homesites into winter retreats and the old rice impoundments into private hunting land.

Savannah and Human History

Prior to the early 18th Century, the Georgia coastline was home for a group of Native American communities belonging to a southeastern alliance known as the Creek Confederacy. The Muskogee were the major tribe in that alliance. The name "Creek" probably came from the shortening of "Ocheese Creek Indians," the name given by early English settlers to the natives living along the Ocmulgee River. The Creek people lived in large permanent towns surrounded by outlying smaller villages. The towns were centers for festivals, religious ceremonies, and games. Residents lived a primarily agrarian lifestyle, raising crops and livestock.

During the period of European exploration, France, Spain, and England all laid claim to the Georgia Coastal Corridor because of the area's rich resources of timber, wildlife, animal furs, and extensive river systems. Under pressure from colonists in South Carolina, worried about Spanish raids, England established several forts along the Georgia coast, the first being Fort King George along the Altamaha River built in 1721. On February 12, 1733, James Oglethorpe landed on a bluff along the Savannah River with 120 colonists and established the first permanent settlement in Georgia. Oglethorpe laid out the city in a series of grids allowing for wide streets, and public squares. The plan called for six interconnected wards built around central squares, with lots on the east and west sides of the squares reserved for public buildings and churches. Lots on the north and south sides were designated for colonists' private homes. The wards measured 675 feet on each side, excluding the surrounding streets.

Protection from invaders, including pirates, now became increasingly important and Oglethorpe convinced England to construct Fort Prevost on the eastern end of the bluff along the Savannah River, continuing the walled protection that had already been constructed around the city. The walls were constructed of talus faced with pine saplings set in the ground and a blockhouse was built to serve as barracks for soldiers and a storage facility for ammunition and other supplies.

By 1754, Georgia had officially become a British colony with Savannah as its capitol. The low marshes were converted into rice fields and slaves were imported from West Africa to work the plantations. During the Revolutionary War, Savannah remained firmly under British and loyalist control. The first known American golf course opened in the city in 1792 and one of the oldest Black Baptist congregations in the country was founded in 1773. For a time, the city housed the Savannah Cotton Exchange, a place where brokers serving the planters' interests could set the market value of cotton being exported to larger markets such as New York and London. Planters on both the Georgia and South Carolina sides of the Savannah River shipped their cotton downriver to market there. The export of naval stores, such as pitch and turpentine, as well as lumber, from the yellow pine forests of the interior, helped to diversify the economy of the port.

The Georgia Coastal Corridor largely avoided major conflicts during the Civil War, although several minor skirmishes occurred at forts located on several of the barrier islands. Those forts were all eventually brought under Union control. But the major conflict was General Sherman's 1864 'March to the Sea' that ended with the capture of the city of Savannah on December 22. After securing the city, Sherman sent the following telegram to President Abraham Lincoln, offering him the city as a Christmas present: "I beg to present you as a Christmas gift the City of Savannah, with one hundred and fifty guns and plenty of ammunition, also about twenty-five thousand bales of cotton." President Grover Cleveland visited the city in 1888 to dedicate a statue to Revolutionary War hero Sergeant William Jasper.

During the 1930s and 1940s several buildings in the historic district were demolished in an attempt to revitalize commerce in the downtown area. This led to the formation of the Historic Savannah Foundation, which was able to halt further destruction and preserve several prominent landmarks. As a result, the city has been reborn as a major tourist destination, aided by the popularity of a best-selling 1994 book, "Midnight in the Garden of Good and Evil," authored by John Berendt, and a subsequent movie by the same name, both set in Savannah. Several statues memorialize famous heroes of the city. The James Oglethorpe statue stands in Chippewa Square, while statues honoring Sgt. William Jasper and famous preacher John Wesley stand in Madison Square and Reynolds Square respectively. Tourists can stroll along the brick sidewalks of a revitalized historic district under massive oak trees, planted more than 100 years ago after a hurricane blew down the original pine trees. And although the historic area has no official public gardens, the entire district seems covered with ferns, azaleas and hydrangeas, as well as flowering vines that cover walls and fences. The old waterfront has also been revitalized as many old warehouses have been refurbished and converted into restaurants and shops. Of Oglethorpe's original 24 squares, 21 of them still exist.

Activity 9C-1: Coastal Geology of the Sea Islands

POWER THINKING EXERCISE - "Silty Sounds"

The City Councils of Brunswick and Savannah, the two largest coastal cities in Georgia, have just finished a joint meeting to discuss the shrinking supply of fresh water along the coast. Most coastal cities get their drinking water from wells, but as pumping has increased over the years, salt-water incursion into the wells has made many of them unusable. Expected population growth in this area will most likely increase the demand for fresh water in the future. Locate the cities of Savannah and Brunswick on the Georgia Sea Islands topographic map on MAP 9C, GEORGIA COASTAL CORRIDOR and predict the most likely direction of population growth around these cities. Be able to explain the reasoning behind your answer.

The unanimous decision of the group was to consider constructing a desalinization plant somewhere along the Georgia coast and use pipelines to carry the water to the two cities. A desalinization plant would use evaporation to separate dissolved salts from seawater, then condense the water vapor to produce pure, fresh water that can be piped to the cities. Your group has been hired to study the entire Georgia coastline and recommend the best site for the new plant.

The plant itself must be built on land, so seawater must be pumped into the facility from either the open ocean or one of the river estuaries, called sounds. You would prefer the pipeline to be as short as possible. Also, you want to pump only clear seawater into the plant. Silty or muddy water will cause problems over time with pipe valves and other machinery within the plant. Fortunately, the infrared wavelengths of light used by most satellite imagery easily distinguish between silty/muddy water (light blue color) and clear water (black color).

Use the Georgia Sea Islands ERTS satellite image mosaic on MAP 9C, GEORGIA COASTAL CORRIDOR to help you select your preferred site for the new plant. Mark this location, with a wipe-off pen, on the Georgia Sea Islands topographic map and describe the location using the place names on this map. Also trace, with a wipe-off pen, the pipeline routes you would use to get the water to the cities of Brunswick and Savannah. Present your plan to the rest of the class and be ready to justify and defend your conclusions.

Materials
MAP 9C, GEORGIA COASTAL CORRIDOR
IMAGE 9C, GEORGIA COASTAL CORRIDOR
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. Correlate topographic map features with satellite image. ✈

Use the Georgia Sea Islands topographic map on MAP 9C, GEORGIA COASTAL CORRIDOR to locate the series of barrier islands along the Georgia coastline. What

is the total number of islands shown on the map? Now look at the Georgia Sea Islands ERTS Satellite Image on MAP 9C. Locate these same islands and count them again. Are your counts the same as they were using the topographic map? Explain any differences. To what color on the topographic map does the red color on the satellite image correspond? What feature does this color represent? What color on the satellite image corresponds to the white areas behind the islands on the topographic map? What feature does this color represent? How are beaches, spits, and sand shoals represented on topographic maps and satellite images? Where on the islands does sand generally tend to accumulate?

2. **Locate ancient beach ridges.** ☼

PART I: Locate the cities of Brunswick and Jesup (shaded yellow) on the Georgia Sea Islands topographic map on MAP 9C, GEORGIA COASTAL CORRIDOR. About halfway between these two cities, along U.S. Highway 25 and the railroad line, lies the small community of Mount Pleasant. Mark this location on the map with a green wipe-off pen. The contour line pattern in this part of the map indicates the presence of a long hill or ridge running in a generally southward direction through Waynesville (along U.S. Highway 84) to Midriver (along Georgia Highway 252). Trace the path of this ridge on the map with a black wipe-off pen. Another less obvious but similar ridge runs intermittently from Jesup southward to Folkston, Georgia (near the Florida state line) along U.S. Highway 301. Trace this ridge on the map with a black wipe-off pen too. These ridges represent the sand dune line of old beach ridges, formed long ago when sea level was higher than it is today. These ancient beach ridges run generally parallel to the modern coastline and are noticeably higher in elevation than the land on either side. Examine the topographic map carefully along the path of both ridges you identified and mark (with a green wipe-off pen) the locations of all lookout towers and radio towers. Why is a ridgeline a good location for lookout towers and radio towers? Examine the Georgia Sea Islands ERTS satellite image on MAP 9C, GEORGIA COASTAL CORRIDOR. Locate and mark these same two ancient beach ridges on the satellite image. How can you recognize this feature on the ERTS image? Explain your answer.

PART II: With a blue wipe-off pen, trace the complete drainage pattern (main river and all tributaries) of the Satilla River onto the Georgia Sea Islands topographic map on MAP 9C, GEORGIA COASTAL CORRIDOR. The Satilla River flows into the Atlantic Ocean near Jekyll Island State Park south of the city of Brunswick. Describe how the path of this river system is affected by the presence of the two ancient beach ridges you plotted earlier. Refer to the ERTS satellite image, also on MAP 9C, to get additional information. Which is older, the beach ridges or the river path? Explain your reasoning.

3. **Calculate average spacing of inlets along coast.** 💻

Along the Georgia coast, inlets from the ocean are referred to as sounds, whether they are associated with large river systems or simply local tidal channels. Examine the Georgia Sea Islands topographic map on MAP 9C, GEORGIA COASTAL CORRIDOR, and mark, with a wipe-off pen, the location of every major inlet (sound)

from the Florida border to the Savannah River. How many inlets lie along the Georgia coast? Use the scale bar to determine the approximate distance between adjacent inlets and record this information in a statistical table. Calculate the mean and median values for inlet spacing. Does the statistical pattern appear random or regular? Is there any difference in inlet spacing between the north end of the map (near Savannah) and the south end (near the Florida border). Use your data table to explain your answer.

4. **Explain why port cities are located so far inland.** 🕮
Locate and mark Interstate Highway Route 95 and the two major port cities of Savannah and Brunswick (yellow shading) on the Georgia Sea Islands topographic map on MAP 9C, GEORGIA COASTAL CORRIDOR. Locate and mark these same features on the Georgia Sea Islands ERTS satellite image on MAP 9C. Also locate the city of Savannah on the Savannah NALC image on IMAGE 9C, GEORGIA COASTAL CORRIDOR. Why were these major port cities not located on the beaches or the sounds along the sea islands facing the Atlantic Ocean at the time they were founded? When the railroads were built in the 1800s, and later when the Interstate Highway system was planned in the 1950s, why were these transportation routes placed so far inland, instead of being built out on the sea islands along the ocean? What are the historical advantages to having population centers, highways, ships, and docking facilities so far inland from the ocean? Are there disadvantages to being so far inland? Justify your answers.

5. **Write poem describing sights in Okeefenokee Swamp.** ✍
The background information describes the Okeefenokee Swamp as: "a vast freshwater wetland that features a variety of islands, lakes, jungles, ancient cypress forests, and prairies that provide habitat for black bears, alligators, a variety of wading birds such as the Sandhill Crane, and the Gopher Tortoise." What images do those words create in your mind? What kind of mood is conveyed by that description? Locate and mark the Okeefenokee Swamp on the Georgia Sea Islands topographic map on MAP 9C, GEORGIA COASTAL CORRIDOR (lower-left), and also on the Georgia Sea Islands ERTS satellite image on MAP 9C. Use the description, the map information, and your imagination to write a poem that describes the Swamp. Take turns reading poems to the class and compare writing styles.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Research history of Cumberland Island National Seashore. ✈**
   Locate Cumberland Island National Seashore on both the Georgia Sea Islands topographic map on MAP 9C, GEORGIA COASTAL CORRIDOR, and on the ERTS satellite image, also on MAP 9C. The island was originally designated as a wilderness area with no roads or other human structures permitted. Several attempts have been made since to open up part of the island to more touristy-type attractions. Use local library or internet resources to research the history of the National Seashore, the attempts to change its wilderness status and the results of those efforts.

2. **Explain occurrence of Okeefenokee Swamp. ☼**
   Locate the Okeefenokee Swamp on the Georgia Sea Islands topographic map on MAP 9C, GEORGIA COASTAL CORRIDOR (lower left section) and on the Georgia Sea Islands ERTS satellite image also on MAP 9C. Why does this swamp exist where it does? What topographic features must be present to create such a large swamp area? Why do other similar swamps not occur in the rest of the Georgia Coastal Corridor? Use geologic references from local libraries or internet sites to back up your conclusions. Prepare a brief report to present to the class summarizing your findings.

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Activity 9C-2: Coastal Agriculture and Forestry

POWER THINKING EXERCISE - "Network Navigator"

You are a business manager at the Broadfield Plantation in 1750 and have just finished loading a series of barges with recently harvested rice to be taken to market. The plantation normally sells the harvested rice to an English shipping company that loads their boats in the town of Darien. But a friend has just gotten word to you that a rival French company is willing to pay a much higher price for your rice harvest, but of course they are not welcome to dock in the English controlled town of Darien. You are told that the French ship is anchored in Doboy Sound, just north of the Wolf Island spit, but it will only be there until sunrise tomorrow. That gives you a total of only twelve hours to reach Doboy Sound with your harvest. Your task is to find the shortest route from Wright's Island (where the barges are loaded) to Doboy Sound (where the French ship is waiting). You can travel all night because there is a full moon and your boat captains will be able to see well enough to navigate the complex network of waterways to the ocean.

Locate all of the place names mentioned above on the Altamaha River Wetlands orthophotoquad mosaic on IMAGE 9C, GEORGIA COASTAL CORRIDOR. Mark, with a wipe-off pen, the locations of Wrights Island (far left side of map) and the Wolf Island Spit (far right side of map). Plan your best (quickest) route to the French ship by measuring the distance along several different possible routes. Place a piece of string along your proposed route and mark the length of that route on the string. Pull the string straight and use the scale bar on the map to measure the length. Try this method several times until you are sure you have located the shortest route. Make sure to measure your distances in miles, because the metric system hadn't been invented in 1750.

After you have determined the distance of the shortest route, you must calculate whether you have enough time to reach the French ship before it leaves. You don't want to travel all that distance for nothing. Make a reasonable guess as to how fast the barges can move. Remember that there were no motorboats in 1750. Then calculate how many hours it would take to reach your destination traveling at that speed. Will you be successful? Be prepared to show your calculations to justify your answer. Are any segments of your route dangerous to take? What other factors might influence your choice of the best route? Explain.

Materials
MAP 9C, GEORGIA COASTAL CORRIDOR
IMAGE 9C, GEORGIA COASTAL CORRIDOR
Figure 9C-2, "Hofwyl-Broadfield Plantation Layout"
Story, "How the Alligator got its Bumpy Skin" on Page 9C-11
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Locate and describe rice field impoundments. ✈**
   Locate and mark Butler Island, southwest of the town of Darien on the Altamaha River Wetlands orthophotoquad mosaic on IMAGE 9C, GEORGIA COASTAL CORRIDOR. Identify the rectangular map patterns made by the rice field impoundment dikes and ditches. Similar patterns are barely visible on Cambers Island, Wrights Island, and Carrs Island. Why were these islands chosen for rice cultivation? What is the approximate elevation of most of the rice fields? Select one individual rice field that you think is typical in size and shape. Refer to the scale bar on the map to measure the length and width of that field (in feet) and calculate the surface area (in square feet). Convert your answer into acres (1 acre = 43,560 square feet). What function do the levees serve?

2. **Evaluate likely sites for tidewater rice production. ☼**
   Tidewater rice cultivation requires large quantities of fresh water and extensive tracts of low lying land so that tidal forces can alternately flood and drain the fields. Using the Darien region on the Altamaha River Wetlands orthophotoquad mosaic on IMAGE 9C, GEORGIA COASTAL CORRIDOR as a model, list the landscape characteristics that make this area so successful for rice cultivation. Now look at the Savannah NALC satellite image also on IMAGE 9C. Use your list to evaluate the potential of the Savannah River area as a rice cultivation area. Mark on this map, with a wipe-off pen, where you think the best rice-growing sites might be located and be prepared to justify your choice to the class. Finally, examine the entire Georgia coast, using the Georgia Sea Islands topographic map and the ERTS satellite image on MAP 9C, GEORGIA COASTAL CORRIDOR. Identify and mark (with a wipe-off pen) several regions that you think would be successful at growing rice, based on your list of characteristics. Compare your list of sites with those of other groups in the class.

