2.0 Why Study the Gulf Coast?

Lead Authors: Virginia R. Burkett, Robert C. Hyman, Ron Hagelman, Stephen B. Hartley, and Matthew Sheppard

Contributing Authors: Thomas W. Doyle, Daniel M. Beagan, Alan Meyers, David T. Hunt, Michael K. Maynard, Russell H. Henk, Edward J. Seymour, Leslie E. Olson, Joanne R. Potter, and Nanda N. Srinivasan

■ 2.1 Overview of the Study Region

2.1.1 Regional and National Significance

The Phase I Study area includes 48 contiguous coastal counties in 4 States, running from the Galveston Bay region in Texas to the Mobile Bay region in Alabama. This region is home to almost 10 million people living in a range of urban and rural settings, contains some of the Nation's most critical transportation infrastructure, and is highly vulnerable to sea level rise and storm impacts.

This area has little topographic relief but is heavily populated. Given its low elevation and the regional climate, the area is particularly vulnerable to flooding and storm surges that accompany hurricanes and tropical storms – almost half of the Nation's repetitive flood damage claims are paid to homeowners and businesses in this region. These effects may be exacerbated by global sea level rise and local land subsidence.

In addition, the central Gulf Coast's transportation modes are both unique and economically significant. The study area contains transportation infrastructure that is vital to the movement of passengers and a variety of goods domestically and internationally. Ports and pipeline infrastructure represent perhaps the most conspicuous transport modes in the region. Some of the Nation's most important ports, such as the ports of Houston-Galveston, South Louisiana, and New Orleans are found in the study area. The Port of South Louisiana, for example, is a critical agricultural export center. Agricultural producers in the Midwest depend on the continued operation of this port to ship their products for international sale. Likewise, disruptions in the functioning of pipelines and fuel production and shipping facilities in the study region have broad domestic and international impacts. Roughly two-thirds of all U.S. oil imports are transported through this region, and pipelines traversing the region transport over 90 percent of domestic Outer Continental Shelf oil and gas.

The importance of these marine facilities and waterways to the study area, and to the Nation as a whole, is difficult to overstate. These are vital National resources, providing essential transportation and economic services. While some of these functions could be considered "replaceable" by facilities and waterways elsewhere, many of them – by virtue of geography, connections to particular industries and markets, historic investments, or other factors – represent unique and largely irreplaceable assets.

In addition to ports and pipelines, the study region contains critical air, rail, highway, and transit infrastructure. Passenger and freight mobility depend both on the functioning of each mode and the connectivity of the modes in an integrated transport network. The efficacy of evacuation during storms is an important determinant of the safety and well-being of the region's population. The region sits at the center of transcontinental trucking and rail routes and contains one of only four major points in the United States where railcars are exchanged between the dominant eastern and western railroads.

The region is experiencing a population shift from rural to urban and suburban areas. Much of the population inhabiting the study area, as well as the transportation infrastructure supporting them, reside in low-lying areas vulnerable to inundation and flooding. In addition, parts of the population face challenges that may make it more difficult for them to adapt to the conditions imposed by a changing climate, such as poverty, lack of mobility, and isolation. Some of Louisiana's rural counties and the urban centers of New Orleans and Mobile County, AL, have particularly high proportions of vulnerable citizens.

2.1.2 Study Area Boundaries

This initial study focuses on the central portion of the low-lying Gulf of Mexico coastal zone. The study region extends from Mobile, AL, to Galveston, TX, as shown in figure 2.1. The study area encompasses all coastal counties and parishes along that stretch of the Gulf of Mexico as well as their adjacent inland counties (figure 2.2). In addition, the boundaries of the study area were extended so that all portions of Metropolitan Planning Organizations (MPOs) within a two-county swath of coastline would be included (figure 2.3). Table 2.1 provides the resulting list of counties and parishes included in the study area.

[INSERT FIGURE 2.1: Map of study area]

[INSERT FIGURE 2.2: Study area counties and Federal Information Processing Standard (FIPS) codes]

[INSERT FIGURE 2.3: Metropolitan planning organizations in the study area]

[INSERT TABLE 2.1: Study area counties and Federal Information Processing Standard (FIPS) codes]

2.1.3 Structure of This Chapter

The following sections provide a more detailed overview of the central Gulf Coast study region, as follows:

- Section 2.2 describes the transportation system in the study area;
- Section 2.3 describes the physical setting and natural environment of the study area, including factors that make it more susceptible to climate change impacts; and
- Section 2.4 discusses the social and economic setting, including factors that make portions of the population more vulnerable to climate impacts.

2.2 The Transportation System in the Gulf Coast Region

The transportation network of the Gulf Coast study area comprises a complex system of multiple modes that enables both people and goods to move throughout the region and supports national and international transport. While roadways are the backbone of the region's transportation system, the viability of the network as a whole depends on reliable service connections across all modes. Section 2.2.1 provides an introduction to passenger travel, freight transport, intermodal facilities, and emergency management in the Gulf Coast study area, while Section 2.2.2 provides an in-depth look at each of the transportation modes present in the region. Climate impacts to this transportation system are then discussed in Section 4.0. The transportation facility location information cited and shown in maps throughout the report is from the National Transportation Atlas Database (BTS, 2004).

2.2.1 Overview of the Intermodal Transportation System in the Gulf Coast Region

Passenger Travel

Passenger travel in the Gulf Coast study area is accommodated by a variety of modes, including highway, transit, rail, and aviation. Roads are the most geographically extensive system in the study area, and autos traveling on the highways serve as the principal mode for passenger travel. Some of those highways, particularly I-10/I-12, serve substantial national travel that is passing through the study area. The 27,000 km (17,000 mi) of major highways within the study area comprise about 2 percent of the Nation's major highways. These highways carry 134 billion vehicle km of travel (83.5 billion vehicle mi of travel) annually.

Public transit provides an important function – particularly in urban areas – by carrying passengers more efficiently (in densely populated areas) than they could be carried in autos and thus relieving congestion. Further, transit provides essential accessibility to those passengers who do not own or cannot rely on autos for transportation. Lower-income workers rely heavily on city and intercity bus services for basic needs: getting to and from work, transporting children to school or childcare services, and shopping. The majority of transit ridership in the study area is carried by scheduled bus services. Other transit services available include light rail, ferries, and unscheduled paratransit vans and minibuses.

Intercity passenger rail services are provided by the National Railroad Passenger Corporation (Amtrak), which operates three long-distance routes connecting the study area to other parts of the nation. Passenger rail services are not extensive, but they do supply an alternative mode of transportation and are important to certain segments of the population.

Airports are critical in connecting local, regional, and national economies, as well as the global economy. Several major airports serve the larger cities of the study area; in addition, numerous airports outside of the major metropolitan markets serve smaller municipal markets, and many provide general aviation services. Smaller regional airports are critical infrastructure elements as they are often used for the movement of emergency medical supplies and patients.

Freight Transport

The Gulf Coast Study area is a critical crossroads for the Nation's freight network, with marine, rail, pipeline, trucking, and air cargo all represented. A large portion of the Nation's oil and gas supply originates in the study area, either as domestic production or imports. New Orleans provides the ocean gateway for much of the U.S. interior's agricultural production and is a major interchange point for freight railroads. Products are shipped from the study area to points throughout the United States. Figure 2.4 depicts Federal Highway Administration (FHWA) Freight Analysis Framework data describing combined domestic truck flows originating in Louisiana (FHWA, 2004).

[INSERT FIGURE 2.4: Combined truck flows shipped domestically from Louisiana]

The pipeline network along the Gulf of Mexico coast is vital to the supply and distribution of energy for national use everywhere east of the Rocky Mountains. Approximately one-half of all the natural gas used in the United States passes through or by the Henry Hub gas distribution point in Louisiana. The pipelines originating in this region provide a low-cost, efficient way to move oil and gas long distances throughout the United States.

The study area also is home to the largest concentration of public and private freight handling ports in the United States, measured on a tonnage basis. These facilities handle a huge share – around 40 percent – of the Nation's waterborne tonnage. The study area also hosts the Nation's leading and third leading inland waterway systems (the Mississippi River and the Gulf Intracoastal Waterway) based on tonnage. The inland waterways traversing this region provide 20 States with access to the Gulf of Mexico, as shown in figure 2.5.

[INSERT Figure 2.5 Navigable inland waterways impacting the study area, shown as named waterways]

The rail links in the study area provide crucial connectivity to the national rail network for ports in the region and, via intermodal facilities, the major highway freight corridors. Figure 2.6 shows the network of major freight railroads nationwide, illustrating an obvious divide between the eastern railroads and the western railroads along the Mississippi River. New Orleans is one of four major gateways nationwide where the dominant eastern and western railroads interchange transcontinental shipments (Chicago, St. Louis, and Memphis are the others). At New Orleans, for example, CSX interchanges over 1,000 cars per day with the western railroads. A disruption to any of the four major gateways has implications for the entire U.S. rail network.

[INSERT Figure 2.6 National network of Class I railroads]

Intermodal Facilities

Intermodal facilities are critical infrastructure facilities that enable the transfer of goods and passengers between different transport modes. These facilities are critical to transportation logistics processes and provide a key link in industrial and public sector supply chains.