3. **Solve Alexander the Ant's problem. 💻**
   Alexander the Ant lives in the middle of an active rice field on the northern end of Butler Island in the Altamaha River system, southwest of the town of Darien. He moved in when the rice was beginning to grow and the water levels were kept low. He worked long and hard to store up the 3,000 rice grains for his future food supply that he will need to stay alive until the next rice crop comes in. Just when Alexander is ready to rest for the season and enjoy his well-earned vacation, he overhears some field workers say that the land is going to be flooded soon for harvest. Alexander is rather smart for an ant, so he realizes that he had better move his home to the nearest levee before the flooding begins. He does a quick estimate of the distance he will have to travel and determines that the levee is about 1,000 feet away. Alexander of course wants to take with him the rice he worked so hard to collect. He knows that he can carry a maximum of 1,000 rice grains at a time [ants are known to be able to carry items several times their body weight]. He also knows that he has to eat one rice grain for every foot that he travels in order to keep up his strength.

   Locate Alexander the Ant's home as precisely as you can on the Altamaha River Wetlands orthophotoquad mosaic on IMAGE 9C, GEORGIA COASTAL CORRIDOR. Mark this spot with a wipe-off pen. Compare your location with other

groups in the class. What factors make it hard to locate the exact site of Alexander's home? What is the largest number of rice grains that he can bring safely to the levee to store? Explain in detail how you determined your answer.

4. **Locate remnants of historic features at Broadfield Plantation.** 🕮
Review Figure 9C-2 "Hofwyl-Broadfield Plantation Layout" then locate and mark as many of these historic features as you can on the Altamaha River Wetlands orthophotoquad mosaic on IMAGE 9C, GEORGIA COASTAL CORRIDOR. The plantation is located in the bottom-left part of the map along the highway marked in red. Which types of features from the original plantation are still visible on the modern map? Outline these features on the map with a wipe-off pen. Why do you think they were preserved? List the types of features that are completely missing from the modern map. Speculate as to whether natural geologic forces or human intervention caused those features to disappear. Present your group's hypothesis to the rest of the class and explain your reasoning.

5. **Write a Pourquoi Tale based on life in rice fields.** ✍
PART I: Read the story, "How the Alligator got its Bumpy Skin" on page 9C-11 and underline all words or phrases that refer to the rice field environment. Study these words and descriptions carefully, then search the Altamaha River Wetlands orthophotoquad mosaic on IMAGE 9C, GEORGIA COASTAL CORRIDOR to find and mark a possible location where this story could have been set. Compare your selected location with that of other groups in your class and evaluate the appropriateness of each selection, based only on landscape information included in the story. What category of words gives the most information?

PART II: Many Brer Rabbit stories qualify as Pourquoi Tales, because they explain some fact of nature in an entertaining way that totally ignores science. Remember that the word "porquoi" means "why" in the French language. Use the rice field environment of the Altamaha River system as the setting to write your own Pourquoi Tale. You can use the Brer Rabbit characters, or you may invent your own. You may select one of the titles below, or develop your own topic. Package all the stories from your class into a booklet to share with other classes or post on your class web page.

- Why the mosquito has such a nasty disposition
- Why fiddler crabs fight all the time and only walk sideways
- Why shrimp caught in the Darien area taste so much better than others

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Construct chart showing timetable of steps in rice cultivation.** ☼ 🕮
   Rice cultivation required a year-round commitment from large numbers of slave workers. Read the background information on rice cultivation, then do additional research using local library and/or internet resources to provide details on the different steps or stages required for successful rice cultivation. Construct a chart, with appropriate drawings and/or pictures, which shows what workers would be doing in the rice fields and on the plantation grounds during each month of the year.

2. **Collect samples of Porquoi Tales.** ✍
   Use local library and/or internet resources to locate samples of a variety of Pourquoi Tales that deal with coastal plants and animals or other coastal settings. Read through these stories and determine, as closely as you can, the specific landscape in which each story took place. Mark, with a wipe-off pen, a possible location for each story on the Georgia Sea Islands ERTS satellite image on MAP 9C, GEORGIA COASTAL CORRIDOR. Do certain environments lend themselves better to story telling? Explain your answer to the class and show the distribution of story sites on your map.

Activity 9C-3: Savannah and Human History

POWER THINKING EXERCISE - "Site Selection"

An historian doing research to explain land settlement patterns in the state of Georgia has contacted you with a question. She cannot understand why the city of Savannah, Georgia has only expanded on the southwest side of the Savannah River. Almost no development has occurred on the South Carolina side of the river or along Hutchinson Island. Locate the city of Savannah, and adjacent Hutchinson Island, near the top of the Georgia Sea Islands topographic map on MAP 9C, GEORGIA COASTAL CORRIDOR. Also locate the city of Savannah, and Hutchinson Island, on the Georgia Sea Islands ERTS satellite image on MAP 9C, and on the three Savannah segments (1793 sketch, 1998 photo, and NALC satellite image) on IMAGE 9C, GEORGIA COASTAL CORRIDOR. Notice that in all these cases, urban land use really is restricted to the southwest side of the Savannah River and Hutchinson Island remains essentially undeveloped.

Use information from any or all of the cartographic products to come up with a reasonable speculation as to why the southwest side of the river is highly favorable for urban development while the northeast side of the river is not. Back up your statement with as many observations as you can regarding landscape differences between the southwest and northeast banks of the Savannah River. Compare your speculations and supporting data with other class groups and discuss which of the possible explanations should be forwarded to the historian.

Materials
MAP 9C, GEORGIA COASTAL CORRIDOR
IMAGE 9C, GEORGIA COASTAL CORRIDOR
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Locate forts and explain reason for location. ✈**
   Starting with the age of exploration and proceeding through the colonial period until the late 1800s, several forts were constructed along the Georgia Coastal Corridor to protect shipping from pirates and port cities from invasion. Locate each of the following forts on the Georgia Sea Islands topographic map on MAP 9C, GEORGIA COASTAL CORRIDOR and explain why the forts were located in those particular places. How far apart are these forts from each other? Is there an optimal distance? Explain your reasoning for your answer.

   Fort Pulaski (labeled on map; near Tybee Island at mouth of Savannah River)
   Fort McAlister (labeled on map; on Ogeechee River inland from river mouth)
   Fort Wimberly (not labeled; on Pine Island at Ossabaw Sound [Ogeechee R.])
   Fort Frederica (labeled on map; on Saint Simons Island near city of Brunswick)
   Fort Clinch (labeled on map; on north end of Fernandina Beach FL, St. Mary R.)

2. **Distinguish between clouds and other white areas.** ☼
   Examine the Savannah NALC satellite image on IMAGE 9C, GEORGIA COASTAL CORRIDOR. Notice the many small white features on the image, especially in and to the west of the city of Savannah. Some of these white features are clouds, others are piles of sand, and still others represent parking lots, building roofs, or industrial parks. Clouds can be separated from other whitish features on the map because clouds cast shadows and the other features do not. Look again at the white splotches on the NALC image. With a wipe-off pen, mark those which have shadows associated with them. Shadows will appear as darker spots, but not black. The solid black splotches represent ponds or other standing water. How many clouds did you find on the image? Where in the sky was the sun located (relative to the city of Savannah) when this satellite image was taken? Why are satellite images with a lot of cloud cover not used very often?

3. **Estimate dimensions of residential lot in original city plan.** 💻
   Oglethorpe's original city plan called for six interconnected wards built around central squares. Each ward was centered on a square and had two rows of house lots, each row containing ten residential lots, on both the north and south side of the square. Each ward measured 675 feet on each side (not counting the streets along the edges).

   Study the 1734 black and white sketch of Savannah on IMAGE 9C, GEORGIA COASTAL CORRIDOR and trace, with a wipe-off pen, the boundary of one ward. From the information given above, devise a mathematical method for calculating the dimensions of one residential lot. Also calculate the area and perimeter of one lot.

4. **Compare street patterns in 1734 and 1998 city of Savannah.** 🕮
   Compare the street patterns for the city of Savannah shown on the 1734 sketch and the 1998 photograph on IMAGE 9C, GEORGIA COASTAL CORRIDOR. What features are similar? What features are different? What advantages does a street pattern of square blocks have that a random arrangement of streets would not have? On the 1998 photo, note that the routes of interstate highways and other major thoroughfares do not necessarily follow the typical pattern of streets in the rest of the city. Why do these high-traffic routes not follow the standard city street pattern?

   Many of the original wards with their large squares are still visible on the 1998 photograph, especially when viewed through a magnifying glass (the large squares show up as black squares near the riverfront that are spaced an equal distance apart). As Savannah grew, a total of 24 squares were laid out on this grid; 21 of them still exist. How many squares can you count on the photograph? Can you pinpoint the location of the original waterfront area? What clues exist on the photograph that helped you find the location?

5. **Write journal entry describing a day in the life of a city resident.** ✍
   PART I: Examine the historic sketch (1734) and the aerial photograph (1998) of the city of Savannah on IMAGE 9C, GEORGIA COASTAL CORRIDOR. The historic sketch is more than just a map; it also contains many features (like people and

animals) which communicate information about living conditions in the city and often depict common activities of the inhabitants. List at least two features that the artist included in his sketch that would not be obvious in a modern aerial photograph.

PART II: Divide the class into six groups. Half of the groups should work with the historic 1734 sketch, the other half should work with the modern 1998 photograph. Each group should use information from their map product to speculate about life in the city during their assigned time frame. Discuss this information within your group and write a journal article (as you would in a diary) describing your typical day as a resident of the city of Savannah. For each activity you list, be sure you can back it up with information from your map product. Have each group read their journal entry aloud to the class. Discuss whether it would be more exciting to live in Savannah in 1734 or 1998 and why.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Research shipping activity in port cities.** 🕮
   Locate the shipping channels for the port cities of Savannah and Brunswick on the Georgia Sea Islands topographic map on MAP 9C, GEORGIA COASTAL CORRIDOR. Write to the Port of Savannah or the Port of Brunswick and find out what kinds of products these cities import and export. Look up references on the internet or in a local library to get additional information. Examine this data over time and note any major differences in the type or amount of cargo handled at these ports.

2. **Read book or watch movie about Savannah.** ✍
   Much of Savannah's recent popularity as a tourist destination is credited to the publication of a novel "Midnight in the Garden of Good and Evil" written in 1994 by John Berendt. A movie version of the book was later produced and was also a hit. As a class project, read the novel or watch the movie. Then discuss how a book or movie could make people want to visit the site on which the story was based. Research other examples of how books or films made an area famous and/or popular.

THE SUN HERALD

December 21, 2001

Gulf Coast Teeming with Alien Fish

By Patrick Peterson
JACKSON COUNTY, MS.

A voracious alien fish species has inhabited two bayous connected to Mississippi Gulf Coast aquaculture operations.

Tilapia, originally from the Nile River in Egypt, have been caught in Simmons Bayou east of Ocean Springs, Mississippi, and in Robinson Bayou north of Moss Point, Mississippi. Scientists are concerned that the hardy fish will spread across the coast and crowd out native species. They can live in salt water and eat plants, insects, or other small fish.

"When we find lots of them in an area, we don't find many native fishes," said Mark Peterson, fisheries biologist with the Gulf Coast Research Laboratory The tasty tilapia was imported to the United States to grow in aquaculture ponds. It is becoming increasingly popular in restaurants and supermarkets. In Florida, tilapia have escaped and become the dominant species in some waterways. Though the fish prefer warmer climates, they seem to have survived winters on the Coast.

"Everyone says they'll all die when it gets cold," Peterson said. "Our data indicates that's not exactly true. We've gotten some real big ones. They certainly have made it through one winter, maybe two or three winters." The fish brood their young in their mouths and have reproduced in Robinson Bayou, he said

Seachick Inc. pumps eight million gallons of warm water a day into Robinson Bayou as it raises tilapia for commercial markets. The water is warm enough in the winter to allow non-native fish to survive. The aquaculture operation filters its effluent to trap eggs and small fish, but osprey carry fish away and spread the young to other waters, said aquaculturist Don Robohm.

RATIONALE

The Mississippi Sound and its adjacent bays comprise a highly productive estuarine system that has been called the 'Fertile Fisheries Crescent.' The Sound is quite wide but relatively shallow, being separated from the Gulf of Mexico by a series of barrier islands. Three artificial channels have been cut through the Sound to provide deep-water access to several important port cities. The Intracoastal Waterway route also crosses the Sound. The original marshy coastline has been altered by the construction of seawalls and the addition of a series of artificial beaches.

The coastline, especially the barrier islands, has been significantly impacted by hurricanes and other storms. The shapes and dimensions of several islands have been changed significantly over time; some have even been cut in two. Other islands, essentially shallow sand shoals, appear periodically and then disappear as currents change direction. Tourism has always been the economic center of the region, sometimes referred to as the Sun Belt or the American Riviera, and many of the barrier islands have been protected by inclusion in the Gulf Islands National Seashore.

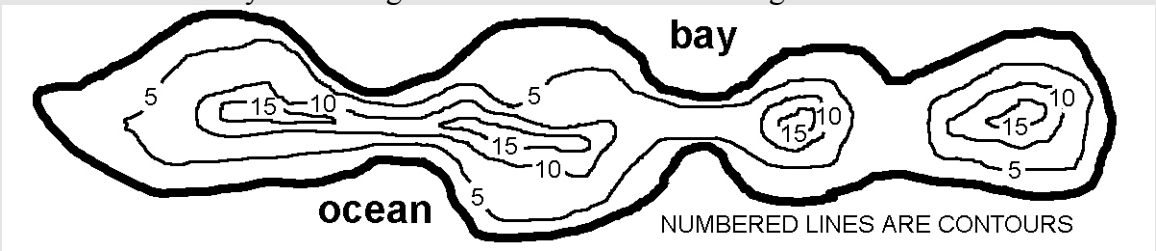
PERFORMANCE OBJECTIVES

1. Determine where the most likely locations for cut-throughs exist on barrier islands.
2. Explain historical land use of islands based on topography and land cover.
3. Differentiate between remnant islands and barrier islands using topographic data.
4. Explain how wide artificial beaches can protect seawalls and shoreline property.
5. Estimate extent coverage of floods generated by storm surge during hurricanes.
6. Calculate volume of sediment contained in spoil pile produced by dredging.
7. Evaluate economic impact of introducing non-native fish into estuarine ecosystem.
8. Explain routing decisions for path of Intracoastal Waterway and submerged pipelines.
9. Write poetry relating hurricane activity to devastation in city.
10. Write short story in the style of a ghost tale regarding disappearance of island.

SAMPLE ASSESSMENT RUBRICS

EXAMPLE #1 (relates to Performance Objective #1)

Give students a copy of this topographic map of a barrier island and ask them to mark the most likely cut-through location of the ocean during a hurricane.



Best answer is narrow area above words "lines are" because even though the island is wider here than some other places, the elevation never even reaches five feet here.

A (level 4) – correct spot chosen and correct reason given
B (level 3) – correct spot given but explanation not clear or logical
C (level 2) – correct spot given but explanation wrong or misleading
D (level 1) – incorrect spot given but explanation makes some sense
F (level 0) – incorrect spot given and explanation wrong, misleading or missing

EXAMPLE #2 (relates to Performance Objective #7)

Ask students to name two reasons why introducing a non-native species of animal into a habitat could adversely affect the entire ecosystem and also to name two reasons why such an introduction could adversely affect the economy of the region.

Some reasons affecting ecosystem: eating native species; eating food that native species need; destroying habitat that the native species needs; reproducing out of control.

Reasons affecting economy might include: reducing commercial harvest of native species; driving away hunters who only want native animals; attacking people or pets

A (level 4) – four correct reasons given
B (level 3) – three correct reasons given
C (level 2) – two correct reasons given
D (level 1) – one correct answer given
F (level 0) – no correct answer given

Cartographic Product Information

MAP 9D: Mississippi Gulf Coast

TITLE: Mississippi Sound, MS (topographic map)
DATA SOURCE: Mobile USGS 1:250,000 Quadrangle
DATE: 1952 (photorevised 1970)
SCALE: 1:125,000 [1 inch ~ 2 miles] [1 cm ~ 1.5 kilometers]
OTHER IMPORTANT DATA:
- The contour interval of this map is 50 feet.
- The bathymetric contour interval is 2 meters.

POINTS OF SPECIAL INTEREST:
- Ship Island is located near the center of the map.
- Horn Island is located in right-center of map.
- Petit Bois Island is located in lower-right corner of map.
- Deer Island is located near Biloxi in upper-center of map.
- Cat Island is located in left-center portion of map.
- Dog Keys Pass (former location of Dog Island) is between Ship & Horn Islands.

OTHER FEATURES TO LOOK FOR:
- US Highway 90 passes through all major cities along coastline.
- Shipping channels are marked by thick, dashed, double black lines.
- Spoil areas are where sand dredged from the channels is dumped.
- The Intracoastal Waterway runs through the middle of the Sound from W to E.
- Note the abundance of marshland along the mainland coast away from cities.
- Several submerged pipelines cross the Mississippi Sound.

TITLE: Ship Island, MS (topographic map)
DATA SOURCE: Ship Island and Dog Keys Pass USGS 1:24,000 Quadrangles
DATE: 1950 (photorevised 1970)
SCALE: 1:24,000 [1 inch = 2,000 feet] [1 cm ~ 250 meters]
OTHER IMPORTANT DATA:
- The contour interval of these maps is 5 feet.
- The bathymetric contour interval is 6 feet and depth soundings are in feet.

POINTS OF SPECIAL INTEREST:
- Dog Keys Pass is located at the eastern end of Ship Island (far-right of map).
- Old Fort Massachusetts is located at the western end of Ship Island (far-left).
- Gulfport Shipping Channel runs south to north along left edge of map.

OTHER FEATURES TO LOOK FOR:
- Several shoals are marked on this map.
- The stippled gray pattern represents areas of shallow sand surrounding islands.
- Note changes in shape and configuration of Ship Island from 1950 to 1970.

Cartographic Product Information

IMAGE 9D: Mississippi Gulf Coast

TITLE: Mississippi Sound, MS (CIR air photo mosaic)
DATA SOURCE: NASA/UL Lafayette CIR photographs, Rolls 5048 and 5049
DATE: 1996
SCALE: 1:125,000 [1 inch ~ 2 miles] [1 cm ~ 1.5 kilometers]
OTHER IMPORTANT DATA:
- The dark areas where photos join are a product of the mosaic process and not real
- This image is a color infrared product, so all true colors have been shifted.
- Forested areas show up in red colors; salt-marsh shows up in dark gray-green.
- Lighter milky-blue water is full of sediment; darker 'black' water is clear.

POINTS OF SPECIAL INTEREST:
- Ship Island is located near the center of the map.
- Horn Island is located in right-center of map.
- Petit Bois Island is located in lower-right corner of map.
- Deer Island is located near Biloxi in upper-center of map.
- Cat Island is located in left-center portion of map.
- Dog Keys Pass (former location of Dog Island) is between Ship & Horn Islands.

OTHER FEATURES TO LOOK FOR:
- US Highway 90 passes through all seaport towns very close to shoreline.
- The white bands along the shoreline and barrier islands are sand beaches.
- Note abundance of marshland along mainland coast away from cities.

TITLE: Ship Island, MS (various aerial photographs)
DATA SOURCE: 1952: Earth Imaging Center - Stennis Space Center
1996: NASA/UL Lafayette CIR photographs, Rolls 5048 and 5049.
1997: US Navy - Naval Oceanographic Office
1998: US Navy - Naval Oceanographic Office
DATE: 1952, 1996, 1997, 1998
SCALE: 1:40,000 [1 inch ~ 3,368 feet] [1 cm ~ 40 meters]
OTHER IMPORTANT DATA:
- The three color photographs are infrared images, so true colors have been shifted.
- Red color represents forested areas; milky-blue color shows sediment in water.

POINTS OF SPECIAL INTEREST:
- Note low elevation of areas where storm waves cut through the island.
- Note stability of forested bluff area near eastern end of island.

OTHER FEATURES TO LOOK FOR:
- The white bands along the shoreline are sand beaches.
- Note changes in shape and configuration of island shoreline over time.

Change Through Time in the Mississippi Sound

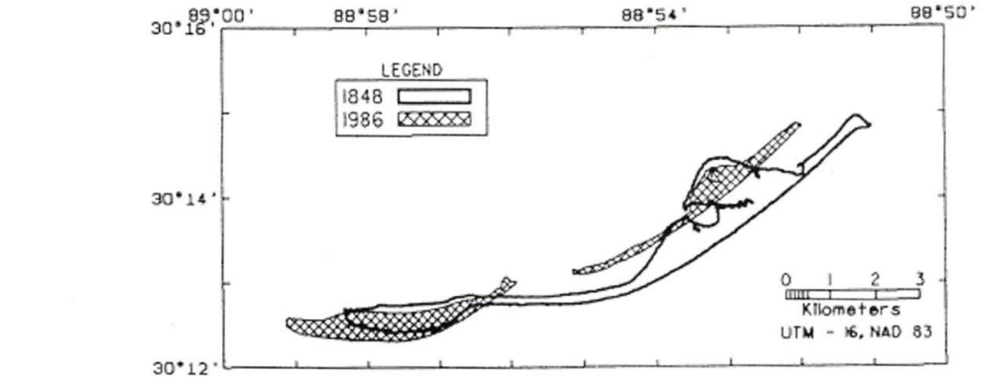
The Mississippi Sound is 150 miles (241 kilometers) long and averages 13.5 miles (22 kilometers) in width. However its average depth is only 9.8 feet (3 meters). The shallowness of the Sound combined with the presence of a series of barrier islands separating the area from the Gulf of Mexico has produced an estuary-like environment that is much less salty than normal ocean water. The brackish water and the protected coastal marshes provide an ideal habitat for shellfish such as oysters, crab, and shrimp, as well as nurseries for game fish such as speckled trout, striped mullet, black drum, and southern flounder. Several hundred species of marine life inhabit the Sound as well as a large number of freshwater and terrestrial organisms. The coastal marshes also provide prime habitat for wading birds and a convenient stopover location for migrating flocks of ducks, kites, and a variety of other species.

Rivers deliver not only fresh water to the Sound, but also an enormous amount of sediment, mostly mud. Except for sandy shoals near the barrier islands, the bottom of the Sound is entirely mud, which is often churned up by currents and wave action. The almost constant condition of suspended sediment gives the Sound its characteristic milky-blue color when viewed on infrared aerial photographs. Because the barrier islands have generally low elevation and very little vegetation, their sand is highly mobile. Longshore currents almost always move from east to west in this region causing the eastern ends of the islands to experience erosion while the western ends experience deposition. The result is that the shape and size of these islands do not stay constant. Horn Island, for example, has drifted about two miles west since the mid 1800s. Both storms and normal wave and tide activity constantly move sand from one place to another.

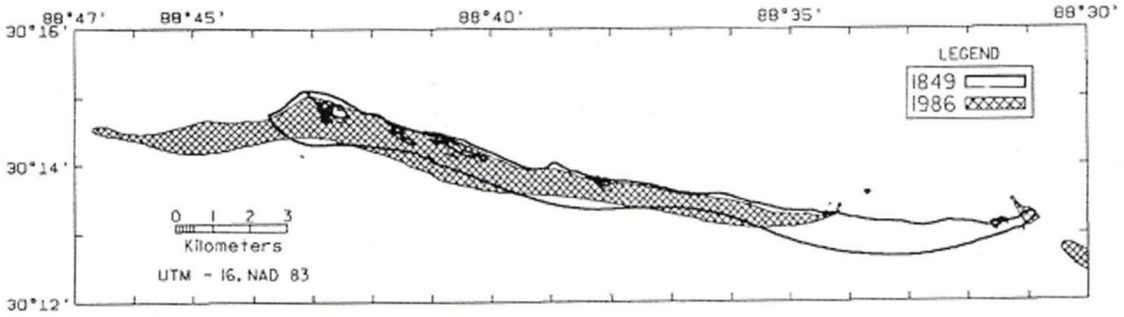
Two islands in the Mississippi Sound, Deer Island (near Biloxi) and Round Island (south of Pascagoula) are not barrier islands, but rather seem to be an extension of coastal topography. Both probably existed as small hills before sea level rose to present levels. Both are high in elevation and have very sandy soil and are extensively wooded with pine trees. The outer islands, Petit Bois, Horn, Ship, and Cat, are all considered to be barrier islands, formed between 3,500 to 6,000 years ago from sand brought in and deposited by wave action and tidal currents. The primary sand source is thought to be Mobile Bay in Alabama, where extensive ebb-tidal deltas collect sand brought to the coast by rivers draining the upland of that state. Fair-weather wave action tends to build up the islands while storms tend to cause major erosion. Ship Island has been cut in two at least three times since the 1700s, and each time wave activity has built the island back together.

With the exception of Cat Island, all the barrier islands are from six to twelve miles long and one-half mile wide, aligned in an east-west direction by the longshore currents. Early maps show another island, Dog Island, between Ship and Horn Islands. This island was inhabited and existed until 1931, when it became a partly submerged shoal and all its buildings were destroyed. It is now known as Dog Keys Pass.

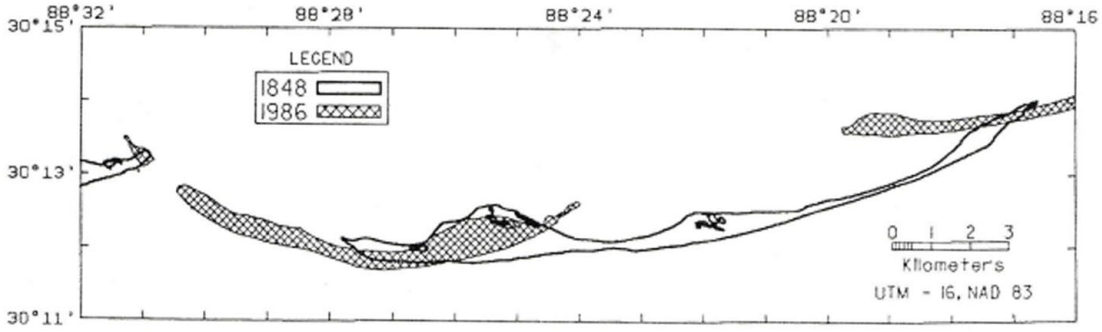
Figure 9D-1: Changes in Barrier Island Configurations



Ship Island



Horn Island



Petit Bois Island

Cat Island has a slightly different origin. It is shaped like the letter "T" with several forested ancient beach ridges running east-west that are abruptly truncated by north-south trending sand spits. Geologists speculate that about 2,500 years ago, the Mississippi River emptied into the St. Bernard delta, far to the east of its current delta position, and diverted the normal east-west longshore currents to more of a north-south orientation. The new wave direction eroded sand from the ancient ridges and redistributed it as sand spits along the eastern edge of the island. When the Mississippi River abandoned the St. Bernard delta, the entire coastline began to subside and submerge. So Cat Island is no longer migrating, but sinking and eroding in place.

Historically, major hurricanes have been the cause of dramatic changes that have affected the barrier islands, such as Ship Island being cut in half. In 1969, Hurricane Camille scooped out a channel four to six feet deep near the center of the island, leaving the two halves of the island separated by several hundred yards. Although Ship Island has been divided twice in the past thirty years, evidence suggests that during storms in 1780 and the early 1880s, the island was similarly divided and yet over time grew back together. The entire Gulf of Mexico coastline is a prime target for hurricanes, some forming in the Gulf, others entering the Gulf waters after forming in the Atlantic and crossing over Florida. Since 1699, at least 40 storms with hurricane-force winds have impacted the Mississippi Gulf Coast. Camille was the most destructive hurricane ever to hit Mississippi, entering the state as a Category 5 storm on the Saffir-Simpson Scale.

Figure 9D-2: Major Hurricanes Impacting the Mississippi Coast
(data from years 1890 through 2000)

YEAR	NAME	CATEGORY	LANDFALL LOCATION
1893	un-named	3	Pascagoula, MS
1901	un-named	2	Pascagoula, MS
1906	un-named	4	Pascagoula, MS
1909	un-named	4	Grand Island, MS
1916	un-named	3	Pascagoula, MS
1969	Camille	5	Bay St. Louis, MS
1979	Frederick	3	Pascagoula, MS
1985	Elena	3	Pascagoula, MS
1998	Georges	4	Biloxi, MS

Hurricanes have visited the Mississippi coastline repeatedly both during recorded and prerecorded history. Some of these unwelcome visitors have ruined entire harvests, flooded plantations and cities, destroyed houses and businesses in coastal communities, and killed thousands of people. The eye of a hurricane is strangely calm due to its higher pressure as air within the eye gradually descends and compressively warms, but it is surrounded by the eye wall, the part of the storm with the most destructive winds and intense downpours. If the eye of the hurricane moves over land during high tide, the damage increases because the storm surge is piled on top of an already higher sea level. Storm surges are usually highest under the northeast side of the counter-clockwise turning storm (in the northern hemisphere), and can sometimes submerge an entire low lying island as well as low-lying portions of the mainland.

Many hurricanes are remembered long after they occur because of the tremendous destruction to life and property. Hurricane warnings must be taken seriously, as past experience tells us of the likely dangers associated with these unwelcome visitors from the sea. A writing project in South Carolina following the destructive landfall from Hurricane Hugo, a Category 5 storm, in 1989 asked Junior High School students to write about their experiences with the hurricane. Here is one example that was submitted.

The Winds Blew
Chad Hayes, J.V. Martin Junior High, Dillon

Reprinted from *Hugo Blue.* Project REACH, Clemson University, 1991.
Edited by Lyn Zalusky Mueller

I sat in silence.../ And the winds blew.
I watched the trees bend back and forth / And the winds blew.
I listened to the leaves holding on for their life / And the winds blew.
I heard a big crash / And still the winds blew.
The morning sun rose over the horizon / And the winds blew no more.

Human Impact on Coastal Geography

Petit Bois Island was mentioned in the log of a Spanish voyager in 1519, the first recorded European visit to the Mississippi coast. Archeological evidence indicates that Native Americans had a religious temple on this island. The barrier islands in the Mississippi Sound saw a lot of action in the 1700s as the area, originally under French control, was ceded to England, and later to Spain. In 1795, the islands became the property of the United States. The British selected Ship Island as their staging ground for the armada that tried to capture New Orleans during the War of 1812, and this island changed hands three times during the Civil War, although no major battles were fought here. Fort Massachusetts, on the western end of Ship Island, was the most important deep South outpost for the Union. It served as a federal military prison until 1870. Today, Ship Island is a seashore playground with beaches on both the Gulf of Mexico and Mississippi Sound sides of the island. It, along with Horn and Petit Bois Islands, became part of the Gulf Islands National Seashore in 1971.

Several of the islands have had a colorful history. Before disappearing completely off the charts in 1932, Dog Island occupied the space between Ship and Horn Islands. Even though Native American legends spoke of this mysterious island appearing and disappearing, three local entrepreneurs pooled their resources in 1925 to purchase the three-mile (4.8 kilometer) long island for $1.25 an acre and constructed a resort, complete with a 1,000 foot (305 meter) pier, a casino, a restaurant, and bath houses. They even dug a 600 foot (183 meter) deep artesian well to supply fresh water to the facilities. They also changed the name of the island to "The Isle of Caprice", thinking it more attractive than "Dog Island." By 1930, it was one of the most popular tourist locations in the South, attracting famous Hollywood performers like Ethel Barrymore. Two years later, all that remained of the island was the pipe of the artesian well, still gushing fresh water into the ocean. No one knows exactly what caused the sands to shift and disappear.

Singing River Island in the Pascagoula River channel is Mississippi's newest island. It is not a natural island, but was the dumping site for mud dredged from the Pascagoula River shipping channel. The island first surfaced in the 1960s and grew to its present size by 1970. It is known by locals as the "mud lump" and is a great place to hunt rabbits. The name "Singing River" was given because of a faint singing sound that some people say they can hear in late summer in the stillness of the evening. Barely

audible at first, the music grows nearer and louder until it seems to be directly underfoot. Legend connects the sound to the mysterious extinction of the Pascagoula Indians. This Native American tribe was thought to be a peaceful, inoffensive people while the nearby Biloxi Indians mentioned in the legend were more warlike and domineering.

The Legend of the Singing River
--traditional; as recounted by Gary H. Horman--

Anola, a princess of the Biloxi Tribe, though betrothed to a chieftain of her people, loved Altama, a young chieftain of the Pascagoula. She fled with Altama to his tribe. This enraged the Biloxi chieftain, who led his warriors to battle against Altama and the neighboring Pascagoula. Recognizing the desperation of his tribe, Altama begged his tribe to give him up for atonement. The Pascagoula swore to save the young chieftain and his bride, or perish with them. When thrown into battle against terrible odds, they soon lost any hope of victory. Outnumbered, the faced subjection to the Biloxi or death. With their women and children leading the way into the River, the tribe joined hands, each chanting his song of death, and marched into the river. The chants were heard until the last voice was hushed by the dark engulfing waters.