There are more than 100 intermodal facilities in the study area. Figure 2.7 shows the locations of these facilities in the study area, with coded symbols for the various mode combinations handled at each. Unsurprisingly, many of these facilities are clustered in the port and rail hubs of New Orleans and Houston.

[INSERT Figure 2.7: Intermodal facilities in the study area]

Emergency Management

Interstates and arterial roadways provide the majority of the transportation infrastructure for emergency management and evacuation along the Gulf Coast. While public transportation facilities exist, they typically rely on the highway system; there are no large scale transit systems operating on separate right-of-ways. This substantial reliance on a single mode of transportation represents a risk if the highway infrastructure is damaged or made inaccessible during an emergency.

Existing infrastructure may be able to handle local evacuations and diversions such as in the case of spilled hazardous material from a tanker truck or risk from a point source event – like a ruptured pipeline. However, network-wide roadway capacity is not designed nor built to handle large-scale evacuations or emergencies. Further, evacuation protocols require time-sensitive actions that existing roadway infrastructure cannot accommodate.

The limitations of the existing infrastructure to accommodate a major evacuation during a broad-scale emergency were dramatically illustrated during the 2005 hurricane season. As Hurricane Rita demonstrated, evacuating a substantial portion of the population from a major metropolitan area is problematic and, in many ways, difficult to accomplish in a timely and orderly fashion. The "normal" condition of the already capacity-constrained transportation infrastructure does not allow for a major ramp-up of evacuation capabilities during daylight hours in major urban areas.

Managing the transportation infrastructure and leveraging its available capacity is highly dependent upon: (1) means for gathering real-time traffic information and (2) robust and integrated communication systems that are consistent across regional jurisdictional boundaries. In this regard, the state of practice within the region varies considerably. Advanced transportation management systems such as the TranStar Traffic Management Center in Houston and a similar array of intelligent transportation system (ITS) technologies and a traffic control center in New Orleans represent relatively new and effective advancements in obtaining accurate real-time data upon which to base transportation system management decisions. On the other hand, the interagency and interjurisdictional communication systems in the Gulf Coast region are sometimes independent from one another, with multiple radio systems in use by emergency responders in each State.

2.2.2 Modal Characteristics

Highways

Highway Network and Usage

Highways provide the overwhelming majority of the public transportation infrastructure in the Gulf Coast study area. There are 28,154 centerline km (17,494 centerline mi) of highway in the study region (table 2.2, figure 2.8) (FHWA, 2005). Highway facilities in the Gulf Coast study area are primarily owned and operated by the state departments of transportation (DOT). Roads are classified as:

- **Interstates –** Highways that are designated as part of the Dwight D. Eisenhower National System of Interstate and Defense Highways;
- **Arterials –** Highways that provide longer through travel between major trip generators (larger cities, recreational areas, etc.);
- **Collectors –** Roads that collect traffic from the local roads and also connect smaller cities and towns with each other and to the arterials; and
- **Local –** Roads that provide access to private property or low-volume public facilities.

Local roads serve mainly a land-access function, carry little of the demand for transportation compared to the Interstates and the arterial roadways, and are not included as part of the highways studied in this report.[1] State DOTs administer 100 percent of the

[1] According to FHWA's Highway Statistics, while local roads represent 75 percent of the miles of the

(Footnote continued on next page...)

centerline miles on interstate highways, 60 percent of the centerline miles on arterial highways, and 50 percent of the centerline miles on collector highways.

[INSERT Table 2.2: Gulf Coast study area centerline miles of highway, by classification and ownership]

[INSERT Figure 2.8: Highways in the study area]

The volumes on the interstate, arterial, and collector roads are primarily on the State-owned highways, to an even greater extent than that of centerline miles. Of the 83.5 billion annual vehicle miles of travel (VMT) in the study area, 63.7 billion (76.3 percent) of that travel is on State-owned nonlocal roads (FHWA, 2005).

State-owned nonlocal roads carry an even larger share of truck volumes. As shown in figure 2.9, 92 percent of the truck VMT is on State roads. Additionally, while truck VMT is 7.5 percent of the total VMT, which compares closely to national truck percentages of volumes, trucks represent 9.1 percent (5.7 billion of 63.7 billion) of traffic on all State-owned roads and 10 percent of the VMT (2.4 billion of 24.4 billion) of all traffic on State-owned interstate highways (FHWA, 2005).

[INSERT Figure 2.9: Total and truck annual vehicle miles of travel (VMT) on nonlocal roads, 2003]

Intermodal Connectors

Access to intermodal facilities is most often provided by highways. Because this access function is critical to the viability of other modes, States have been given the authority to designate major intermodal passenger and freight terminals and the road connectors between these terminals and the National Highway System (NHS) as NHS intermodal connectors. The NHS intermodal connectors for the Gulf Coast study area were identified from an FHWA database (FHWA, 2006). The official listing of the NHS Intermodal Terminals and Connectors includes the following:

- Ferries/Ports:
  - Five ferry terminals served by 25 intermodal connector segments totaling 478.2 km (297.1 mi); and
  - Twenty-three ports served by 54 intermodal connector segments totaling 380.9 km (236.7 mi).
- Bus/Transit:
  - One intercity bus terminal served by 12 intermodal connector segments totaling

Nation's highways (Table HM-18), they carry less than 0.2 percent of the Nation's vehicle miles of travel (VMT) (Table HM-44) (FHWA, 2005).

26.7 km (16.6 mi);

  – Two multipurpose passenger terminals served by nine intermodal connector segments totaling 13.0 km (8.1 mi); and
  – Eight public transit stations served by 14 intermodal connector segments totaling 17.7 km (11.0 mi).

- Railroads:
  – Two Amtrak stations (Houston and New Orleans) served by four intermodal connector segments totaling 3.9 km (2.4 mi); and
  – Thirteen rail freight terminals served by 23 intermodal connector segments totaling 49.4 km (30.7 mi).
- Pipelines:
  – Four pipeline terminals served by seven intermodal connector segments totaling 30.7 km (19.1 mi).
- Airports:
  – Six airports served by 24 intermodal connector segments totaling 44.7 km (27.8 mi).

Bridges

Highway bridges are structures that carry the highway over a depression or an obstruction, such as water, a highway, or railway. As shown in figure 2.10 there are almost 8,200 bridges that serve nonlocal roads in the study area. The overwhelming majority, 80 percent, of those bridges are owned by the States. Of those State bridges, almost 80 percent serve interstate or arterial highways. Seventy-five percent of the bridges in the study area pass over water, making them susceptible to scour of their piers by water runoff (FHWA, 2001).

[INSERT Figure 2.10: Nonlocal bridges in the study area (National Bridge Inventory (NBI) latitude and longitude location)]

Eighty-one percent of the bridge structures are concrete compared to 15 percent of the bridges which are steel, and 80 percent of the road surface on bridge decks are concrete compared to 16 percent that are asphalt (FHWA, 2001).

Other Facilities

While roads and bridges are the primary facilities that comprise the highway system in the Gulf Coast Study area, highway agencies own and operate many ancillary facilities necessary to operate and maintain the highway system. These facilities include maintenance buildings and facilities, truck weight and inspection stations, rest areas, toll booths, traffic controls/signs, luminaries, fences, guardrails, traffic monitoring equipment, etc.

Transit

The American Public Transportation Association (APTA) lists over 136 public transit providers that serve the Gulf Coast study area (APTA, 2005). Most of those providers offer transportation as a social service to elderly, disabled, or low-income passengers. These transit providers include 13 major transit agencies that receive funding from the Federal Transit Administration (FTA) and are included in the National Transit Database (NTD) (FTA, 2005). Statistical information on transit services in the study region have been drawn from this database.

By far the largest transit networks in the study area are found in Houston and New Orleans. As an illustration, in 2003 the NTD listed Houston as having almost $88 million in citywide transit revenues and New Orleans with almost $35 million –while no other city in the study area topped $4 million.

Fixed Guideway (Light Rail)

There are three transit agencies that operate fixed guideway rail service in the Gulf study Area. Fixed guideway rail service carries passengers in vehicles moving on fixed light rails. The service operated by the Regional Transit Authority (RTA) in New Orleans and Metro in Houston consists of street cars operated by overhead power lines, over 47 km (29 mi) and 27 km (17 mi) of routes, respectively. The service operated by Island Transit in Galveston consists of heritage streetcars powered by diesel and operated on rails, on 29 km (18 mi) of route. These light-rail services account for a relatively small portion of total transit passengers in the study area: the New Orleans light rail service carried 8.9 million passengers in 2004, Houston's carried 5.4 million, and Galveston's carried 40,000. By comparison, fixed-route bus services in the study area carried 10 times as many passengers in 2004 (FTA, 2005).

Fixed-Route Buses

Not including the ridership for HART/Hub City Transit (Hattiesburg, MS), Lake Charles Transit System, LA, and Saint Bernard Urban Rapid Transit which was not reported, fixed-route bus service in the Gulf Coast study area in 2004 carried 139 million passengers traveling 650 million passenger mi for an average trip length of 7.6 km (4.7 mi).