Along the mainland coast, natural beaches were few, small, and far between. They also had little to no surf because of the protection provided by the barrier islands. However, in the 1840s, affluent New Orleans tourists began vacationing in Biloxi and Bay St. Louis. By 1900, the coast featured many grand hotels and beach cottages and even an electric trolley running along the beach from Biloxi to Pass Christian. But in 1915 a great hurricane wiped out every structure along the shoreline. To prevent further destruction, the three coastal counties began constructing seawalls and behind them a two-lane asphalt highway that became US Route 90, a nationally designated route that linked St. Augustine, Florida with San Diego, California. In 1947, another hurricane destroyed parts of the seawall, and in 1950 the Federal government repaired and improved the seawall, expanded Route 90 to four lanes, and began construction of a 300 foot (90 meter) wide sloping sand beach as a buffer for the seawall. The new 2 million dollar beach became the area's greatest tourist attraction and is considered the longest artificial beach in the world. A combination of artificial dune construction and sand fencing was added to keep the sand on the beach and off the highway. Today, the only stretch of natural beach left along the coast is the Belle Fontaine Beach, fronting on Pascagoula Bay between Biloxi and Pascagoula.

Three artificial channels cross Mississippi Sound from the Gulf of Mexico to the mainland. Because the Sound is so shallow, all of the major port cities have had to dredge these channels to allow larger ships to access their terminals. The ports of Pascagoula and Gulfport keep their channels open to a depth of 40 feet (12 meters) while the Biloxi Channel is only authorized to a 12 foot (3.6 meter) depth. Sediment dredged from these channels is dumped nearby at designated disposal sites. The Intracoastal Waterway, which extends through the full length of the Sound, has an authorized depth of 12 feet (3.6 meters), but because it follows a route whose bathymetry is greater than that depth, dredging is required only west of Cat Island to a point just north of Grand Island.

Activity 9D-1: Change Through Time in the Mississippi Sound

POWER THINKING EXERCISE - "Island Intuition"

Your uncle worked for the US Army Corps of Engineers in Mississippi in the 1990s when Hurricane Georges cut a new channel all the way through Ship Island. He has told you stories about the storm and the clean-up work that followed. He also told you that the Corps wants to know where the next cut-through will occur when the area gets hit by the next major hurricane so they can reinforce the beach area and prevent a new channel from cutting through the island. Since you have a map of the area (MAP 9D, MISSISSIPPI GULF COAST), you offer to help him out with this problem. The Corps can't afford to protect all of the barrier islands, so it is important to them for you to identify the most likely spot in danger of being cut through.

Study the topography and shape of the four major barrier islands in the Mississippi Sound (Petit Bois, Horn, Ship, and Cat) and predict which island is most likely to experience a cut-through during the next storm. With a wipe-off pen, circle the island you select on the map and mark the exact spot where you expect the storm to cut through. Explain to your uncle why you think this particular location is destined for destruction.

Materials
MAP 9D, MISSISSIPPI GULF COAST
IMAGE 9D, MISSISSIPPI GULF COAST
Figure 9D-2: "Major Hurricanes Impacting the Mississippi Coast"
Newspaper article, "Gulf Coast Teeming with Alien Fish" Page 9D-1
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Explain location of Ship Island cut-through channels. ✈**
   Examine the four Ship Island photographs on IMAGE 9D, MISSISSIPPI GULF COAST. Note the location of the Hurricane Camille cut and the Hurricane Georges cut. Locate these same two areas on the Ship Island maps on MAP 9D, MISSISSIPPI GULF COAST. What topographic features were common to both cut-through areas? Use the photographs to determine how much of each cut-through area was vegetated? Explain why you think the storms broke through the island at these specific locations.

2. **Differentiate between barrier islands and remnant islands. ☼**
   Locate the four major barrier islands (Petit Bois, Horn, Ship, and Cat) on the Mississippi Sound topographic map on MAP 9D, MISSISSIPPI GULF COAST. Also locate the two remnant islands (Deer and Round) closer to the mainland near Biloxi and Pascagoula. Also locate each of these islands on the Mississippi Sound photo mosaic on IMAGE 9D, MISSISSIPPI GULF COAST. Explain how these two categories of islands are different from each other and how they are similar. Also, use bathymetric information from the map to explain why Deer and Round Islands do not qualify as true barrier islands.

3. **Estimate flooding limit of storm surge.** 💻

In 1998, Hurricane Georges made landfall near the city of Biloxi. The maximum storm surge reached an elevation of nearly 10 feet (3 meters) above normal sea level. Use information from the topographic maps on MAP 9D, MISSISSIPPI GULF COAST to determine the extent to which these land areas were flooded.

PART I: Examine the Ship Island topographic maps on MAP 9D. Pay particular attention to the contour lines and the point elevations (look for small numbers next to a small "x"). Circle, with a wipe-off pen, all areas on each map that are above 10 feet and therefore would NOT be flooded by the storm surge.

PART II: Examine the Mississippi Sound topographic map on MAP 9D. Note that the first contour line that shows up on land is the 50-foot contour line. Assume that the land rises at a constant slope from sea level (0 feet elevation) to the 50-foot line. [This assumption is not true everywhere on the map, but it is a reasonable approximation] Draw, with a wipe-off pen, on this map the approximate position of a hypothetical 10-foot contour line (pay attention to spot elevations that show up in a few places). Explain mathematically why you drew the new contour line where you did.

4. **Explain economic impact of introduction of non-native fish.** 🕮

Read the newspaper article on Page 9D-1, "Gulf Coast Teeming with Alien Fish" and locate the cities of Ocean Springs (just east of Biloxi) and Moss Point (just north of Pascagoula) on the Mississippi Sound topographic map on MAP 9D, MISSISSIPPI GULF COAST. The specific bayous mentioned in the article are not labeled on the map, but the location of "Quinn Fisheries" is marked (about five miles west of Moss Point). Mark the 'fisheries' location with a wipe-off pen. Propose several ways in which you think the exotic tilapia fish might escape from the fisheries site and get into Mississippi Sound. Brainstorm in your group about possible solutions that might prevent such escape. Also discuss how a population boom of non-native fish in the Sound might hurt the economy of the region, especially fishing-related tourism.

5. **Write a poem relating hurricane activity to Pascagoula.** ✍

Look through the chart on Figure 9D-2, "Major Hurricanes Impacting the Mississippi Coast," and note how many times the city of Pascagoula has been the landfall site for recent hurricanes. Whether there are scientific reasons for this fact or whether it is just bad luck, the city and its residents are probably getting tired of being a consistent hurricane target. Pretend that you are a resident of Pascagoula and you are really getting angry and frustrated about the situation.

Write a short poem expressing your anger at the unfairness of the situation and at hurricanes in general. Follow basic language arts conventions for poetic compositions. Include as many references to specific hurricane damage (wind, storm surge, etc.) as you can, and use key words that descriptively convey your emotion about the subject.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Research paths and impacts of Hurricanes Camille and Georges.** 🕮
   Use local library and/or internet resources to look up information about two of the largest hurricanes to affect the Mississippi Sound, Hurricane Camille in 1969 and Hurricane Georges in 1998. Plot on an appropriate map the location at which each of these storms became a hurricane and draw their paths from that point until they were downgraded to a tropical storm. How similar or different were the paths of the two storms. Also research the damage caused by each hurricane. Which storm caused the most damage? What was the nature of that damage? Was it mostly from wind, rainfall, storm surge, or something else? Explain your answer.

2. **Explain meaning of numbers on Saffir-Simpson Hurricane Scale.** 💻
   Since the late 1800s, hurricanes have been categorized using the Saffir-Simpson Scale. Use local library or internet resources to look up information on this scale. Note what specific wind speeds are required to reach a particular category. Why were these particular wind speeds chosen? Does the category of a storm have any relation to its dimensions (how large or small the storm is)? Why does Category 5 mark the upper end of the scale (is a Category 6 storm impossible)? Explain your answers.

Activity 9D-2: Human Impact on Coastal Geography

POWER THINKING EXERCISE - "Dredging Discourse"

You are on the City Council of Bay St. Louis attending a meeting at which a fish-packing and shipping company wants to build a facility in your city for processing the striped mullet fish they are purchasing from fishermen in your area. As part of their plans, they want the city to dredge a shipping channel to the Gulf of Mexico so they can export their canned fish product. You realize that the ports of Gulfport, Biloxi, and Pascagoula already have such channels available, but the fish company complains that those ports are too expensive and that they will make more money shipping fish out of Bay St. Louis. You know that the fish company will employ lots of people in your city and help your economy, but you also wonder why the city has never bothered to construct a dredged shipping channel before.

Examine the Mississippi Sound topographic map on MAP 9D, MISSISSIPPI GULF COAST and locate the city of Bay St. Louis [on the far left side of the map]. Pay special attention to the bathymetric contour lines - note that these lines are numbered in meters. How feasible do you think it would be to dredge a channel 6 meters deep (that is the depth required by the shipping company) from your city to the Gulf of Mexico?

After studying the map, what recommendation will you make to City Council? Use information from the map to explain your decision. Would your answer change if the fish company agreed to pay the initial cost of dredging the channel provided the city pay all later maintenance costs?

Materials
MAP 9D, MISSISSIPPI GULF COAST
IMAGE 9D, MISSISSIPPI GULF COAST
Background information about the Isle of Caprice on Page 9D-8
Story, "The Legend of the Singing River" on Page 9D-9
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Explain reasons for historical uses of barrier islands. ✈**
   Locate each of the following barrier islands on the Mississippi Sound map on MAP 9D, MISSISSIPPI GULF COAST and also on the Mississippi Sound photo mosaic on IMAGE 9D, MISSISSIPPI GULF COAST: Petit Bois, Horn, Ship, and Cat. Consider historical usage of each island and explain why each activity took place on that specific island. Use information from both the map and photo to justify your answers.

   - Petit Bois = relatively untouched and unused by anyone
   - Horn = raise livestock & crops; later used by Army for barracks for soldiers
   - Ship = has deep-water harbor on north side; Fort Massachusetts on west end
   - Cat = raise livestock & crops; British troops stationed here in War of 1812

2. **Explain need for artificial beach to protect seawall.** ☼

Locate the shoreline from Pass Christian to Biloxi on the Mississippi Sound topographic map on MAP 9D, MISSISSIPPI GULF COAST. This is the area where a large seawall was constructed to protect Highway 90 and houses and other structures along the coast. A 300 foot (91 meter) wide artificial beach was placed in front of the seawall as further protection. Also locate this beach (thin white line) on the Mississippi Sound photo mosaic on IMAGE 9D, MISSISSIPPI GULF COAST.

Based on your knowledge of shoreline processes, especially wind action, wave activity and longshore drift, identify specific dangers to the seawall that would have existed before the artificial beach was constructed. How would the presence of a wide beach prevent seawall damage from all of these dangers? Explain your answers. Would any of those same shoreline processes also threaten the artificial beach? Explain what could happen and why; and suggest ways to prevent damage to the beach. If damage can not be prevented, suggest ways to restore the beach afterwards.

3. **Calculate volume of spoil dredged from Intracoastal Waterway.** 💻

Locate the straight segment of the Intracoastal Waterway running between Lower Point Clear and the Harrison County line in the southwest corner of the Mississippi Sound topographic map on MAP 9D, MISSISSIPPI GULF COAST. Notice the white rectangular area just to the south of the waterway labeled "spoil." Assume that all of the sediment in the spoil area has been dredged out of the Intracoastal Waterway and that the top of the spoil pile is right at sea level.

PART I: Calculate the volume of the spoil area by multiplying its length by its width by the average depth of the sea floor in that area. Measure length and width using information from the map scale and convert your answers to units of feet (there are 5,280 feet in one mile). Use bathymetric contour line data to estimate the average depth of the Sound in that area (remember that bathymetric contours are in units of meters - you must convert the metric average depth to feet [1 meter ~ 3.3 feet]). Your answer should be expressed in units of cubic feet.

PART II: The water depth all along the Intracoastal Waterway is required to be at least 12 feet (3.7 meters). Estimate how deeply the channel must be dredged below the bottom of the Sound along the straight segment that runs alongside the spoil pile. You must subtract the average water depth (in feet) from 12 feet in order to estimate the depth of sediment that had to be removed from the channel (remember that bathymetric contours are in units of meters - you must convert the metric depth to feet [1 meter ~ 3.3 feet]). The mandated width of the Intracoastal Waterway channel is 90 feet (27 meters). Measure the length of the straight channel using the map scale and convert your answer to units of feet (5,280 feet = one mile). Calculate the volume of sediment dredged from the channel by multiplying length by width by the average depth of sediment removed. Your answer should be expressed in units of cubic feet.

Why is the volume of the spoil pile so much greater than the volume of the sediment removed during the dredging of the Intracoastal Waterway? Explain your answer.

4. **Explain routing decisions for Intracoastal Waterway and pipeline.** 🕮
   Trace with a wipe-off pen the route of the Intracoastal Waterway all the way across the Mississippi Sound topographic map on MAP 9D, MISSISSIPPI GULF COAST. The channel is marked by a black dashed line that runs across the center of the Sound and is labeled near the center of the map. Why is this route so straight, especially in the center part of the map? Why does the route stay so close to the center of the Sound instead of closer to the land or closer to the barrier islands? The channel of the Intracoastal Waterway is required to be at least 12 feet (3.7 meters) deep. Note that the bathymetric contour lines on this map are numbered in meters. Does the water depth in this area have anything to do with the route selection? Explain your answer. How do boaters sailing through the Mississippi Sound know where the channel is located? How can they be sure they are staying inside the channel boundaries as they travel? How would you mark the channel if you were in charge?

   Another feature, marked by a different style of single dashed black lines, crosses part of the Mississippi Sound. Starting just to the east of the city of Pascagoula (right edge of map), three 'submerged pipelines' head out from land into the Sound. The lines are labeled. Two pipelines head directly south past the eastern end of Horn Island. The other pipeline goes west for a while before heading south underneath Ship Island Pass. Where do you think those pipelines go? What resource is abundant in the Gulf of Mexico that these pipelines might be carrying? Why do these pipelines go around the barrier islands instead of passing directly under them? Explain your answers.

5. **Speculate about the fate of the Isle of Caprice.** ✍
   Read the background information about the Isle of Caprice on Page 9D-8. Note that in one short year, the island, formerly called Dog Island, simply washed away and everything on the island vanished, except for the artesian well. Also read the story, "The Legend of the Singing River" on Page 9D-9, about a group of people who disappeared in a single day. Write a short story, in the same style as "Singing River", to explain the disappearance of the island. Be sure you include something mystical or magical that might remain from the island and can still be seen or heard today to remind visitors of what once was there.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Research the rise and fall of the "Isle of Caprice". 🕮**
   The brief account in the background information of this site regarding the tourist resort known as the "Isle of Caprice" that was established on Dog Island, and the complete disappearance of the island over a short period of time, only touches the surface of a fascinating story. Use local library or internet resources to research the full history of the resort, including all of the facilities that were constructed there, the boat ride that was required to access the island, and the various festivals and events that were held there over the years the resort was in full operation.

2. **Investigate navigation signals used in Intracoastal Waterway. ✈**
   The Intracoastal Waterway uses a large number of navigation buoys, lights, and other signals and symbols to help direct ships that sail through the Waterway to stay in the marked channel and avoid running into each other. Use local library resources or the internet, or write to the Commerce Department of the Federal Government or your own state, to collect information on reading and interpreting navigational signals along the Intracoastal Waterway. Make a poster showing pictures or photos of the most common signals and what they mean.

NEW ORLEANS TIMES PICAYUNE

March 26, 1996

Human Intervention Breaks Ancient Rhythm

By Mark Shcleifstein

For more than 7,000 years, the Mississippi River kept meandered along creating long, sediment-rich deltas and then abandoning them for another route to the Gulf of Mexico.

As the abandoned deltas deteriorated, their marshes provided rich grounds for fisheries and other wildlife. The marshes eventually sank under their own weight or were overcome by Gulf waters, becoming a low point on the coast and pulling the river back in a repetitive cycle that guaranteed that the Gulf's fisheries would be sustained indefinitely – or at least until the next ice age resulted in a shallower Gulf of Mexico.

In the river's new paths, fresh-water wetlands formed and new land was built. In the abandoned courses, the sea slowly invaded, increasing the coastal area of brackish water used as a nursery for juvenile fish native to the Gulf.

When Europeans settled the area, they quickly moved to rein in the river. They began what has grown into the vast network, of levees protecting urban areas and farmland along the river from spring flooding. The levees also cut off the supply of sediment that flooding once brought into the marsh interior. The sediment was a key to the marshes' survival; the levees have proven to be its death sentence.

Loss of the sediment tipped the scale toward a more rapid loss of wetlands along the coast; the levees blocked the river's return. It was the turning point in the region's development. From the forces of nature to the control of man.

As Albert Cowdrey wrote in "Land's End," a history of the Army Corps of Engineers' battle with the lower Mississippi River. "When men set about building a civilization in the flood plain, they had to interfere with this natural balance. Unless they were willing to give up cities, towns, industry and large-scale agriculture, and live at a subsistence level, the river had to be restrained.

RATIONALE

New Orleans is a major commercial port city, one of the largest in the country. Its mixed heritage has blended to provide it with a unique cuisine, architecture, music, and rich history, making it one of the most popular tourist destinations in the South. Few cities are as intimately controlled by their geology and geography as New Orleans.

New Orleans is unique in that it is built on the delta plain of a great river, the Mississippi. Because of its geologic setting, the city and its surroundings have been continually subsiding as its soil, made up of fine sediment and decaying organic material, compacts. As a result, many parts of the city lie below sea level, requiring special pumping systems and building techniques to keep the water out of neighborhoods and buildings.

The land south of New Orleans is economically very important. The delta plains form extensive wetlands that serve as nurseries for many commercial fish but are also a prime target for oil and gas exploration. These two activities can interfere with one another, creating problems that require hard compromises based on an understanding of natural systems.

PERFORMANCE OBJECTIVES

1. Describe how a river delta forms and evolves through time.
2. Explain how delta switching has influenced the coast and land use in south Louisiana.
3. Identify topographic features and land-use patterns on infrared aerial photographs.
4. Use time-sequence maps to document habitat changes through time.
5. Model processes of river erosion and deposition and delta subsidence.
6. Track path of hurricane using latitude and longitude coordinates.
7. Explain why New Orleans is so susceptible to flooding and how it has been controlled.
8. Relate cultural landmarks and activities to settlement patterns in New Orleans.
9. Identify all modes of transportation that carry commercial goods to and from the city.
10. Explain how growth patterns of New Orleans have been controlled by topography.

SAMPLE ASSESSMENT RUBRICS

EXAMPLE #1 (relates to Performance Objective #5)

Ask students to draw a cross-section of a river delta floodplain, starting at the center of the river and continuing to the center of the adjacent floodplain. Ask them to show any elevation changes and label each feature on their cross-section.

Answer should look something like this; with levee being the highest and floodplain lowest

A (level 4) – Cross-section correct; features labeled; relative elevations accurate.
B (level 3) – Cross-section correct; features labeled; relative elevations wrong; or
Cross-section correct; some features mislabeled; elevations OK.
C (level 2) – Cross-section mostly correct; some features labeled, elevations OK;
or Cross-section mostly correct; some features mislabeled; elevations wrong
D (level 1) – Cross-section incorrect, some features mislabeled; elevations OK, or
Cross-section incorrect; features labeled OK; elevations wrong
F (level 0) – Cross-section incorrect, features mislabeled, elevations not logical

EXAMPLE #2 (relates to Performance Objective #7)

Give students the New Orleans historical map on MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO and have them identify at least two areas susceptible to floods and explain why those areas are susceptible. *Answers could include locations that are: below sea level; areas labeled as 'swamp'; areas along bayous; river areas without levees*

A (level 4) – Two locations reasonable and explanations correct.
B (level 3) – Two locations reasonable; but explanations not entirely correct.
C (level 2) – Only one location reasonable; only one explanation correct.
D (level 1) – Only one location reasonable; but explanations incorrect; or
No reasonable location marked; but one explanation correct.
F (level 0) – No locations reasonable; explanations not logical.

Cartographic Product Information

MAP 9E: New Orleans to the Gulf of Mexico

TITLE: New Orleans, LA (topographic map)
DATA SOURCE: Gulfport, Black Bay, New Orleans, and Ponchatoula USGS 1:100,000 Quadrangles
DATE: Gulfport: 1982; Black Bay, New Orleans, Ponchatoula: 1983
SCALE: 1:100,000 [1 inch ~ 1.6 miles] [1 cm = 1 kilometer]
OTHER IMPORTANT DATA:
- The contour interval of this map is 2 meters.

POINTS OF SPECIAL INTEREST:
- Lake Ponchartrain occupies most of the top portion of the map.
- The Mississippi River meanders across the lower part of the map.

OTHER FEATURES TO LOOK FOR:
- The Intracoastal Waterway crosses the map from lower center to upper right.
- The rectangular white area on lower-right side of map is spoil from dredging.

TITLE: New Orleans, LA (historical map)
DATA SOURCE: Department of the Gulf, Map No. 5, "Approaches to New Orleans"
DATE: 1863
SCALE: 1:80,000 [1 inch ~ 1.25 miles] [1 cm ~ .8 kilometers]
OTHER IMPORTANT DATA:
- Red markings and labels represent locations of military fortifications.
- Straight black lines labeled 'canals' are actually drainage ditches.

POINTS OF SPECIAL INTEREST:
- Lake Ponchartrain forms the northern boundary of the map.
- The Mississippi River meanders across the center of the map.

OTHER FEATURES TO LOOK FOR:
- A number of railroads enter New Orleans from several different directions.
- Landscape features such as 'open prairie' and 'cypress swamp' are labeled.

TITLE: Habitat Change: Lower Mississippi River Delta (computer generated images)
DATA SOURCE: USGS - National Wetlands Research Center, NASA/USL Regional Application Center; RAC 980012 & RACP990039
DATE: 1956, 1978, 1983, 1986
SCALE: 1:250,000 [1 inch = 4 miles] [1 cm ~ 2 kilometers]
OTHER IMPORTANT DATA:
- Image scale and legend explaining colors are located above the 1956 image.

POINTS OF SPECIAL INTEREST:
- The Mississippi River runs diagonally across the image from upper-left corner.
- The various distributary channels of the delta are clearly shown.

OTHER FEATURES TO LOOK FOR:
- Note dramatic decrease in amount of 'fresh marsh' habitat visible on images.
- Note progressive flooding of delta through time.

Cartographic Product Information

IMAGE 9E: New Orleans to the Gulf of Mexico

TITLE: Lower Mississippi River Delta, LA (TM [satellite image])
DATA SOURCE: EOSAT Landsat Thematic Mapper
DATE: 1995
SCALE: 1:250,000 [1 inch ~ 3.2 miles] [1 cm ~ 2 kilometers]
OTHER IMPORTANT DATA:
- This image is 'pseudo-true-color' emphasizing wetlands (green) and water (blue).

POINTS OF SPECIAL INTEREST:
- Lake Ponchartrain is at the top upper-left region of the image.
- The Mississippi River runs diagonally from upper left to lower right of image.
- City of New Orleans is located in upper-left portion along Lake Ponchartrain.

OTHER FEATURES TO LOOK FOR:
- Distributary channels on Birdfoot Delta in lower-right portion of image.
-.Barrier island beaches occur along shoreline in bottom-center and left corner.

TITLE: New Orleans, LA (CIR [infrared aerial photograph])
DATA SOURCE: USGS – National Wetlands Research Center, NASA/USL Regional Application Center
DATE: 1995
SCALE: 1:65,000 [1 inch ~ 1 miles] [1 cm ~ .65 kilometers]
OTHER IMPORTANT DATA:
- This image is a false-color infrared photo, so all true colors have been shifted.
- Red colors indicate forests or vegetated fields; black = clear water.
- Wetland areas are very dark and non-reflective.

POINTS OF SPECIAL INTEREST:
- The Mississippi River runs west to east across the center of the photograph.

OTHER FEATURES TO LOOK FOR:
- Sections of Intracoastal Waterway are seen in upper right-center and lower-right.

TITLE: Lower Mississippi River Delta, LA (thermal infrared satellite image)
DATA SOURCE: USGS – National Wetlands Research Center, NASA/USL Regional Application Center RAC980012 & RACP990039
DATE: 1995
SCALE: 1:250,000 [1 inch ~ 4 miles] [1 cm ~ 2 kilometers]
OTHER IMPORTANT DATA:
- Colors on this image represent surface temperatures (legend is above image).
- Horizontal stripes on image are not real but an artifact of the computer imaging.

POINTS OF SPECIAL INTEREST:
- Distributary channels of delta are located at bottom of image.

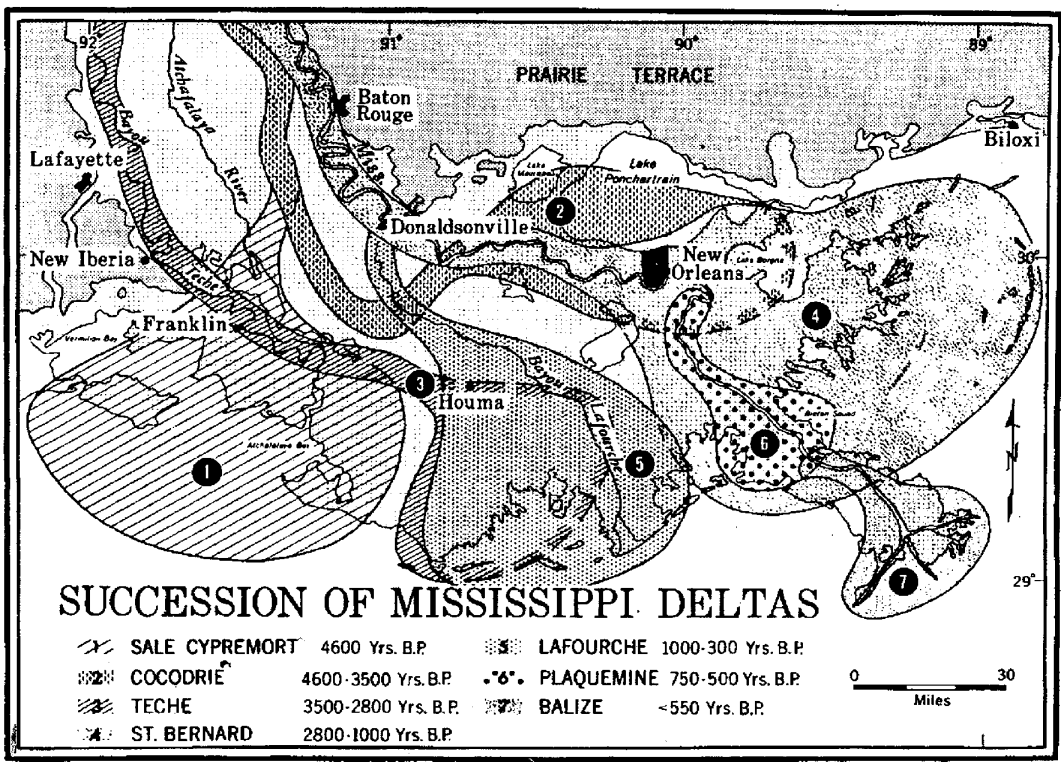
OTHER FEATURES TO LOOK FOR:
- Warmer temperatures occur along levees bordering the Mississippi River.

Geological Processes on the Delta

The mighty Mississippi River, 2,350 miles in length, is the longest river in North America and the third longest in the world. The Mississippi River drains one and a quarter million square miles covering 31 states and two provinces in Canada. This river brings more than 150 trillion gallons of water each year to the Mississippi River's mouth. The waters of the Mississippi River carry an enormous volume of sediments to the coast. Each day the Mississippi dumps near its mouth enough sand, mud, and fine gravel to fill a freight train 150 miles long or to cover the state of Connecticut with a layer of sediment one inch thick. The sediments deposited by the present day river and its predecessors form a flat, low-lying delta plain that extends for almost 320 kilometers (200 miles) along the coast and more than 100 kilometers (60 miles) inland. Topographic relief on the delta is generally less than 4 meters (13 feet).

The Mississippi River has been flowing through Louisiana for more than 9,000 years. The sediments deposited over this time have made a highly irregular shoreline that is characterized by natural levees, marshes, swamps, bays, lakes, and barrier islands. The Mississippi Delta region consists of a series of shifting, prograding (i.e. seaward building) sedimentary lobes deposited by the Mississippi River. These lobate masses of sediments are named after their main stream channel that was active at that time.

Figure 9E-1: Succession of Mississippi Deltas



The Mississippi Delta region grows by what is known as the delta cycle. The delta cycle is composed of two phases: a construction phase and a destruction phase. The construction phase of the delta cycle begins when the river deposits sediments at its mouth. As the sediments are deposited, the river naturally grows seaward (progrades), increasing its length and building new land. When the river floods - generally this happened each year in the time before strict flood control measures were initiated - it overflows its banks and deposits a considerable amount of sediment near its channel as natural levees. Because of this, over time the river and its levees increase in elevation, leaving the rest of its flood plain at a lower level. Eventually, the river breaks through its natural levees, generally during a flood. It abandons the old channel, and finds a lower, commonly shorter, route to the Gulf of Mexico. With each channel change, river-borne sediments are diverted into new areas, a new deltaic "lobe" is created, and a new deltaic cycle begins. Each change represents a major shift in the course of the river and each stage consists of a similar network of distributary channels that radiate out from a trunk channel and are separated from each other by interdistributary troughs or basins.

The destructive phase of the delta cycle begins after the river has switched its course to a new channel. The sediments in the now abandoned lobe begin to undergo the natural processes of subsidence and erosion. These destructive processes now dominate the abandoned delta lobe because no new sediments are being brought into the area to continually build it up and replenish it. The delta lobe that was once above sea level gradually sinks from sight beneath the ocean.

Over the last 9,000 years there have been seven major delta cycles on the Mississippi River. Each of these delta cycles deposited a deltaic lobe that was named after the channel that carried the Mississippi's waters to the Gulf Coast. Except for the modern "birdsfoot" delta, each of these deltaic lobes built outward into the continental shelf's shallow waters (these are waters less than 200 m [600 ft.] deep). Since the 1930s, human-made control and leveeing of the Mississippi River has forced the River to remain within its banks and unable to change course. The modern Mississippi "birdsfoot" delta continues depositing sediments at its mouth, meaning that sediments are being deposited into the deep (greater than 200 m depth) continental slope waters of the Gulf of Mexico. Once in deeper waters, the sediment cannot get back into shallow waters to counteract the natural compaction and subsidence processes going on there. Thus, the Mississippi River is no longer being allowed to begin a new constructive phase of its delta cycle.

Instead, the destructive phase of the delta cycle is now dominating the delta region. The natural process of subsidence occurs as the sediments that are deposited on the delta plain compact due to their own weight. This natural compaction means that the older delta lobes are slowly sinking as well. Normally this would not be much of a problem, as the Mississippi River would simply be depositing more sediment on top and continually building up the surface of the land. But today, lacking that process, coastal erosion has become a major concern for the citizens of Louisiana.

Changes in the "natural plumbing" system of the Mississippi Delta region have had far-reaching and unfortunate effects on the environment of south Louisiana. Changes

along the river have been made in many ways, including the building of levees along the Mississippi and Atchafalaya Rivers to contain floodwaters, and the dredging of straight canals through the swamps and marshes to lay pipelines for the oil and gas industry. These changes have interrupted the natural flow of water through these river systems and have resulted in a tremendous loss of freshwater marsh and other coastal land.

The leveeing of the Mississippi and Atchafalaya Rivers prevents the seasonal flooding that once occurred during the spring. Homeowners who enjoy living in these low-lying areas are grateful for the protection from the floods. However, these floods were a way of bringing nourishment to the marshes. Sediments brought to the marshes replenished not only the nutrients needed for healthy marsh growth, but also brought sediment that helped to build up these low-lying areas. Levees have cutoff this supply of nutrients and sediments from the marshes and, as a result, they are slowly subsiding.

Canal dredging has also changed the landscape of the south Louisiana wetlands. Along with the leveeing of the Mississippi River, the river water and sediment that normally would have once replenished this region during annual flooding is now funneled through canals into the deep waters of the Gulf of Mexico. Between the 1950s and the 1970s, the booming oil industry dredged mazes of navigation and oil field canals in order to access their oil platforms. Channels interrupt the natural drainage of the wetlands. As dredging of these channel occurs, the material taken from the bottom of the channel is piled up next to the channel in what are known as spoil banks. Spoil banks can isolate the marsh from water flow and result in an area of marsh that receives less nutrients and sediments. Another result of channel dredging is that salt water from nearby open bays is able to reach into marshes that are normally composed of fresh water. The combination of variable salinity and increased flooding from subsidence causes stress on the marsh plants. Too much stress causes the flooded marsh plants to die, leaving no living material to hold marsh soil together. The once healthy marsh is ultimately broken up into larger and larger areas of open water.