Table 2.3 shows data on equipment, service levels, and ridership for fixed-route bus service of the 13 major transit agencies in the Gulf Coast study area. Houston's Metro, New Orleans' RTA, and Jefferson Transit provide a small portion of this service as Bus Rapid

Transit (BRT).[2] A total of 586 route km (364 route mi) of BRT are provided in the study area, of which 558 km (347 mi) are in the Houston area (FTA, 2005).

[INSERT Table 2.3: Equipment, annual service, and passengers for fixed-route bus operations in the study area, 2004]

Paratransit

Transit agencies also provide special services to elderly, disabled, and other disadvantaged passengers. These paratransit services are offered in addition to accessible service on the fixed routes and are typically offered in smaller buses or vans with door-to-door service for passengers on a demand-responsive, flexible schedule. Twelve agencies in the study area offer paratransit service annually carrying 2.3 million passengers over 24 million passenger mi for an average trip of 17.1 km (10.6 mi) per trip. By far the largest paratransit provider in the study area is Houston's Metro, which accounts for 80 percent of the paratransit vehicles in the region, 64 percent of the passengers, and 69 percent of the passenger miles.

Other Facilities

In addition to transit vehicles and guideways, transit agencies may own other facilities to serve vehicles or riders. According to the 2004 NTD, within the Gulf Coast Study area 10 transit agencies own 86 terminals and transfer stations. Those terminals are most numerous in the light-rail systems operated by the New Orleans RTA and the Houston Metro. Also included are the terminals associated with passenger ferries within the study area.

Other facilities include vehicle maintenance facilities, of which the NTD lists six major facilities owned by six transit agencies. In addition, transit agencies also own numerous small passenger shelters and signs and other controls that are neither inventoried nor located in the NTD.

Rail

The Gulf Coast region has an extensive rail network, with east-west lines linking the southern United States, north-south lines paralleling the Mississippi River, and diagonal lines connecting the region to the northeastern and northwestern U.S. Six of the seven class I railroads in the United States serve the study region, along with several short lines.[3,4] These railroads support important regional industries, such as chemicals, paper,

---

[2] i.e., scheduled bus service on fixed guideways or HOV lanes.

[3] Railroad classification is determined by the Surface Transportation Board. In 2004, a class I railroad was defined as having $289.4 million or more in operating revenues. A class II railroad, often referred to as a regional railroad, was defined as a non-class I line-haul railroad operating 563 km (350 mi) or more with operating revenues of at least $40 million. Class III railroads, or short lines, are the remaining non-class I or II line-haul railroads. A switching or terminal railroad is a railroad engaged primarily in switching and/or terminal services for other railroads.

lumber, and international trade. The Gulf Coast region also serves as a critical junction for national freight movements, with New Orleans serving as a major gateway between the eastern and western railroads (most rail freight using New Orleans infrastructure is interchanging rather than originating or terminating in New Orleans).

Intercity passenger rail services are provided by the National Railroad Passenger Corporation (Amtrak). Amtrak operates nationwide routes through the region over track owned by the class I railroads. Passenger rail services are not extensive, but they do supply an alternative mode of transportation and are important to certain segments of the population.

Freight Rail

Six class I railroads operate in the study region: Burlington Northern Santa Fe (BNSF); Canadian National Railway (CN); CSX; Kansas City Southern Railroad (KCS); Norfolk Southern (NS); and Union Pacific (UP).

Figure 2.11 shows the annual density of traffic on the rail lines in the Gulf Coast study region (BTS, 2004). The most densely used lines (60 million to 99.9 million gross ton-miles per mile per year [mgtm/mi]) are short segments in Houston, TX, and New Orleans, LA. In the 40 to 59.9 mgtm/mi category is part of the UP line between Houston and New Orleans, some segments around Houston, and the CSX line east of Mobile. The 20 to 39.9 mgtm/mi range includes the remainder of the UP line into New Orleans, the CSX line between Mobile and New Orleans, the NS line into New Orleans, and several lines around Houston.

[INSERT Figure 2.11: Freight railroad traffic density (annual millions of gross ton-miles per mile) in the study area]

In addition to track infrastructure, there are 94 major freight facilities (owned and served by rail lines) in the study region, including rail yards, intermodal terminals, and transloading facilities.[5] These facilities originate and terminate rail traffic, reclassify inbound railcars to outbound trains for through traffic, and interchange railcars between railroads. They include facilities owned by the railroads and nonrailroad-owned facilities that depend on rail service, such as ports. Although these facilities can be found throughout the region, there are clearly two major hubs: New Orleans and Houston.

[4] Canadian Pacific Railway is the only North American class I railroad not serving the study region.

[5] A transloading facility handles “nonflowing” commodities transferred between railcars and trucks for customers without direct rail service. Examples include steel, lumber, and paper. A transflow facility handles “flowing” commodities transferred between railcars and trucks, such as corn syrup, petroleum products, and plastic pellets.

Table 2.4 provides a more complete description of the railroads operating in the Gulf Coast study area, showing the geographical service area and primary commodities hauled by each. A complete list of freight rail facilities in the study area is provided in appendix C.

[INSERT Table 2.4: Freight railroads in the Gulf Coast study area]

Passenger Rail

The National Railroad Passenger Corporation (Amtrak) offers three intercity passenger rail services in the Gulf Coast study Region: City of New Orleans, Crescent, and Sunset Limited. The City of New Orleans provides north-south passenger service between New Orleans, LA, and Jackson, MS, Memphis, TN, and Chicago, IL, over track owned by CN. The Crescent provides service between New Orleans, Atlanta, GA, Washington D.C., Philadelphia, PA, and New York City, NY. Both the City of New Orleans and the Crescent services travel north from New Orleans and have relatively little track mileage in the study area.

The Sunset Limited, however, traverses a distance of 4,448 km (2,764 mi) between Orlando, FL and Los Angeles, CA, and makes stops throughout the Gulf Coast study region, as shown in figure 2.12. East of New Orleans, the service runs along the coast and has been indefinitely suspended since Hurricane Katrina occurred in 2005. However, even before Katrina, the Sunset Limited was one of the lowest ridership long-distance trains operated by Amtrak, with fewer than 100,000 passengers per year according to Amtrak ridership reports. A complete list of Amtrak stations in the study area is provided in appendix C.

[INSERT Figure 2.12: Sunset Limited route map, Houston, TX – Mobile, AL segment]

Marine Facilities and Waterways

Freight Handling Ports and Waterways

Ports can be comprised of a single facility or terminal, but most are actually made up of a mix of public and private marine terminals within a given geographic region along a common body of water. The U.S. Army Corps of Engineers identifies almost 1,000 public and private freight handling facilities throughout the study area, including different terminals within various defined port areas. These are mapped in figure 2.13. Major port complexes include, from west to east:

- Port of Freeport, TX;
- Ports of Houston, Texas City, and Galveston, TX;
- Ports of Port Arthur and Beaumont, TX;
- Port of Lake Charles, LA;

- Mississippi River ports of Baton Rouge, South Louisiana, New Orleans, St. Bernard (included in the New Orleans district by the U.S. Army Corps of Engineers), and Plaquemines, LA;
- Ports of Bienville, Gulfport, Biloxi, and Pascagoula, MS; and
- Port of Mobile, AL.

[INSERT Figure 2.13 Freight handling ports and waterways in the study area]

Waterborne Freight Types and Volumes

Table 2.5 shows that four of the top five ports in the United States, as measured by annual tonnage of goods handled by the port, are located in the study area. South Louisiana – at almost 199 million tons – is the Nation's leading tonnage port, while Houston – at over 190 million tons – ranks second. Collectively, study area ports handle almost 40 percent of all tonnage moved through all U.S. ports.

The study area also includes 4 of the Nation's top 30 container ports[6], including Houston, TX (number 11), New Orleans, LA (number 19), Gulfport, MS (number 21), and Freeport, TX (number 30) (AAPA, 2004).

Along with these fixed marine facilities, the study area hosts critically important navigable marine transportation networks. Among the most significant are the Gulf Intracoastal Waterway, a protected coastal route running from the Texas-Mexico border to Appalachee Bay in Florida; the Mississippi River and its tributaries; and the Tombigbee, Tennessee, and Black Warrior rivers, feeding the Mobile River in Alabama. These inland waterways and their associated lock structures (numbering in the hundreds) provide 20 States with access to the Gulf of Mexico, mostly through the Mississippi River and the Tennessee-Tombigbee River systems. Tonnage data (table 2.6) shows that largest volumes are on the Mississippi River (almost 213 million tons between Baton Rouge and New Orleans and 116 million tons between New Orleans and the Gulf of Mexico) and the Gulf Intracoastal Waterway (almost 118 million tons) (Institute for Water Resources, 2003). In fact, these two systems comprise the Nation's leading and third leading inland waterway systems by tonnage. Agriculture and other industries depend on efficient, reliable inland water transportation to move goods downriver to ports in Louisiana and Alabama, where goods are transloaded from domestic barges to international vessels. Petroleum, chemicals, and bulk products utilize the Gulf Intracoastal Waterway as an alternative to congested highway and rail corridors within the region.

[INSERT Table 2.5: Domestic and international waterborne tonnage of study area ports, 2003]

[INSERT Table 2.6: Tonnage on study area inland and coastal waterways, 2003]

---

[6] Ports with the ability to load and unload container ships, and transfer the shipping containers to or from other modes of travel, usually rail or truck.

[INSERT Figure 2.14: Barge tow on the Mississippi River]

Key Commodities and Industries

Overall, more than half of the tonnage (54 percent) moving through study area ports is petroleum and petroleum products – gasoline, fuel oil, natural gas, etc. This is not surprising, as the Gulf is a major petroleum producing and processing region, and an estimated 60 percent of U.S. petroleum imports passes through Gulf gateways. Of the rest, the majority – around 18 percent – is made up of food and farm products such as grains and oilseeds. Around 12 percent is chemicals, and the remaining commodities – around 4 percent to 6 percent each – are crude materials, manufactured goods, and coal (Institute for Water Resources, 2003).

There are important differences between ports in different parts of the study area. The Alabama and Mississippi ports specialize in coal, petroleum, manufactured (containerized) goods, and crude materials. In contrast, around 38 percent of tonnage through the Mississippi River ports consists of food and farm products, much of it related to the transloading of barge traffic from the Nation's interior, with petroleum accounting for another 30 percent of tonnage. The western Louisiana and Texas ports are dominated by petroleum, which represents 75 percent of their tonnage.

Nonfreight Marine Facilities

The study area also hosts a large array of nonfreight maritime uses. The U.S. Army Corps of Engineers database lists around 800 nonfreight facilities (including unused berths) in the study area. These serve a variety of functions, including commercial fishing; vessel fueling, construction, repair, and outfitting (including shipyards); marine construction services (channel dredging and maintenance, construction of berths and other facilities); government and research facility docks; recreational and commercial vessel berthing; passenger ferry and cruise docks; and support for offshore oil facilities.

Aviation

The system of airports analyzed in the Gulf Coast Study includes 61 publicly owned, public-use airports. Private facilities are excluded from the sample as are the 387 heliports located in the study area.[7] Twenty-eight of these airports (more than 45 percent) are in Louisiana, 16 are in Texas, 9 are in Mississippi, and 8 are in Alabama.

There are over 3,800 aircraft based at publicly owned, public-use airports in the study area. Over 3.4 million aircraft takeoffs and landings take place at these airports annually, with the majority of operations taking place at commercial service airports.

---

[7] Heliports primarily serve hospitals, office buildings, and oil and gas industry facilities.

Of these 61 airports, 44 are general aviation airports, 11 are commercial service, 4 are industrial, and 2 are military, as described below:

- **Commercial service airport (CS) –** Commercial service airports primarily accommodate scheduled passenger airline service. Two Houston airports led the region in passenger enplanements in 2005 (George Bush Intercontinental Airport [IAH] and William P. Hobby [HOU]), followed by Louis Armstrong New Orleans International [MSY].

- **Military airfield (MIL) –** Military Airfields accommodate strictly military aircraft and are off limits to civilian aircraft. The two active military airfields in the study area are Keesler Air Force Base [AFB] in Mississippi and the New Orleans Naval Air Station/Joint Reserve Base. Keesler AFB is notable for being the home of the 53rd Weather Reconnaissance Squadron, the "Hurricane Hunters," who fly aircraft into tropical storms and hurricanes to gather weather data.

- **Industrial airport (IND) –** Industrial airports are airports that can accommodate both commercial and privately owned aircraft. Typically, an industrial airport is used by aircraft service centers, manufacturers, and cargo companies, as well as general aviation aircraft. The four industrial airports in the study area are former military airfields, designed to accommodate the largest aircraft. None of them have scheduled passenger service.

- **General aviation airport (GA) –** General aviation airports accommodate aircraft owned by private individuals and businesses.

In addition to leading the region in passenger enplanements, George Bush Intercontinental IAH in Houston also is the leading airport in the study area for cargo tonnage, processing 75 percent of all cargo enplaned in the study area. It ranks 17th nationally for cargo, with 387,790 annual tons (ACI, 2005). Louis Armstrong New Orleans International ranked second for cargo, followed by Mobile Downtown, an industrial airport.

Table 2.7 details the passenger enplanements and cargo tonnage for the major study area airports. Figure 2.15 identifies the location of airports in the study area.

[INSERT Table 2.7: Passenger enplanements and cargo tonnage for select commercial service and industrial airports in the study area, 2005]

[INSERT Figure 2.15: Study area airports]

Pipelines

The pipeline system in and around the Gulf Coast is a major transporter of gas, petroleum, and chemical commodities. It links many segments of the country with energy sources located on the Gulf Coast. Unlike other transportation systems, pipelines are singularly a transportation system for bulk commodities that have little or no time sensitivity for product delivery. The entire pipeline network is privately funded and held. The onshore portion is principally regulated by the Office of Pipeline Safety (OPS), within the United States. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA). Regulation focuses on safe operations to protect people, the environment, and the national energy supply. Off-shore pipelines are regulated by the U.S. Department of the Interior, Minerals Management Service.

There is a total of 42,520 km (26,427 mi) of onshore liquid (oil and petroleum product) transmission and natural gas transmission pipelines in the Gulf Coast area of study, with some extended sections beyond its boundaries. This includes 22,913 km (14,241 mi) of onshore natural gas transmission pipelines and 19,607 km (12,186 mi) of onshore hazardous liquid pipelines (PHMSA, 2007). The liquid pipelines are concentrated in Texas while the natural gas pipelines are concentrated in Louisiana.

Approximately 49 percent of U.S. wellhead natural gas production either occurs near the Henry Hub, which is the centralized point for natural gas futures trading in the United States, or passes close to the Henry Hub as it moves to downstream consumption markets. The Henry Hub is located near the town of Erath in Vermilion Parish, LA. The Henry Hub interconnects nine interstate and four intrastate pipelines, including: Acadian, Columbia Gulf, Dow, Equitable (Jefferson Island), Koch Gateway, LRC, Natural Gas Pipe Line, Sea Robin, Southern Natural, Texas Gas, Transco, Trunkline, and Sabine's mainline.

■ 2.3 Gulf Coast Physical Setting and Natural Environment

The unique natural environment and geology of the Gulf Coast study region brings its own set of considerations and challenges in designing the built environment. Some of these physical characteristics, such as low topography, high rates of subsidence, and predilection for coastal erosion, significantly increase the vulnerability of the area to climate change impacts. A robust transportation system must accommodate the natural features of this landscape.

A variety of physical datasets were compiled for phase I of the Gulf Coast study and posted on a Web site for review and use by the project research team (appendix A). Most of the spatial data is organized in GIS-type formats or "layers" that can be integrated for the purposes of assessing the vulnerability and risks of the transportation infrastructure in the study area and informing the development of adaptation strategies in phases II and III of the study, respectively. Examples of the spatial data products developed for the study are presented in the following sections.

2.3.1 Geomorphology

The Gulf Coast region of the United States is in the physiographic province called the southeastern Coastal Plain, which is a broad band of territory paralleling the Gulf and South Atlantic seacoast from North Carolina to Texas, with a deep extension up the

Mississippi River valley. The Coastal Plain is relatively flat, with broad, slow-moving streams and sandy or alluvial soils (figure 2.16).

Much of the land area in the Coastal Plain is overlain with sediments deposited during the Holocene or Recent Age epoch, i.e., during the past 10,000 years. The remainder of the Coastal Plain surface consists primarily of late Cretaceous deposits (65 to 100 million years old). These sedimentary rocks, deposited mostly in a marine environment, were later uplifted and now tilt seaward; part of them form the broad, submerged Continental Shelf. Coastal Plain deposits overlap the older, more distorted, Paleozoic and Precambrian rocks immediately to the north and west (more than 250 million years old) (U.S. Geological Survey [USGS], 2000a).

The center of the study area is dominated by the Mississippi Embayment, a geologic structural trough in which the underlying crust of the Earth forms a deep valley that extends from the Gulf Coast inland to the confluence of the Ohio and Upper Mississippi Rivers. The Lower Mississippi Valley occupies the center of the inland part of the embayment and ranges from 30– to 180–km (20–to 110–mi) wide. Large rivers, such as the Mississippi, Arkansas, and Ohio Rivers, have flowed through this region, carved the surface, and deposited clay, silt, sand, and gravel, collectively called alluvium.

Nearly annually, the Mississippi River and its tributaries flood vast areas of the lower alluvial valley. Traditionally, these floods have lasted for several months and a few for even longer periods. For example, the great flood of 1927 occurred from April to June when the lower Mississippi River system stored the equivalent of 60 days of discharge in its 22–million-acre alluvial valley. The river flows through the Lower Mississippi River Valley in a 15- to 30-km (10- to 20-mi) wide meander belt, and historical and prehistoric records indicate the river is continually creating new channels and abandoning old ones. The alluvium provides the rich soils for massive agricultural development.

Where the Mississippi River empties into the Gulf of Mexico, old deltas are abandoned and new ones formed. This Mississippi River deltaic plain lies at the center of the Gulf Coast study area. During the formation of the deltaic plain, millions upon millions of tons of sediment were deposited in a series of overlapping delta lobes that are presently in various phases of abandonment and deterioration. The barrier island chains off the coast of Louisiana are remnant features of old deltas that are naturally eroding and retreating landward as sea level rises. Erosional forces dominate this part of the central Gulf Coast landscape.