Over the past 50 years more than 1,500 square miles of wetlands have disappeared from Louisiana's Gulf Coast through erosion and subsidence brought on by natural and human activities. Just over 5,000 square miles of salt-water, brackish-water and fresh-water wetlands now remain. These remaining wetlands support a delicate ecosystem that is a spawning ground and nursery for a multitude of young fish, crabs, oysters, and shrimp. In addition, wetlands also filter pollutants out of runoff, reduce flooding, provide habitat for many waterfowl and other wildlife, and protect the coast from storm surges and rising sea level. An estimated 98 percent of the commercially important fish in the Gulf of Mexico begin their lives in these coastal wetlands. These important hatcheries are now sinking under their own weight, as the natural processes of compaction and subsidence take over.

Citizens of Louisiana face many challenges with regard to the management of their rivers and estuaries. Because Louisiana is at the mouth of the Mississippi River drainage basin, all the sediments, nutrients, and waste products that have been introduced into the river upstream finally finish their journey in the bays and estuaries of the

Louisiana coast. The Challenge for Louisiana residents is to ensure that they do not allow pollutants to be washed into the Mississippi River through runoff; and to work with states upstream of Louisiana to enlist their help in reducing runoff pollutants as well.

The natural environment of the Mississippi Delta region suffers under the impact of many pollution sources, including agricultural, residential, and industrial. For example, several areas of Lake Pontchartrain experience pollution from a multitude of sources. Pesticide, insecticide, and herbicide runoff from agricultural land as well as municipal sewage have been blamed for the closure of north shore rivers to swimmers. Urban storm-water runoff is the single largest pollution source in Lake Pontchartrain. Storm-water runoff carries oil, grease, heavy metals, lawn chemicals, and sediments into the lake. This polluted water input affects the water chemistry in the bays, lakes, and bayous, severely damaging the biological productivity of these waters.

Nutrient over-enrichment can cause eutrophication, which is the excessive growth of tiny algae in the surface water of an ocean or lake. These are sometimes known as green tides or brown tides. The Mississippi River brings high levels of nutrients such as nitrogen, phosphorus, and silica to the Louisiana Gulf Coast. These nutrients enter the River in runoff from agricultural farms in the upper part of its watershed. These nutrients include agricultural waste such as fertilizer runoff and livestock manure. When these nutrients are discharged by the Mississippi River into the shallow waters of the Gulf of Mexico, they initially encourage plant and algal growth. This new plant growth eventually uses up the extra nutrients, and the plants and algae begin to die and decompose. The decomposition process uses up oxygen in the water, which leads to the production of a "dead zone", or an area of water and sediment that has little or no oxygen left in it. Because organisms need oxygen to live, organisms that can move, such as fish, shrimp, and crabs, leave the area. Organisms that grow attached to the bottom often die. Only a few specially adapted organisms are able to survive these low-oxygen events.

Water Themes

Because Louisiana's coast lies so close to sea level, tropical storms and hurricanes are concerns for citizens living along the coast. Since 1900, hurricanes striking the states bordering the Gulf of Mexico have killed more than 9,000 people and caused tremendous damage. When adjusted to 1990 dollars, the cost of damages inflicted by those storms is more than $30 billion. Hurricane winds are only one part of the problem coastal residents face. Flooding due to rising water from the storm surge and heavy rainfall are among several other concerns. In fact, many of the fatalities associated with hurricanes are drowning deaths of people caught in these dangerous rising floodwaters.

Storm surge is defined as the abnormal rise in water level caused by wind and pressure forces of a hurricane. It can be extremely devastating and is in fact the major cause of damage from hurricanes. The storm surge itself is caused by wind pressure "pushing" continental shelf water onto the coastline. The height of a surge is basically measured as a deviation from the mean sea level in the area, and in some historical storms, this value has reached over 20 feet.

Hurricane Andrew was born off the coast of Africa on August 16, 1992. On August 26, 1992, it cut a tremendous path of destruction and devastation through southern Florida, just south of Miami. As it left the Florida coast and entered into the Gulf of Mexico, it was downgraded from a Category 5 storm to a Category 3 storm. These hurricane categories are based on the sustained wind speed of the hurricane and can be used to estimate the potential property damage and flooding expected along the coast. The higher the number, the more powerful the storm. As Andrew crossed the Gulf of Mexico, it again strengthened to a Category 4 hurricane and was headed northwest toward Louisiana. Before Andrew made landfall in Louisiana, an estimated 1,250,000 people evacuated from parishes in southeastern and south-central Louisiana, and about 250,000 evacuated from Orange and Jefferson counties in Texas. When Andrew made landfall on the Louisiana coast about 20 miles west-southwest of Morgan City on August 26th, it had weakened to a Category 3 hurricane. As typically happens after a hurricane makes landfall, Andrew moved north, then northeastward, and then weakened rapidly to tropical storm strength (39-74 mph winds) over the next 10 hours, and to a tropical depression (35-39 mph winds) 12 hours later.

Figure 9E-2: Saffir/Simpson Hurricane Scale

Category	Wind Speed (mph)	Effects
One	74 - 95	Minimal damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, trees, and street signs. Storm surge is 4 to 5 feet.
Two	96-110	Moderate damage, considerable damage to vegetation, mobile homes, and piers; some roofing material, door, and window damage to buildings. Storm surge is 6 to 8 feet.
Three	111-130	Extensive damage, some structural damage to small residences. Mobile home destroyed. Foliage torn from trees. Extensive flooding of low-lying areas (< 5 feet above sea level).
Four	131-155	Extreme damage, complete destruction to mobile homes and large trees uprooted. Major beach erosion. Extensive flooding of low-lying areas (< 10 feet above sea level).
Five	> 155	Catastrophic damage. Small building blown away. Complete roof failure on many residences and industrial buildings. Few trees left at all. Massive evacuation of residential areas on low ground within 5 to 10 miles of the shoreline may be required.

Storm-surge tides from Hurricane Andrew in Louisiana were at almost nine feet, and caused flooding from Lake Borgne westward through Vermilion Bay. Andrew and its remnants continued to produce heavy rains that locally exceeded ten inches. Fifteen people in Louisiana lost their lives in Andrew's winds and waters, including two deaths from a tornado. As of 1998, Andrew was the most expensive hurricane in the history of the United States, with damages exceeding $26.5 billion. Because of its intensity and

extensive damage to life and property, the name "Andrew" has been retired from the Atlantic-Caribbean tropical storm and hurricane name list.

New Orleans is today a port city that lies between 1.5-3.9 meters (5-13 feet) below sea level, with an average elevation of about .39 meters (l.3 feet). The city is protected from the waters of the Mississippi River and the Gulf of Mexico by large artificial levees maintained by the Army Corps of Engineers, and a well-developed and extensive pump-drainage system. The original French colony, the Vieux Carre, was established in 1718 about 2.5 meters (15 feet) above sea level on the natural levee bordering the Mississippi River. Soon after the colony was established, artificial levees were constructed to further protect the Vieux Carre. By 1812, a continuous levee stretched from Baton Rouge to more than 20 kilometers (12 miles) downstream of New Orleans! As space on the natural levees was occupied, people began draining and filling in the swamps and marshes between New Orleans and Lake Pontchartrain. Homeowners in these reclaimed wetland areas now face local subsidence, cracked foundations, and other water-related problems.

The struggle to keep New Orleans dry has been going on for more than 300 years. Large pumps have been installed to pump rainwater, groundwater seepage, and flood waters out of the city. This water is pumped into Lake Pontchartrain via a canal system the length of which is more than 140 kilometers (87miles). The New Orleans pumping system is the largest in the world, with a capacity to pump more than 94.6 billion liters (25 billion gallons) of water a day from the city. This amount of water is equivalent to the volume of a lake 16 kilometers square (10 miles square) and 3.3 meters (11 feet) deep! In addition, two spillways were built to divert water from the Mississippi River during flood events. The Morganza Spillway, located north of Baton Rouge, diverts Mississippi River water into the Atchafalaya River Basin, and the Bonnet Carre Spillway, located between Baton Rouge and New Orleans, diverts water into Lake Pontchartrain. Both of these spillways divert water when the Mississippi River is at very high river stages. As can be imagined, a water-pump failure, a crevasse splay (a break in the levee system), or a hit from a tropical storm or hurricane would have disastrous results for New Orleans and the surrounding areas.

In the early days of New Orleans, settlers built their houses and businesses on high ground, which of course meant the natural levees of the Mississippi River and its distributaries. Soon, the prime real estate was all taken and new settlers had to build on land that was prone to flooding. Soon, marshland was being filled in and sold to housing developers. Owners of houses built on reclaimed wetlands soon realized they had a problem. They had built their homes and businesses on marsh deposits, which are commonly composed of soft, spongy peat deposits that over time compact to less than 25 percent of their original thickness. These deposits also cannot support heavy concrete slabs and building foundations very well, and the foundations will often shift, sink, and break over time. A drive through neighborhoods built on these reclaimed wetlands will reveal considerable tilting and cracking of slabs. Foundations are now constructed over pilings, which are driven down into the more stable underlying marine clays and sands. These pilings help to stabilize the building and prevent further subsidence.

Unfortunately, the area around the buildings continues to subside as the peat material compacts, causing differential subsidence between the house slab and the surrounding area. Many homeowners have to add fill to their yards to compensate for the subsiding ground. Problems associated with subsidence are expensive and not limited only to building foundations; damage to sewer, water, and natural gas lines as well as to streets, driveways, and sidewalks are of considerable concern in the greater New Orleans area.

The 'Ins' and 'Outs' of New Orleans

Louisiana was purchased from Napoleon in 1803 and became a state in 1812. Throughout much of the nineteenth and twentieth centuries Louisiana was an important trading and financial center, and the fertility of its land made it one of the richest regions in America as first indigo, then sugar and cotton, rose to prominence in world trade markets. Many Louisiana planters were among the wealthiest men in America and many of the banks in New Orleans were very powerful. In addition to agriculture, the commercial fishing industry continues as an important part of Louisiana's commerce base, and aquiculture, especially of crawfish and catfish, is becoming increasingly important as well. New Orleans, as one of the country's largest ports, remains an important center of commerce, processing millions of tons of imports and exports annually. This is made inevitable by the city's location at the terminus of a river system that drains the vast interior of the country.

Louisiana fisheries are an important part of the economic base of the state. Louisiana's commercial fisheries produce enormous numbers of menhaden, tuna, and black drum, as well as shrimp, blue crabs, oysters, and crawfish. In 1994, Louisiana produced more than 1.7 billion pounds of fishery products.

Fishing seasons are tied to the annual cycle of the year. Fishery management personnel monitor the various fish, bivalve, and crustacean populations so that our Gulf waters do not become over fished. For instance, Louisiana shrimpers harvest two shrimp species: white and brown shrimp (*Penaeus setiferus* and *Penaeus aztecus)*. Both species spawn offshore; the white shrimp from spring through fall, while the brown shrimp spawn continuously all year with peaks from April to June and from September to November. The microscopic eggs hatch within a few hours. In three to five weeks, the transparent-colored post-larvae, which are now around ½ inch in length, migrate into Louisiana's estuary nursery grounds. Once in the estuary, a wide tolerance to salinity and temperature enables the shrimp to survive in a large range of habitats. They remain in the protective waters of the bays and estuaries for several months, where they will continue to grow, obtain their characteristic color, and become bottom dwellers. When they reach the sub-adult stage, they begin migrating back into the Gulf of Mexico. For the brown shrimp, this migration happens in early summer. For the white shrimp the migration to the Gulf begins in the fall and is dependent on the shrimp size and the passage of cold fronts. The state and federal government have set shrimping seasons and regulations so that their natural life cycle is not disturbed. For the last 25 years, Louisiana fishermen have caught an average of 92 million pounds of shrimp. Careful management of the shrimp fishery ensures that there will be a healthy shrimp population for future harvests.

Numerous packinghouses process Louisiana's enormous seafood catch. Although land is being lost to open water at the rate of nearly 80 square kilometers (30.8 square miles) annually, the region's water bottoms currently continue to sustain a large inland fishing fleet, with a smaller offshore fishing fleet component. Louisiana is the second largest marine fishery state in the nation. In 1994, 1.7 billion pounds of seafood products valued at $336 million were brought to Louisiana docks. In fact, five of the ten largest commercial fishing ports by weight are in Louisiana: Empire-Venice; Cameron; Intracoastal City; Dulac-Chauvin; and Morgan City-Berwick. In 1991, they collectively processed nearly 495 million kilograms (1.09 billion pounds); the catch at Dulac-Chauvin and Empire-Venice was valued at nearly $100 million. Industry growth and expansion resulted in shrimp becoming Louisiana's most valuable fishery. The shrimp catch is second only to the menhaden catch in quantity and is first in dollar value. Louisiana's commercial shrimp landings vary from 23 million to 46 million kilograms (50 million to 100 million pounds) annually. Twenty to 25 percent of the shrimp processed in the United States are caught in Louisiana.

At the turn of the century, Louisiana and Mississippi were leaders in the production of the American oyster *(Crassostrea virginica* Gmelin). In 1995, more than 13,800,000 pounds of oyster meat were processed in Louisiana. While oysters can survive in open ocean waters, natural predators in these waters reduce the population of oysters in normal marine waters. Fortunately for the oysters, they also have the ability to survive in lower-salinity (brackish) waters, while their natural predators are unable to survive in that environment. Thus oysters are able to establish flourishing natural reefs in brackish water estuaries. In the early days, fishermen harvested these tasty bivalves from shallow estuary bottoms with a pair of tongs that resembled two long-handled rakes tied together so that their teeth faced each other. The oyster dredge, a large, basket-like framework with curved teeth that was dragged through the beds to snag the oysters, has largely replaced tongs. With this new technology the oyster harvest increased. As a result, Louisiana is second only to Maryland in the production of oysters. However, because of increased saltwater intrusion, oyster leases are moving up the estuaries into waters that are more easily polluted causing contamination problems that often shut down portions of the industry.

Native Americans have been making their home in Louisiana for the last 12,000 years. The Neo-Indians occupied Louisiana from 2000 B.C. to 1600 A.D. and made good use of the abundant game and fruit of southern Louisiana. Later (from 600 B.C. to 200 A.D.), the Tchefuncte peoples appear to have lived in the coastal areas of Louisiana and near bayous. In these areas, they camped on the high ground of natural levees, terraces, salt domes, and cheniers. These Indians were the first in Louisiana to make abundant pottery. On the north shore of Lake Pontchartrain, the Tchefuncte site contains two large shell middens. A midden is a heap of broken pots and tools, shells, and food remains that is found on the site of an ancient settlement. The Tchefuncte middens contained thousands of pieces of pottery, artifacts made of bone, shell, and stone. Also found at this site were the graves of more than 40 Neo-Indians. Many Native American folktales have been handed down through the ages. Here is one from the Choctaw tradition that explains how snakes got their poison.

How the Snakes Got Their Poison

--traditional Choctaw tale as recounted by Fred Kniffen--

Long ago there was a vine that grew along the edges of bayous in shallow water. The vine was very poisonous. When the Choctaw swam close to the vine they were poisoned and very often they died.

The vine liked the Choctaw and didn't want to poison them. So he called all the snakes together to see what could be done. Up to that time the snakes had no poison. The vine explained his trouble. "What shall I do?" he asked the snakes.

The rattlesnake spoke up, "I'll take part of your poison, but before I strike, I'll give warning by rattling my tail." This he always does.

The water moccasin was next. "I'll take part of your poison, but before I strike, a Choctaw must step right on me." And the water moccasin keeps his word.

The little ground rattler was the last of the snakes to speak. I'll take the rest of your poison, but I'll jump at a person whenever I have a chance." And the ground rattler lives up to his word.