[INSERT FIGURE 2.16: Surface geology of the southeastern United States.]

Due largely to its sedimentary history, land along the central Gulf Coast tends to be low and flat and is dissected by numerous slow-moving streams or bayous that drain runoff from the Coastal Plain and the adjacent uplands. The central Gulf coastal zone includes many barrier islands and peninsulas, such as Galveston Island, TX, Grand Isle, LA, and the land between Gulfport and Biloxi, MS. These landforms protect numerous bays and inlets. The low-lying areas of the central Gulf Coast region are (or were) primarily marshland and wetland forests.

Erosion, sediment transport and deposition, and changes in elevation relative to mean sea level (i.e., subsidence, discussed in greater detail below) are the main land surface processes that interact with climate change and variability in a manner that could adversely affect transportation in the study area. Erosion is exacerbated by increased water depth, increased frequency or duration of storms, and increased wave energy – and all of these changes could potentially accompany an increase in the temperature of the atmosphere.

2.3.2 Current Elevation and Subsidence

The great majority of the study area lies below 30 meters in elevation (figure 2.17) (USGS, 2004). Due to its low relief, much of the central Gulf Coast region is prone to flooding during heavy rainfall events, hurricanes, and lesser tropical storms. The propensity for flooding is higher in areas that are experiencing subsidence (i.e., the gradual lowering of the land surface relative to a fixed elevation). Near the coastline, the net result of land subsidence is an apparent increase in sea level.

Land subsidence is a major factor in the study region. The rate of subsidence varies across the region and is influenced by both the geomorphology of specific areas as well as by human activities. Parts of Alabama, Texas, and Louisiana are experiencing subsidence rates that are much higher than the 20^{th}–century rate of global sea level rise of 1-2 mm/year (IPCC, 2001). For example, in the New Orleans area the average rate of subsidence between 1950 and 1995 was about 5 mm/year (Burkett et al., 2003), with some levees, roads, and artificial-fill areas sinking at rates that exceed 25 mm/year (Dixon et al., 2006). As a result of subsidence, which was accelerated by the forced drainage of highly organic soils and other human development activity, most of the city of New Orleans is below sea level.

[INSERT FIGURE 2.17: Relative elevation of study area counties (delineated in blue)]

Subsidence in the Houston-Galveston-Baytown region is associated primarily with groundwater withdrawals, which peaked in the 1960s. By the mid 1970s, industrial groundwater withdrawals had caused roughly two meters of subsidence in the vicinity of the Houston Ship Channel, and almost 8,300 km^2 (3,200 mi^2) of land in this region had subsided more than one foot. The growing awareness of subsidence-related flooding in southeastern Texas prompted the 1975 Texas Legislature to create the Harris-Galveston Coastal Subsidence District, which was authorized to regulate ground water withdrawals and promote water conservation programs (Coplin and Galloway, 1999). Shallow oil and gas withdrawals also have contributed to subsidence in southeast Texas (Coplin and Galloway, 1999) and coastal Louisiana (Morton et al., 2005). Recent geological and geophysical investigations suggest that subsidence across the Central Gulf Coast is occurring more rapidly than previously thought (Shinkle and Dokka, 2005; Dixon et al., 2006).

Recognizing the increasing trend in flooding in the region, the Federal Emergency Management Agency (FEMA) currently is updating its Base Flood Elevations Maps of the region. However, even new elevation maps can be outdated within just a few years due to the high rates of subsidence in some parts of the study area (American Geophysical Union [AGU], 2006).

While the Gulf Coast is considered at very low risk for earthquakes, it does have hundreds of subsurface faults that can be expressed at the surface by differences in elevation, by the zonation of plant communities, or by patterns of wetland loss (Morton et al., 2005). Generally, these faults run parallel to the shoreline and are displaced "down to the coast" due to the slow sliding of thick sediments towards the Gulf of Mexico. Subsidence and subsurface fluid withdrawals can activate shallow faults and cause ground failure along highways and beneath buildings. Since the late 1930s, 86 active faults in the Houston-Galveston area have offset the land surface by slow seismic creep at rates of up to 2.5 cm per year (Holzer and Gabrysch, 1987; Coplin and Galloway, 1999).

2.3.3 Sediment Erosion, Accretion, and Transport

The northern Gulf of Mexico coastal zone is highly dynamic due to a unique combination of geomorphic, tectonic, marine, and atmospheric forcings that shape both the shoreline and interior land forms. Most of coastline of the study area is classified as "highly vulnerable" to erosion (Theiler and Hammar-Close, 1999). The retreat of shoreline of the reticulated marshes that dominate much of the coastal zone is often translated to "wetland loss," which occurs via submergence of land or erosion of the land/water interface. Highest erosion and wetland loss rates are associated with tropical storms and frontal passages. It is estimated that 56,000 ha (217 mi^2) of land were lost in Louisiana alone during Hurricane Katrina (Barras, 2006).

The barrier islands of the central Gulf Coast region are shaped continually by wind and wave action and changes in sea level, including the short-term increase in sea level associated with storm surge. The Chandeleur Islands, LA, which serve as a first line of defense for the New Orleans region, are extremely vulnerable to intense tropical storms, having lost 85 percent of their surface area during Hurricane Katrina (USGS, 2007). As barrier islands and mainland shorelines erode and submerge, onshore facilities in low-lying coastal areas become more susceptible to inundation and destruction. Many Gulf Coast barrier islands are retreating and diminishing in size, with the most significant breaching and retreat occurring during storms and frontal passages. The combined effects of beach erosion and storms can lead to the erosion or inundation of other natural coastal systems. For example, an increase in wave heights in coastal bays is a secondary effect of sandy barrier island erosion in Louisiana where increased wave heights have enhanced erosion rates of bay shorelines, tidal creeks, and adjacent wetlands (Stone and McBride, 1998; Stone et al., 2003).

Theiler and Hammar-Close (1999) assessed the relative importance of six variables that influence coastal erosion rates and developed a coastal vulnerability index (CVI) for the Gulf Coast region. Their analyses indicated that geomorphology and tide range are the most important variables in determining the CVI for the Gulf of Mexico coast, since both variables reflect very high vulnerabilities along nearly the entire shoreline. Wave height, relative sea level rise, and coastal slope explain the large-scale (50-200 km alongshore) variability of erosion rates. They concluded that erosion and accretion rates contribute the greatest variability to the CVI at short spatial scales. Rates of shoreline change, however, are the most complex and poorly documented variable in this dataset developed by the USGS. To best understand where physical changes may occur, large-scale variables must be clearly and accurately mapped, and small-scale variables must be understood on a scale that takes into account their geologic and environmental influences. Marshes that receive sufficient inputs of mineral or organic sediments, for example, can offset the potential for submergence due to subsidence and sea level rise (Rybczyk and Cahoon, 2002).

Sediments eroded by winds, tides, and waves are transported generally towards shore and continually reworked into a mosaic of wetlands, shallow bays, and barrier islands. Some sediments, however, are lost to the Gulf or deposited along the shoreline to the east or west of the study area. Nearshore currents east of the mouth of the Mississippi River carry sediments eastward. To the west of the Mississippi River delta, the predominant direction of this nearshore drift is westward.

At the geographic center of the study area, the Mississippi River alluvial or deltaic plain has been built on the continental shelf during the past 6,000 years, during a period of relatively slow sea level rise when most of the world's present deltas were formed (Woodruffe, 2003). In recent times, sediments that would be delivered to the Mississippi River delta marshes via seasonal overbank flooding have been cut off by levees and deep channel dredging of the Mississippi River for navigation (Reed, 2002). Thousands of miles of smaller navigation channels, access canals to oil and gas fields, and other development activities have contributed to the vulnerability of the Mississippi River deltaic plain to sediment deprivation and land loss (Minerals Management Service [MMS], 1994).

2.3.4 Land Use and Land Cover

Land use of the Gulf Coast study area was defined by using the National Land Cover Dataset (NLCD). The NLCD consists of 21 classifications, of which 19 were found in this study area. The data were collected from the Landsat Thematic Mapper satellite in the early to middle 1990s and are of 30–meter resolution. Table 2.8 summarizes this data for the study area.

The central Gulf Coast study area covers an area of approximately 1 million ha (23.4 million acres or 36,485 mi^2). Land cover is dominated by wetlands (32.4 percent), agriculture (19/1 percent), and upland forests (17.7 percent). The study area can be broadly divided into six ecological units based on Bailey's classification of U.S. ecoregions (Bailey, 1976) (figure 2.18). Land cover within the study area has strong similarities from east to west across the study area and appears to be influenced more by soils, topography, and human activity than by climatic differences. Natural plant community distributions are generally oriented along north/south gradients, reflecting salinity, water level, and disturbance regimes.

Nonurbanized land use in the region is devoted mainly to Federal/State protected lands, large-scale commercial agriculture, and relatively undeveloped wetlands associated with the Mobile River in Alabama; the Pearl River in Mississippi and Louisiana; the Mississippi, Atchafalaya, and Calcasieu Rivers in Louisiana; and the Neches, Sabine, and Trinity Rivers in Texas. In addition to contributing to the formation of wetlands running inland from the coast, each of these rivers intersects or connects with the Gulf Intracoastal Waterway, and each forms the basis for urbanized port areas, of varying sizes, adjacent to the coast.

[INSERT Table 2.8: Land use of the central Gulf Coast study area as defined by the 1992 National Land Cover Dataset]

[INSERT Figure 2.18: Map of terrestrial ecoregions within and adjacent to the study area]

■ 2.4 Social and Economic Setting

Transportation networks exist to facilitate the movement of people and goods and are an integral part of a region's social and economic fabric. The need for these networks, or transportation demand, therefore, is defined by demographic and economic considerations – connecting population centers, providing access to economic resources, etc. It is important, therefore, to understand the people and the economy that exist in the Gulf Coast study region in order to assess the significance of climate impacts on its transportation systems.

The Gulf Coast study region, like many parts of the country, has been growing in population and economic activity and has become increasingly urbanized in recent decades. These trends were seriously disrupted by the 2005 hurricanes, which caused massive property damage and wide-scale relocation of residents in affected areas. It is too early to know what long-term impacts Hurricanes Katrina and Rita will have on the region's population distribution.

According to the U.S. Census Bureau estimates for 2004, the 48 counties of the designated study area are home to about 9.7 million people. Within the region are 419 cities, towns, and villages (defined as "places" by the U.S. Census Bureau), ranging in population from less than 50 residents to nearly 2 million. A quick perusal of the interstate and highway map illustrates, to some degree, the interconnectedness of the region. The majority of these places are served by a vast land- and water-based transportation grid designed to move people and goods eastward and westward along the coast, as well as into and out of the United States via Gulf of Mexico port facilities.

Figure 2.19 illustrates the degree to which urbanized zones have spread throughout the study area. Population growth and industrialization in the region are continuing to urbanize the central coast of the Gulf of Mexico. Nonetheless, major contrasts remain among urban, suburban, and rural settings within the region.

Mean household income for the study area population was lower than for the nation ($53,600 per household compared to $56,500 in the Nation). The study region also experiences higher poverty rates (15.6 percent of all persons compared to 12.4 percent in the Nation), and higher rates of children below 5 years living in poverty (17.4 percent compared to 12.5 percent nationally). The demographic distribution showed a slightly younger population when compared to the Nation (52.8 percent of the population was less than 35 years, compared to 49.3 percent nationwide).

[INSERT FIGURE 2.19: U.S. Census Bureau Metropolitan Statistical Areas in study area]

2.4.1 Population and Development Trends

Before the impacts of the hurricanes in 2005 were fully realized, the region had experienced an average population growth rate from 1990 to 2000 of 16 percent, with an additional 5 percent growth estimated for the period from 2000 to 2004 (figures 2.21 and 2.22). Measured in terms of building permits issued, the region has experienced an overall housing growth rate of 12 percent during the period of 1997 to 2002. However, a wide variation in growth rates exists among counties in the study area, including 17 counties (primarily rural) that have experienced declines in building permit issuance over this period.

[INSERT FIGURE 2.20: Population density in study area, 2004]

[INSERT FIGURE 2.21: Estimated population change in study area, 2000 to 2005]

Population and housing growth patterns for the region are dominated by urban-rural migration and the increasing suburbanization of the larger urban areas of Houston/Galveston, TX, Baton Rouge/New Orleans, LA, Hattiesburg, MS, and Mobile, AL. Rural counties along the western and central portions of the Louisiana coast, which tend to be dominated by wetland landscapes of the Atchafalaya and Mississippi Rivers, have experienced low and/or declining population growth over this period. These counties primarily host agricultural economies, and, like many similar rural counties in the United States, they have been experiencing slowly declining population growth rates for many decades.

Urban growth has been primarily characterized by spatial expansion around existing urbanized areas. In the case of Houston/Galveston, growth has been focused on those counties surrounding the core county of Harris, especially due to the residential and commercial expansion along I-10 to the west and I-45 to the south and east. The Baton Rouge/New Orleans area is experiencing a similar suburbanization process focused on the "Northshore" of Lake Pontchartrain. This growth in "bedroom" communities on the Northshore is supported by commuter pathways along I-12 and I-10 and the Lake Pontchartrain Causeway. Baton Rouge continues to grow eastward toward these Northshore counties, and the New Orleans metro area has been undergoing the same cross-lake residential migration for many years. One of the numerous impacts of Hurricane

Katrina appears to be an acceleration of this trend among residents of Orleans and St. Bernard Counties,[8] as many residents are finding the Northshore communities more affordable or attractive despite the greater commute into New Orleans. Mobile, AL, appears to be experiencing a similar pattern of suburbanization as the greatest growth is taking place in the less densely populated county of Baldwin east of Mobile Bay. Figure 2.22, "Mean Travel Time to Work," illustrates this trend toward suburbanization in the region.

[INSERT FIGURE 2.22: Mean travel time to work in study area]

It is still too early to know what the long-term impacts of Hurricane Katrina will be on regional demographics. Some locations, particularly New Orleans, experienced major shifts. According to the 2005 American Community Survey Special Product for the Gulf Coast Area (U.S. Census Bureau, 2005), in the months following the storm, the New Orleans Metropolitan Statistical Area [MSA] showed a 30 percent drop in population, accompanied by a nearly 4-year increase in median age (from 37.7 years to 41.6 years). The civilian labor force dropped from nearly 600,000 to about 340,000. The survey measured higher median incomes for those remaining, indicating that more higher-income workers in relatively stable professions have tended to stay in place, while lower-income, low-skilled workers have been more likely to relocate. Many people moved to other locations within the study area, such as the Houston-Galveston and Baton Rouge areas, while others left the study area entirely.

2.4.2 Employment, Businesses, and Economic Drivers

Energy production, chemical manufacturing, and commercial fishing dominate the economy of the study region. While the economy in the overall area has grown, certain parts of the region have not shared in this development. Table 2.9 shows the top 10 industries in the study area by employment, according to the 2000 Census (U.S. Census Bureau, 2007). On the whole, these mirror national-level census results. Differences include a smaller share of workers employed in manufacturing (11.6 percent in the study region, compared to 14 percent in the Nation) and a larger share in construction (8.6 percent in the Gulf Coast area compared to 6.8 percent in the Nation). In addition, a much larger share of study area workers are employed in extraction industries (2.2 percent in the study area, versus 0.3 percent nationally).

[INSERT TABLE 2.9: Top 10 industries in the study area by employment percentage, 2000]

The study region is host to nationally significant concentrations of several industries:

- **Oil and natural gas production and refining –** Much of the U.S. domestic oil

[8] The U.S. Census Bureau term "County" is used here for consistency in Louisiana, rather than the more common term "Parish." Both indicate the same political unit.

production is supported by facilities in the Gulf of Mexico region – fixed oil platforms and mobile rigs, transportation systems, refineries, storage facilities, and distribution systems. An estimated 60 percent of all U.S. energy imports come through port facilities in the Gulf of Mexico region.

- **Chemical and petrochemical manufacturing –** Due to the presence of petroleum and natural gas supplies and infrastructure, the Gulf is a leading center for the U.S. chemical industry, which generally relies on expensive investments in fixed infrastructure.

- **Commercial fishing –** This is a multibillion dollar industry that is critical to the economies of many Gulf States.

As of 2003, the study area hosted approximately 214,768 private business establishments employing approximately 3,691,883 employees. The region experienced a 4 percent growth both in the number of establishments during the period from 1998 to 2003, and in the total number of employees. Despite this overall growth, certain counties have experienced decline and/or stagnation in businesses development. The growth versus decline patterns very closely match the same patterns as the population and housing discussed earlier, with suburbanizing counties on the periphery of the larger urban areas realizing most of the growth. Most notable again are the counties currently expanding westward and southward around Houston/Galveston, TX, west of Baton Rouge, LA, the counties of Louisiana's Northshore area, and Baldwin County west of Mobile Bay, AL. Orleans and Jefferson Counties, LA, (constituting the bulk of metro New Orleans) again stand out as having a relatively high rate of business decline in recent years, while the counties to the east and north have flourished.

Most rural counties have experienced decline or stagnation in terms of total businesses and total employees. These patterns again reflect the overall development and growth that is characterized by suburbanization in the region. In some areas, this trend may be more related to technological change in agriculture or petroleum extraction methods than a true decline in the general economy.

Counties with port facilities or Mississippi River access dominate the manufacturing shipments measured in dollar amounts (figure 2.23). Retail sales patterns, on the other hand, exhibit a less rational spatial pattern and seem to be tied to idiosyncratic changes in a small sample of counties. For instance the county of Waller, TX, in the farthest northwestern corner of the Houston area, registers a top value in terms of retail sales but a low value in terms of manufacturer's shipments. Much of this can be explained by the establishment of the Katy Mills Mall, which has caused the county to develop from one dominated by agriculture and industry to one based on a growing retail economy in recent years. Small-scale changes in the economic structure or productivity of specific sectors may be behind other local trends.