The Deltaic Plain's initial European settlements were essentially isolated from the uplands by the region's "inhospitable" swamp and marsh "wasteland." Each cultural group brought with them widely differing customs and languages, which became muted over time as each group struggled to adapt to the deltaic environment. Today, Louisiana is perhaps best known for its French-speaking citizens, the Cajuns and Creoles. There are about a million French-speaking descendants of the exiled Nova Scotians living in south Louisiana today. However, it is not uncommon to find "Cajuns" with non-French surnames like Schexnieder, Robert, Allemand, Richard, Hubal, and Henry - a testimony to the forces that formed the distinctive "Cajun" culture. Another distinct culture of the Mississippi Deltaic Plain is that of the "Creoles" - loosely defined as native born descendants of French, Spanish, or black ancestry, or of all three. As an adjective, the term applies to their manners, inventions, and food (for example, Creole customs, Creole tomatoes, and Creole cooking). Both of these French-speaking groups boast distinctive music - the Cajun French music and the African/Caribbean-influenced zydeco. There are many superstitions and good luck charms associated with Cajun culture that were passed down from generation to generation orally. Here are a few of the most well-known.

Cajun Superstitions and Good Luck Charms

--Excerpted from a book by Lyle Saxon, Edward Dreyer & Robert Tallant--

- "Be sure you cook some cabbage on New Year's Day, even if nobody she don't eat him. You won't have to worry about food all the next year."
- "If you see spider in room, don't kill him, no. That very bad for your luck.
- "Turn up your collar when you is under the full moon and you is get yourself all the fine clothes you want for the whole year."
- "There is magic in the yellow water of the Mississippi River at New Orleans. A visitor who drinks it will surely return to that city; if he washes his face in it, his luck is bound to change from bad to good."
- "You must never throw an animal or fowl into the Mississippi. That is the most dangerous thing you could possibly do."

Originally French engineers, when examining the maps of Louisiana, decided that New Orleans should be located at what is present-day Baton Rouge. The area where New Orleans sits today, as far as they were concerned, was nothing more than a swamp located below sea level and infested with alligators and mosquitoes. The decision to locate New Orleans in this less than desirable place was based on economics. Merchandise that would be shipped down the Mississippi had to make its way efficiently into the Gulf of Mexico once it reached the port city. The problem lay in that the Mississippi was often closed because of sand bars that silted in its mouth (a problem that lasted until the early 1900s). This made getting merchandise in and out of the Mississippi River via the mouth of the river difficult. The solution to the problem, and the reason why New Orleans ended up where it is today, was that merchandise unloaded at the Port of New Orleans could be put on wagons and carried a very short distance to Bayou St. John and barged to Lake Pontchartrain. From there, ships could carry it through the Chef Menteur Pass into the Gulf of Mexico and to the world's market.

The first permanent European settlement in the Mississippi Delta region was within the "Vieux Carre" or "French Quarter," which is considered the birthplace of New Orleans. Houses in New Orleans and throughout the region were built on the highest ground available, which was the crest of the region's natural river levees. The early New Orleans' settlement was long (3-4 kilometers [1.8-2.4 miles]) and narrow (several streets deep) because development was limited to the high ground available on the levees. The German and Acadian Coasts were two centers of agricultural development along the Mississippi River upstream from New Orleans. French people immigrating to Louisiana from Canada and France around 1718 settled the Acadian Coast in what is today St. James and Ascension Parishes (these are equivalent to other states' "counties"). In between the Acadian Coast and New Orleans is the German Coast, which was established in 1719 and is now a part of St. James, St. Charles, and St. John the Baptist Parishes.

New Orleans also achieved fame for its role in the War of 1812, sometimes called the Second War for Independence from England. One of the critical battles of that war was fought near New Orleans where future President Andrew Jackson and a company of militiamen, slaves, Indians, and even a few pirates survived an assault by a superior British force and won a resounding victory. A familiar ballad recounts the story.

The Battle of New Orleans [first verse and chorus]
--music and lyrics by Jimmy Driftwood--

In 1814 we took a little trip;
along with Colonel Jackson down the mighty Mississip
We took a little bacon and we took a little beans;
And we caught the bloody British in the town of New Orleans.

We fired our guns and the British kept a comin;
There wasn't nigh as many as there was awhile ago,
We fired once more and they began to runnin;
On down the Mississippi to the Gulf of Mexico.

Activity 9E-1: Geologic Processes on the Delta

POWER THINKING EXERCISE - "Delta Diversion"

You are in charge of future planning for Army Corps of Engineers projects in Louisiana. Over the years, the Corps has built a series of levees, spillways, and canals to try and stabilize the channel of the Mississippi River and its delta. A friend of yours, who is a geologist, has warned you several times that, despite all your efforts, the river will eventually break through its levees somewhere and form a new channel to the Gulf of Mexico. As proof, she shows you a map (like Figure 9E-1, "Succession of Mississippi Deltas") indicating that about every 500 to 1,000 years there is a dramatic shift of the Mississippi River and the position of its delta.

If your friend is right, the Mississippi River will break through its banks some day, somewhere north of New Orleans, and find a shorter route to the Gulf of Mexico, leaving the city without a waterway to ship its products to the Gulf. You are determined to figure out where this new channel is most likely to form so the Corps can plan in advance to deal with the problem.

Study the landscape and especially the waterways shown in Southern Louisiana on MAP 3A, LANDSCAPES AND LANDFORMS. Also refer to the historical map on Figure 9E-1 that shows former delta positions. Where do you think the Mississippi River is most likely to break through its levees; where do you think the new river channel will flow; and where do you think the new channel will enter the Gulf of Mexico to form a new delta? Be able to support your prediction with information gained from your map studies.

Materials
MAP 3A, LANDSCAPES AND LANDFORMS
MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO
IMAGE 9E, NEW ORLEANS TO THE GULF OF MEXICO
Figure 9E-1: "Succession of Mississippi Deltas"
story, "How the Snakes Got Their Poison" on Page 9E-13
Newspaper article "Human Intervention Breaks Ancient Rhythm" on Page 9E-1
transparency sheet
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Describe and analyze the anatomy of a delta. ✈**
   Read the Times Picayune newspaper article by Mark Schleifstein ["Human Intervention Breaks Ancient Rhythm"] on Page 9E-1 to gain additional background information about delta forming and delta shifting processes. Examine the Lower Mississippi River Delta TM satellite image on IMAGE 9E, NEW ORLEANS TO THE GULF OF MEXICO to get a visual picture of how these processes produce such a unique landform as the birdsfoot delta of the Mississippi River. Discuss in your group what life would be like living at the edge of this delta. What is the proper geographic name for the "toes" of the birdsfoot? Why does the main channel of the river divide

into several channels where the river runs on to the delta? Discuss among your group the process by which individual "toes" grow. Develop an explanation and be prepared to defend it. What is the proper geographic name for the areas between the "toes"?

With a wipe-off pen draw a generalized right-angle cross section through one of the "toes" extending into the areas between the "toes." Label the distinguishing features on the cross section and show where you think the following sediments would collect: a) silty clay and clayey silts, b) sand, and c) clay and organic material. Do you think this topography maintains itself beyond the last land (i.e., maintains itself under water seaward)? How do you think the areas between the "toes" could ever fill in with sediment? If this process stops, what happens to the delta? What is keeping the delta plain from receiving sediment? What deleterious effect does this have on the delta plain wetlands? Note that the areas between the toes exhibit the most severe subsidence. Why do you think this is so? **(HINT**: Of the materials that collect on the delta, which has the greatest compressibility and where does it collect)? If the material in these areas were subject to shrinkage of 85 percent of its original volume, how much subsidence would occur with the shrinkage of a layer 20 feet in thickness? If you were building a house on a delta plain, where on the cross section that you drew earlier would you choose to build your house?

2. **Differentiate between areas of growth and subsidence on delta.** ☼

Locate the birdsfoot delta in the lower-right corner of the Lower Mississippi River Delta TM satellite image on IMAGE 9E, NEW ORLEANS TO THE GULF OF MEXICO. Note that the Mississippi River breaks up into several distributary channels that route the river water into the Gulf of Mexico at different places. Even though the banks of the river channels are building up through the deposition of sand along natural levees, the entire area is undergoing slow subsidence. Compare the 1995 satellite image with the four habitat maps shown on MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO. Which distributary channels are most actively gaining sediment and growing their levees? Which channels are not growing their levees, but rather slowly sinking? Explain, based on the illustrated habitat changes over time, how you can tell the difference. Comparing the 1956 habitat map to the 1986 one, how would you characterize the loss of wetlands (not significant, moderate, heavy)?

3. **Calculate percent change in various delta habitat coverages.** 💻

Divide into groups. Each group will select for study one of the habitats shown in the Habitat Change, Lower Mississippi River Delta computer maps at the bottom of MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO. Place a transparency sheet over the 1956 Habitat Map and with a wipe-off pen carefully outline your habitat. On the same transparency, repeat the process for the 1978, 1983, and 1988 maps. Convert this change to a percent (i.e., between 1956 and 1978, the "such-and-such" habitat doubled, that is to say increased by 100 percent). Be aware that habitats may either increase or decrease, or increase over one period of time and decrease over another. Be sure to use a different color pen for each time frame.

Use your transparency and the habitat map scale to estimate the net area of change in your habitat from 1956 to 1988. Convert this change to a percent. Compare your

habitat study with those of other groups. Which habitats increased in size? Which decreased in size? Discuss among your group the possible reasons for the changes in your habitat. (**HINT**: What human activities affect the wetland habitat and in what way?) Describe some other things that are affected by these environmental changes.

4. **Explain impact of future delta switch on current delta.** 🕮
   Examine the distribution of habitats shown in the Habitat Change, Lower Mississippi River Delta computer maps at the bottom of MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO. Also examine the birdsfoot delta on the Lower Mississippi River Delta TM satellite image on IMAGE 9E, NEW ORLEANS TO THE GULF OF MEXICO. If the Mississippi River channel should switch to another location in the future, how would that switch impact the landscape features present on the current delta? Explain how the various habitats would react to such a change and what their ultimate fate would be. Draw on the TM satellite image, with a wipe-off pen, the position of the future Louisiana shoreline in this area. Explain your reasoning.

5. **Write anthropomorphized story about call for help by river.** ✍
   Anthropomorphism is the act of attributing human characteristics to an animal, plant, or inanimate object. One example is the story, "How the Snakes Got Their Poison" on Page 9E-13, that features talking snakes and talking plants. Use that story as an example as you create a new short story about the Mississippi River complaining about being channeled, hemmed in, and unable to flow freely like it used to. Assume the river would act like a prisoner in a jail, beating on the prison bars and hollering to be let out. Share your stories with the whole class and note any similarities in the writing style.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Research the 'dead zone' in the Gulf of Mexico.** ☼
   Use local library or internet resources to investigate the 'dead zone' in the Gulf of Mexico. Focus your research on the exact nature of the problem, where in the Gulf the problem is the most serious, how eutrophication affects the zone, and what recommendations have been made to eliminate or at least reduce the problem.

2. **Determine if documented past habitat changes are still occurring.** 🕮
   The habitat change maps on MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO cover a thirty-two year period that ends in 1988. Consult local library or internet resources to determine if those same trends are continuing today. Write up a brief report to share with the class.

Activity 9E-2: Water Themes

POWER THINKING EXERCISE - "Levee Limits"

Given that hurricanes are so destructive in terms of both life and property, the Army Corps of Engineers has been petitioned by Orleans Parish to build a higher levee system to provide flood protection for the businesses and homeowners in New Orleans along Lake Pontchartrain from the Jefferson Parish line eastwards to Little Woods. As a Corps engineer, you have been charged with evaluating the costs and benefits of such a project. You need to make a recommendation to the chief engineer regarding the feasibility of building a protective levee around New Orleans.

You know that the current levee system along Lake Pontchartrain is 15 feet high. You also know that a few historic hurricanes have brought storm surges of over 20 feet to this area. Finally, your accountants have estimated that raising the current levee height by 5 feet would cost more than ten million dollars per mile. Use this data to answer these questions.

- Is increasing levee height to 20 feet good enough? How high would you need to raise the levee to insure complete protection for New Orleans?

- Will raising levee height only along Lake Pontchartrain be enough to protect New Orleans, or will other levees have to be raised as well?

- While the levees protect against storm surge, hurricanes also bring lots of rainfall. Will levees be able to protect New Orleans from rain flooding?

- Some have suggested installing giant pumps in the city to pump out floodwater. Would pumps be effective at removing water from storm surge?

After considering all the options, what action do you recommend?

Materials
MAP 3A, LANDSCAPES AND LANDFORMS
MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO
IMAGE 9E, NEW ORLEANS TO THE GULF OF MEXICO
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Analyze effect of diverting floodwaters to other areas. ✈**
   The Army Corps of Engineers has constructed a series of spillways that allows them to divert some of the water from the Mississippi River during flood stages and send the excess water to the Gulf of Mexico through alternate routes. By doing this, the Corps is able to reduce or prevent flooding of New Orleans, which lies downstream from both spillways. Divide the class into two groups. Each group should locate their spillway as closely as possible on MAP 3A, LANDSCAPES AND LANDFORMS, trace the course of the diverted water on the map with a wipe-off pen, and answer the following questions about the areas and cities that could be affected by flood waters:
   a. What effect will opening the spillway have on communities receiving flood water?
   b. What effect will not opening the spillway have on communities down river?

Group I: Bonnet Carre Spillway
The Bonnet Carre Spillway is located about 12 miles (19 km) west of New Orleans. It diverts floodwaters from the Mississippi River to the east through Lake Pontchartrain into the Gulf of Mexico. This route is only about 50 miles long as compared to the 100 miles it would take the floodwater to reach the Gulf via the Mississippi River.

Group II: Morganza Spillway
The Morganza Spillway is located about 50 miles (80 km) northwest of Baton Rouge. It diverts floodwaters from the Mississippi River to the west through the Morganza Floodway to the Atchafalaya River, which eventually enters the Gulf of Mexico near Morgan City. This route is only 142 miles long as compared to the 315 miles it would take the floodwaters to reach the birdfoot delta of the Mississippi River.

2. **Analyze thermal signatures on Mississippi River Delta.** ☼
Orient yourself using the Lower Mississippi River Delta Thermal satellite image on IMAGE 9E, NEW ORLEANS TO THE GULF OF MEXICO by identifying the main outlets or passes of the delta that are shown. Note that the colors indicate relative water temperatures from cooler to warmer, by using purple, blue, yellow, orange and red colors (see thermal infrared legend above map). Do you see this color transition illustrated off the birdsfoot delta? What does the red strip adjacent to the river represent? Is the Mississippi River emptying water into the Gulf of Mexico that is warmer or cooler than the Gulf water? Would those temperature differences change with the seasons? Explain how. What is the evidence for your answer?

On this map, sea-surface temperatures can also be used to infer other properties of the water being discharged; for example: sediment discharge; nutrient discharge; water turbidity; and biological productivity. Explain how temperature data can be used to make predictions about these other properties.

3. **Plot path of Hurricane Georges across Gulf of Mexico.** 💻
Using the tracking information sheet provided on Page 9E-20, track Georges' path on a hurricane-tracking chart [provided on Page 9E-22] as it moved from the Atlantic Ocean, across the Gulf, and into Louisiana. Using the data chart provided for Georges, label each location with the appropriate DATE/TIME. Prepare two graphs to accompany your tracking chart. On the first graph plot wind speed (labeled WIND, values in miles per hour, on the vertical axis) for each DATE/TIME (plot on the horizontal axis). On the second graph plot barometric pressure (labeled PR, values in millibars, plot on the vertical axis) for each DATE/TIME (plot on the horizontal axis). Summarize the graphs by comparing the trends you see on the graphs with the location of Hurricane Georges in the Gulf of Mexico.

Hurricane Georges - Date: 15-29 SEP 1998

DAY--TIME	LAT	LONG	WIND	BP	STAT
09/15--15Z	9.00	-25.90	30	1006	TROPICAL DEPRESSION
09/16--03Z	10.10	-28.40	30	1006	TROPICAL DEPRESSION
09/16--15Z	10.50	-32.40	35	1005	TROPICAL STORM
09/17--03Z	11.00	-35.80	45	1000	TROPICAL STORM
09/17--15Z	12.20	-39.20	50	999	TROPICAL STORM
09/18--03Z	12.60	-43.10	70	984	HURRICANE-1
09/18--15Z	13.10	-46.60	85	978	HURRICANE-2
09/19--03Z	14.00	-50.00	90	970	HURRICANE-2
09/19--15Z	15.00	-52.80	110	948	HURRICANE-3
09/20--03Z	15.80	-55.80	130	939	HURRICANE-4
09/20--15Z	16.30	-58.50	130	939	HURRICANE-4
09/21--03Z	16.90	-61.40	100	966	HURRICANE-3
09/21--15Z	17.70	-64.30	95	966	HURRICANE-2
09/22--03Z	18.10	-66.90	95	978	HURRICANE-2
09/22--15Z	18.30	-69.10	105	962	HURRICANE-3
09/23--03Z	19.10	-71.90	70	986	HURRICANE-1
09/23--15Z	19.70	-74.20	65	996	HURRICANE-1
09/24--03Z	20.60	-75.70	65	992	HURRICANE-1
09/24--15Z	21.50	-77.50	70	989	HURRICANE-1
09/25--03Z	23.20	-79.60	80	985	HURRICANE-1
09/25--15Z	24.30	-81.70	90	981	HURRICANE-2
09/26--03Z	24.90	-83.50	90	974	HURRICANE-2
09/26--15Z	26.10	-85.60	90	974	HURRICANE-2
09/27--03Z	27.30	-86.80	95	968	HURRICANE-2
09/27--15Z	28.40	-88.00	95	963	HURRICANE-2
09/28--03Z	29.50	-88.60	90	961	HURRICANE-2
09/28--15Z	30.50	-88.90	65	972	HURRICANE-1
09/29--03Z	30.50	-88.90	40	985	TROPICAL STORM
09/29--15Z	31.10	-87.90	30	995	TROPICAL DEPRESSION

Information from the **National Weather Service Office**, Birmingham Alabama website:
http://www.aces.edu/department/nws/data/98lat_long.html

4. **Describe requirements for evacuation routes.** 🕮
Due to advances in technology, scientists are becoming better able to predict the track of hurricanes and tropical storms. This provides civic leaders with information that they need in order to call for evacuation of populations living in low-lying coastal areas. Locate New Orleans and Morgan City on MAP 3A, LANDSCAPES AND LANDFORMS and estimate how far inland the inhabitants of these two cities would have to travel to be out of danger. How would you evacuate residents that did not own cars? How soon before the storm arrives would you ask people to evacuate the cities? How soon after the storm would you let people back into the cities? For each answer, explain the criteria that would have to be met for you to issue those orders. What differences did you have to consider in designing an effective plan for Morgan City as compared to New Orleans? Explain your answer.

5. **Debate issues affecting land use in Mississippi Delta.** ✍
Between the 1950s and the 1970s, the booming oil industry dredged mazes of navigation and oil field canals in order to access their oil platforms. These channels

interrupted the natural drainage of the wetlands and created major problems for fishermen and shrimp harvesters. Both seafood harvesting and oil extraction are big businesses in the Mississippi Delta area, but they use the land in very different ways and often these land uses are not compatible. Divide your class into an even number of groups, with half of the groups representing the view of fishermen and the other half representing the view of those working in the oil industry. The issue under debate is whether to allow construction of more navigation and oil field canals in the area around the Mississippi Delta. Each group should put together a convincing case for why more dredging should be permitted (the oil company position) or banned (the seafood industry position). Take turns staging mock debates in the classroom.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

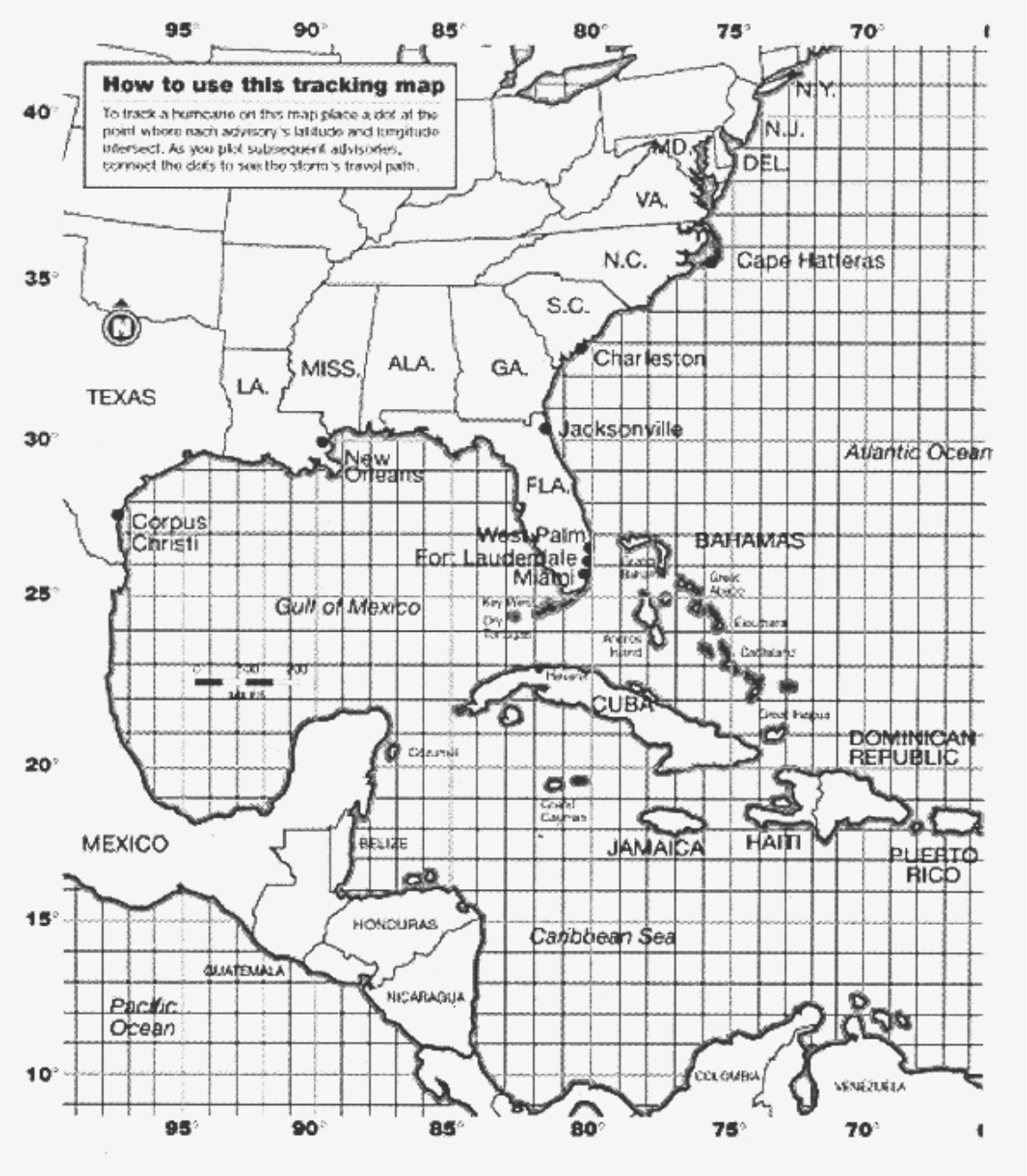
1. **Research Corps of Engineers' role in protecting New Orleans.** 🕮
   Write the Army Corps of Engineers to find out what their responsibility is in the fight to protect New Orleans from periodic flooding. Or use local library and internet resources to collect this information. Potential questions could center on when (under what conditions) spillways are opened, how levees are maintained, and where pumping stations are located and how effective they are in removing floodwaters from low-lying areas, etc. Present your results orally to the class.

2. **Simulate subsidence and explain significance to New Orleans.** 💻
   Wet three sponges with water. Stack the saturated sponges in a clear glass or plastic container. Measure and record the height of the stack of sponges. Place a 5 g mass on top of the sponges. Measure and record the height of the stack of sponges. Note any other changes. Repeat the procedure with other masses (20g, 50 g, 100g, 200g, 500g, and 1000g). Make a graph that shows the correlation between subsidence vs. mass.

SIZE OF MASS	HEIGHT OF SPONGES	OTHER OBSERVATIONS
5 g		
20 g		
50 g		
100 g		
200 g		
500 g		
1000 g		

What do the sponges represent in this experiment? What do the masses represent? What represents the subsidence? What is the relationship between mass and subsidence? What happened to the water in the sponges as increased mass was added to them? How could this happen on a delta plain? Is there any evidence that this is happening today on the Mississippi delta plain? Explain your answer.

HURRICANE TRACKING CHART



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Activity 9E-3: The 'Ins' and 'Outs' of New Orleans

POWER THINKING EXERCISE - "Meandering Metropolis"

Locate the Mississippi River on the New Orleans topographic map on MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO. Also locate the river on the New Orleans infrared aerial photograph on IMAGE 9E, NEW ORLEANS TO THE GULF OF MEXICO. Which bank of the Mississippi River, north or south, has experienced the most development? Explain why population growth was not equal on both banks. Find Bayou Bienvenue in the right-center of the topographic map and Bayou Segnetto in the lower-left of the map. [Bayou Segnetto also appears on the aerial photograph] Why do you think these two Bayou areas have not been developed as residential areas? Can you find any habitable land in the map coverage area that has not already been developed? What features or characteristics determine whether a parcel of land is habitable or not? Explain the rationale behind your answer. What things can a city decide to do with uninhabitable land?

Given the scarcity of vacant lots suitable for building, where must an increasing number of New Orleanians look to find places to live? What evidence on the New Orleans Topographic Mosaic map suggests this process has already begun? Can you think of any solutions to this "living space" shortage? Make a list of pros and cons for each of your solutions.

Materials

MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO
IMAGE 9E, NEW ORLEANS TO THE GULF OF MEXICO
Figure 9E-1, "Succession of Mississippi Deltas"
story, "The Battle of New Orleans", Page 9E-14
Wipe-off Pens

PERFORMANCE TASKS

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Describe changes in New Orleans from 1863 to 1983. ✈**
   Traveling on the delta plain is difficult because most of its land surface is below the water table. Major travel routes tended to follow active or abandoned (bayous) stream channels, either by boat or by foot along the natural levees that bordered the channel. Examine the 1863 New Orleans Historic Map on MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO. Match several features present on this map with the same features on the 1983 New Orleans Topographic mosaic map also on MAP 9E. On the 1863 map, where was most of the construction located? Why? What was happening to the stands of timber by this time? What types of trees populated the swamps surrounding the city? On both the 1863 map and the modern Topographic mosaic map, trace the following features using different color wipe-off pens: railroads in black, canals in blue, and main roads in and out of the city in red. What modifications along the Pontchartrain shoreline are shown on the newer map? What are the arguments for and against making these kinds of modifications?

Was Lake Pontchartrain being used for navigation and transportation in 1863? What evidence is there on the map to support your answer? What was the most important means of land transportation during this time? There are four routes shown on the 1863 map that go from the river to Lake Pontchartrain. With a wipe-off pen mark these same routes on the New Orleans Topographic Mosaic. Find the New Orleans and Carrolton Railroad on the 1863 map. Mark its route on the New Orleans Topographic Mosaic. Were there plans to preserve in the city large areas as public parks as early as 1863? What evidence do you see for this on the map?

2. **Investigate land use along present and former bayous.** ☼

In 1863, there was a more or less continuous bayou extending west to east across the central part of the city of New Orleans. It is now mostly filled in, but was a prominent thoroughfare at that time. To the west, it was known as Bayou Metairie and to the east as Bayou Sauvage. Use a wipe-off pen to trace the course of this channel on the 1863 New Orleans historic map and also on the 1983 New Orleans Topographic Mosaic, both on MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO. This bayou system marks an old main channel of the Mississippi River when it fed one of the ancient delta lobes. Which delta did this channel belong to? (Examine Figure 9E-1 "Succession of Mississippi Deltas.") This Bayou never was important as a waterway across the modern delta plain, but the natural levees associated with it formed a high ground that served originally as an Indian trail and later a major thoroughfare in and out of the city. Two major New Orleans streets now occupy this high ground.

3. **Compare advantages and disadvantages of scale selection.** 💻

Most maps are drawn 'to scale', which means that objects and distances on the map are a certain specific fraction of the real size of the object or the real distance between points. For example, the New Orleans topographic map on MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO is drawn at a scale of 1:100,000, which means that a distance on the map that measures one inch actually represents a real distance of 100,000 inches. That many inches is hard to visualize, so we usually convert that number to a more convenient unit, like 8,333 feet or 1.58 miles. The New Orleans infrared aerial photograph has a scale of 1:65,000, meaning that one inch actually represents a real distance of 65,000 inches (or 5,417 feet or about 1 mile).

Locate these features (all in downtown New Orleans) on the New Orleans map, and then try to locate those same features on the New Orleans aerial photograph.
- **New Orleans Superdome (stadium)** = small black circle near center of map
- **French Quarter (Vieux Carre)** = northeast of Superdome along bend of river
- **Audubon Park** = southwest of Superdome along bend of river

Which feature is easiest to find on the map? Which is easiest to find on the photo?

What are the advantages of using a smaller scale [1:100,000 is smaller than 1:65,000]? What are the disadvantages of using a smaller scale? Why are no street names labeled on the 1:100,000 scale map? If you wanted a map of New Orleans that listed all the street names in the downtown area, what scale would you use to make that possible?

4. **Trace Native American route to New Orleans.** 🕮
   Bringing ships up the river to New Orleans from the Gulf of Mexico, mostly by oar, was hard work and the distance was over 100 miles (161 km). The local Native Americans told the French of an easier route that involved a short portage from the Mississippi River levee in New Orleans to a bayou along which they could boat north to a large lake that opened to the Gulf of Mexico. Shipping could then reach New Orleans by that alternate route of gulf to lake, to bayou, to river without having to struggle to row upstream through the delta. The new route also cut the distance in half. Locate this alternate route on the 1863 Map of New Orleans on MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO. What are the names of the bayou and the lake? Using a wipe-off pen, trace this same route on the New Orleans Topographic Mosaic Map, also on MAP 9E. How much of the original bayou is still visible on the newer map? Using the scale on the topographic map, measure the portage distance. How difficult would it be to move cargo that distance through the city? Is it more likely that they transported the boat along the portage route, or just the cargo?

5. **Write additional verses to Battle of New Orleans song.** ✍
   Note on the 1863 map of New Orleans, on MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO, that military fortifications (in red) were erected at several locations to protect important sites. Name the kinds of topographic features that were being fortified. Find the Chalmette fortification (center-right edge of map) along the Mississippi River. This was the site of the famous Battle of New Orleans during the War of 1812. Refer to the song "The Battle of New Orleans" on Page 9E-14. Using information from the map, and what you know about the topography of the Mississippi delta region, write at least one more verse to the song, being sure to incorporate references to the physical environment of the battlefield and the Mississippi River.

ENRICHMENT

(Icon Key) Overview = ✈; Science = ☼; Math = 💻; History = 🕮; Language Arts = ✍

1. **Research products and goods shipped through New Orleans.** 🕮
   Use local library or internet resources to investigate what kinds of products or goods come into and leave from the New Orleans port. From your product list make categories for the products/goods to fit into (e.g., agricultural products, building materials, etc.). Make a list of the modes of transportation that come to and go from the city. Using your list of products, decide what mode of transportation brought the products into New Orleans. Identify the major transportation avenues that lead into the city. Using your list of major transportation modes, divide them into natural or man-made systems. Examine how New Orleans is connected by these systems to the north, south, east, and west.

   In cooperative groups, simulate a GIS program by overlaying overhead transparencies on a map of New Orleans, with each group tracing a particular transportation mode onto their transparency (e.g., one group would trace only the railroad tracks leading into New Orleans). On an overhead projector, the groups will overlay their maps one at a time. Each new map will add a new layer of data when discussing commerce in

New Orleans. Consult the 1863 Map of New Orleans on MAP 9E, NEW ORLEANS TO THE GULF OF MEXICO to see how much transportation has expanded and changed since the days when this map was drawn.

Do we bring in more of one product than any others into New Orleans? What product, and why? What kinds of things are brought into the city that we may consider to be harmful or unwanted? Canal systems such as the Mississippi River Gulf Outlet (MRGO) are expensive to maintain. Is it worth the trouble and expense to maintain such a system? Riverfronts in the United States are being transformed from warehouse districts to major tourist attractions. Is riverside development a good idea? Is it safe? What is the potential for maritime disasters along riverfront developments? Spring floods make the Mississippi River swift and hard to navigate. How would this affect commerce? Which modes of transportation bring in more people than goods? Which modes of transportation bring in more goods than people?

2. **Research Native American and Cajun folktales from region.** ✍
Read through the examples of Native American and Cajun folktales provided in the background information (on Page 9E-13). Use local library or internet resources to find additional examples of folktales from each of these cultures. Even though the two cultures are very different in many ways, many of their legends and folktales deal with the same subjects. Explain why this would be so. Do you think the environment they lived in would have influenced their literature, music, etc.? Explain how.