[INSERT FIGURE 2.23: Manufacturers shipments in thousands of dollars, 1997]

2.4.3 Societal Vulnerability

Social vulnerability measures are important both as general background to the regional demographics but also to understand implications for future infrastructure needs and for emergency management. In this case, vulnerability refers to the inability of a social group to respond to, adapt to, or avoid negative impacts resulting from extreme or significant long-term deviations from average environmental conditions.

Generally, vulnerability assessments are conducted in respect to a single risk or hazard (flooding, radioactive release, drought, hurricane evacuation, etc.). For this study, the "hazards" are the anticipated impacts of climate change and variability, specifically as it relates to transportation interests. Since this encompasses multiple changes over a protracted time period, it is difficult, at this spatial and temporal scale, to comprehensively measure those features of the current social landscape that will be most vulnerable to future changes as they occur. Therefore, numerous social measures were included in this analysis in an effort to describe the most general patterns of vulnerability. The attributes included in this social vulnerability index are:

1. Percent persons reporting disabilities for civilian noninstitutionalized population five years and over;
2. Percent total population: Age 14 and below;
3. Percent total population: 65 years and over;
4. Percent households: Two-or-more-person household; family households; maritally single; with own children under 18 years;
5. Percent households: All languages; linguistically isolated;
6. Percent population 25 years and over: No high school graduate (includes equivalency);
7. Percent below study area median household income in 1999;
8. Percent households: With public assistance income;
9. Percent population for whom poverty status is determined: Income in 1999 below poverty level;
10. Percent housing units: Mobile home;
11. Percent housing units: Built 1969 or earlier;
12. Percent occupied housing units: No vehicle available;
13. Percent occupied housing units: Renter occupied;
14. Specified owner-occupied housing units: Percent below study area median value; and

15. Specified owner-occupied housing units: Percent housing units with a mortgage; contract to purchase; or similar debt; with either a second mortgage or home equity loan, but not both.

To illustrate how these multiple attributes can be agglomerated, these 15 measures were subjected to an indexing process to create a continuum of vulnerability at both the county- and block-group scale (most vulnerable, more vulnerable, less vulnerable, and least vulnerable). In future phases of this research, particularly for in-depth analysis of one site, the attributes included in this index can be changed or statistically weighted in response to particular transportation management or other concerns at that site. Figure 2.24 maps this vulnerability index for the study region. Maps depicting conditions within the region for each of the 15 societal attributes are contained in appendix B.

A number of patterns emerge from these measures of vulnerability. The first is the obvious pattern of counties with high degrees of social vulnerability expressed in the central portion of the Louisiana section of the study area. These counties correspond with the physical feature of the Atchafalaya River valley, the western portions of the Mississippi River valley, and the wetland landscapes produced by both. One can interpret from this analysis that these populations, if faced with extreme changes in their physical environments, will find coping with those changes extremely difficult. Many of these counties are traditionally rural, impoverished areas (figure 2.25). Also included is the urban-core county of Orleans, which ranks extremely high on many of the vulnerability measures included here.

However, poverty alone does not explain the higher rankings. These counties also tend to rank high in presence of disabled populations, persons over 65 (figure 2.26), absence of a vehicle per household, presence of single parents, linguistic isolation, and a number of other attributes. It can be argued that these are all dimensions of impoverishment. However, it is not the simple fact that a person is poor that makes them vulnerable; rather it is the context that widespread poverty can create in terms of public services, durability of infrastructure, access to egress, etc., acting together that make a community vulnerable to extreme environmental change.

To a lesser degree, this pattern of vulnerability extends southeastward into the delta region of central Louisiana. Other counties with similar characteristics outside central Louisiana tend to be rural and tertiary to urban-suburban growth. Exceptions to this statement are the heavily industrialized counties around Beaumont and Port Arthur, TX, Lake Charles, LA, and St. Bernard County, LA. The rapidly urbanizing county of Mobile, AL, also falls into this category of vulnerability.

Counties that tend to have fewer vulnerability characteristics are those on the periphery of large urban areas that were described earlier as undergoing the fastest rates of suburbanization. Again, this trend is tied heavily to overall income patterns but is not fully explained by that single attribute. For instance, these counties also tend to have higher rates of children per capita and more manufactured housing. It can be assumed that, at least for the time being, the populations of these counties will be better prepared to cope with the negative impacts of extreme environmental change.

From a transportation perspective, it also might be assumed that these areas will have special needs for transportation infrastructure in coming years. Vulnerable areas may need more services and infrastructure in the future to help them reduce their vulnerability – and to cope with destructive natural events – such as severe storms – as they occur.

[Insert Figure 2.24: Social vulnerability index for study area]

[Insert Figure 2.25: Persons in poverty in study area]

[Insert Figure 2.26: Persons aged 65 and older in study area]

■ 2.5 Conclusions

The central Gulf Coast study area contains transportation infrastructure that is vital not just to the movement of passengers and goods within the study area but also to the national transportation network and economy. However, the geomorphology of the region makes it particularly sensitive to certain climate impacts. Due largely to its sedimentary history, the region is low-lying – much of it below 5 m – with little topographical relief. Much of the region experiences high rates of subsidence as these sediments naturally compact over time, while high rates of erosion mean that sections of coastline are literally washed away after tropical storms and hurricanes. As a result, the region is particularly vulnerable to the effects of sea level rise and storm activity.

In keeping with national trends, the region is experiencing a shift in population from rural to urban areas and increasing suburbanization of the larger urban areas. Much of the infrastructure supporting this population is located in vulnerable, low-lying areas. Parts of the population face vulnerabilities that may make it more difficult for them to adapt to the conditions imposed by a changing climate. This pattern of vulnerability is most focused in the rural counties of central coastal Louisiana, the urban core of New Orleans, and to a lesser extent southeastward into the delta region of Louisiana, and also into the rapidly urbanizing Mobile County, AL. On average, the population of the study area shows lower-income levels and higher poverty rates than the rest of the nation.

The following section will present the climate changes projected for the study area, while section 4.0 will discuss the resulting impacts to transportation systems in the central Gulf Coast region.

2.6 Sources

2.6.1 References

Airports Council International (ACI), 2005: *2005 North America Final Traffic Report.* Airports Council International – North America, Washington, D.C.

American Public Transportation Association (APTA), 2005: *Public Transportation Fact Book.* Washington, D.C., page 86. (Available on-line at http://www.apta.com/research/stats.)

Bailey, R.G., 1976: *Ecoregions of the United States.* USDA Forest Service, Intermountain Region, Ogden, Utah, map, scale 1:7,500,000.

Barras, J.A., cited 2006: Land area change in coastal Louisiana after the 2005 hurricanes – a series of three maps. U.S. Geological Survey Open-File Report 2006-1274. (Available on-line at http://pubs.usgs.gov/of/2006/1274/. Accessed October 18, 2006.)

Bureau of Transportation Statistics (BTS), 2004: *National Transportation Atlas Database (NTAD) 2004.* U.S. Department of Transportation, Washington, D.C., CD-ROM. (Available on-line at http://www.bts.gov/publications/national_transportation_atlas_database/.)

Burkett, V.B., D.B. Zilkoski, and D.A. Hart, 2003: Sea level rise and subsidence: Implications for flooding in New Orleans, Louisiana. In: *USGS Subsidence Interest Group Conference* (Prince, K.R., and D.L. Galloway (Eds.)). Proceedings of the Technical Meeting, Galveston, Texas, 27–29 November 2001, Open-File Report Series 03-308, Water Resources Division, U.S. Geological Survey, Austin, Texas, pages 63-70.

Coplin, L.S. and D. Galloway, 1999: Houston-Galveston, Texas. Managing coastal subsidence. In: *Land Subsidence in the United States* (Galloway, D., D.R. Jones, and S.E. Ingebritsen (Eds.)). U.S. Geological Survey Circular 1182, U.S. Geological Survey, pages 35-48.

Dixon, T.H., F. Amelung, A. Ferretti, F. Novali, F. Rocca, R. Dokka, G. Sella, S.-W. Kim, S. Wdowinski, and D. Whitman, 2006: Subsidence and flooding in New Orleans. *Nature*, 441, 587-588.

Federal Highway Administration (FHWA), 2001: *2001 National Bridge Inventory Database.* Office of Infrastructure, Washington, D.C.

Federal Highway Administration (FHWA), 2004: *Freight Analysis Framework.* Freight Management and Operations, Office of Operations, Washington, D.C. (Dataset)

Federal Highway Administration (FHWA), 2005: *Highway Statistics 2004.* Office of Highway Policy Information, Washington, D.C.

Federal Highway Administration (FHWA), cited 2006: *Official NHS Intermodal Connector Listing*. Office of Planning, Environment, and Realty, Washington, D.C. (Available on-line at http://www.fhwa.dot.gov/hep10/nhs/intermodalconnectors/.)

Federal Transit Administration (FTA), 2005: *2004 National Transit Database.* Washington, D.C. (Available on-line at http://www.ntdprogram.com/NTD/ntdhome.nsf.)

Holzer, T.L., and R.K. Gabrysch, 1987: Effect of ground-water level recoveries on fault creep, Houston, Texas. *Ground Water*, 25, 392–397.

Institute for Water Resources, 2003: *Waterborne Commerce of the United States.* Waterborne Commerce Statistics Center, Navigation Data Center, U.S. Army Corps of Engineers, Arlington, Virginia.

Minerals Management Service (MMS), 1994: *Backfilling Canals as a Wetland Restoration Technique in Coastal Louisiana*. MMS Publication 94-0026, Minerals Management Service, Washington, D.C.

Morton, R.A., J.C. Bernier, J.A. Barras, and N.F. Ferina, 2005: *Rapid Subsidence and Historical Wetland Loss in the Mississippi Delta Plain: Likely Causes and Future Implications*. U.S. Geological Survey Open-File Report 2005-1216, 115 pages.

Pipeline and Hazardous Materials Safety Administration (PHMSA), 2007: *Annual Reports: National Pipeline Mapping System.* PHMSA, U.S. Department of Transportation, Washington, D.C.

Reed, D.J., 2002: Sea level rise and coastal marsh sustainability: geological and ecological factors in the Mississippi delta plain. *Geomorphology,* 48**,** 233–243.

Rybczyk, J.M. and D.R. Cahoon, 2002: Estimating the potential for submergence for two subsiding wetlands in the Mississippi River delta. *Estuaries*, 25, 985–998.

Shingle, K.D. and R.K. Dokka, 2004: *Rates of Vertical Displacement at Benchmarks in the Lower Mississippi Valley and the Northern Gulf Coast*. NOAA Technical Report NOS/NGS 50, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Washington, D.C., 135 pages.

Stone, G.W., J.P. Morgan, A. Sheremet, and X. Zhang, 2003: *Coastal land loss and wave-surge predictions during hurricanes in Coastal Louisiana: implications for the oil and gas industry.* Coastal Studies Institute, Louisiana State University, Baton Rouge, page 67.

Stone, L., A. Huppert, B. Rajagopalan, H. Bhasin, and Y. Loya, 1999: Mass coral bleaching: a recent outcome of increased El Niño activity? *Ecology Letters*, 2, 325-330.

Thieler, E.R. and E.S. Hammar-Klose, 2000: *National Assessment of Coastal Vulnerability to Future Sea Level Rise: Preliminary Results for the U.S. Gulf of Mexico Coast*. U.S. Geological Survey Open-File Report 00–179. Available on-line at <http://pubs.usgs.gov/dds/dds68/>, viewed June 28, 2005.

U.S. Census Bureau, 2005: *Special Product for the Gulf Coast Area*. American Community Survey Office, Washington, D.C. (Available on-line at http://www.census.gov/acs/www/Products/Profiles/gulf_coast/index.htm.)

U.S. Census Bureau, cited 2007: *United States Census 2000.* Washington, D.C.

U.S. Geological Survey (USGS), 2000: The coastal plain. In: *A Tapestry of Time and Terrain: The Union of Two Maps – Geology and Topography*. U.S. Geological Survey, Reston, Virginia. Available on-line at http://tapestry.usgs.gov/features/13coastalplain.html, viewed June 20, 2006.

U.S. Geological Survey (USGS), 2004: *National Elevation Dataset (NED).* U.S. Geological Survey, EROS Data Center, Sioux Falls, South Dakota. (Available on-line at http://ned.usgs.gov/.)

U.S. Geological Survey (USGS), 2007: Predicting flooding and coastal hazards. *Sound Waves Monthly Newsletter,* U.S. Geological Survey, Coastal and Marine Geology Program, June, page 1.

Woodroffe, C.D., 2003: *Coasts: Form, Process and Evolution.* Cambridge University Press, Cambridge, United Kingdom, page 623.

2.6.2 Background Sources

American Association of Port Authorities (AAPA), 2004: *North America Port Container Traffic 2004.* American Association of Port Authorities, Alexandria, Virginia. (Available on-line at http://www.aapa-ports.org/Industry/content.cfm?ItemNumber=900&navItemNumber=551).

American Geophysical Union, 2006: *Hurricanes and the U.S. Gulf Coast: Science and Sustainable Rebuilding.* American Geophysical Union, Washington, D.C., page 30. (Available on-line at http://www.agu.org/report/hurricanes/, viewed June 29, 2006.)

Table 2.1 Study area counties and Federal Information Processing Standard (FIPS) codes.

County name	State	FIPS	Name	State	FIPS[1]
Baldwin	Alabama	003	St. Tammany	Louisiana	103
Mobile	Alabama	097	Tangipahoa	Louisiana	105
Acadia	Louisiana	001	Terrebonne	Louisiana	109
Ascension	Louisiana	005	Vermilion	Louisiana	113
Assumption	Louisiana	007	West Baton Rouge	Louisiana	121
Calcasieu	Louisiana	019	Forrest	Mississippi	035
Cameron	Louisiana	023	George	Mississippi	039
East Baton Rouge	Louisiana	033	Hancock	Mississippi	045
Iberia	Louisiana	045	Harrison	Mississippi	047
Iberville	Louisiana	047	Jackson	Mississippi	059
Jefferson	Louisiana	051	Lamar	Mississippi	073
Jefferson Davis	Louisiana	053	Pearl River	Mississippi	109
Lafayette	Louisiana	055	Stone	Mississippi	131
Lafourche	Louisiana	057	Brazoria	Texas	039
Livinston	Louisiana	063	Chambers	Texas	071
Orleans	Louisiana	071	Fort Bend	Texas	157
Plaquemines	Louisiana	075	Galveston	Texas	167
St. Bernard	Louisiana	087	Hardin	Texas	199
St. Charles	Louisiana	089	Harris	Texas	201
St. James	Louisiana	093	Jefferson	Texas	245
St. John the Baptist	Louisiana	095	Liberty	Texas	291
St. Landry	Louisiana	097	Montgomery	Texas	339
St. Martin	Louisiana	099	Orange	Texas	361
St. Mary	Louisiana	101	Waller	Texas	473

[1]The FIPS county code is a number that uniquely identifies each county in the United States.

Table 2.2 Gulf Coast study area centerline miles of highway, by classification and ownership. (Source: Cambridge Systematics from 2004 Highway Performance Monitoring System database for Gulf Coast study supplied by the Bureau of Transportation Statistics)

	State	County	Municipal	Other	Total
Interstate	1,096	0	0	0	1,096
Arterials	4,484	794	2,268	105	7,651
Collector	4,390	1,776	2,016	35	8,747
Total	**9,970**	**2,570**	**4,284**	**140**	**17,494**

Table 2.3 Equipment, annual service, and passengers for fixed-route bus operations in the study area, 2004. (Source: Cambridge Systematics from 2004 National Transit Database)

				Passengers		Revenue	
Agency	**Urban Area**	**Vehicles**	**Type of Vehicle**[1]	**(000)**	**Miles (000)**	**Miles (000)**	**Hours (000)**
Metropolitan Transit Authority of Harris County, MTAHC (Metro)	Houston, Texas	1,434	210 articulated diesel buses, 1224 diesel buses	87,940	504,902	44,097	3,051
New Orleans Regional Transit Authority (RTA)	New Orleans, Louisiana	367	367 diesel buses	38,202	92,252	10,655	748
Capital Area Transit System (CATS)	Baton Rouge, Louisiana	74	5 CNG buses, 51 diesel buses, 18 diesel vans	4,805	15,749	3,172	159
Jefferson Transit (JeT)	New Orleans, Louisiana	63	59 diesel buses, 4 diesel vans	4,192	19,581	2,276	149
Lafayette Transit System (LTS)	Lafayette, Louisiana	22	22 diesel buses	1,156	4,856	536	41
Island Transit (IS)	Galveston, Texas	20	11 diesel buses, 9 diesel vans	940	1,454	555	45
The Wave Transit (The Wave)	Mobile, Alabama	31	26 diesel buses, 5 diesel vans	860	5,233	1,371	97
Beaumont Municipal Transit System	Beaumont, Texas	19	1 CNG bus, 18 diesel buses	662	2,858	729	52
Coast Transit Authority	Gulfport-Biloxi, Pascagoula, Mississippi	18	16 diesel buses, 2 LPG buses	534	2,672	770	61
Port Arthur Transit (PAT)	Port Arthur, Texas	11	10 diesel buses, 1 diesel van	125	935	235	14
Hattiesburg Area Readi Transit, Hub City Transit (HART)	Hattiesburg, Mississippi	5	3 gasoline buses, 2 diesel vans	N/A	N/A	N/A	N/A
Lake Charles Transit System (LCTS)	Lake Charles, Louisiana	8	8 diesel buses	N/A	N/A	N/A	N/A
Saint Bernard Urban Rapid Transit (SBURT)	New Orleans, Louisiana	9	8 diesel buses, 1 diesel van	N/A	N/A	N/A	N/A
Total		**2,081**		**139,416**	**650,492**	**64,396**	**4,417**

[1] CNG – Compressed Natural Gas
LPG – Liquified Propane Gase

Table 2.4 Freight railroads in the Gulf Coast study area. (Source: Bureau of Transportation Statistics, 2004)

Railroad	Class	Service Area	Primary Commodities
Acadiana Railway	III	Crowley, LA, through Eunice and Opelousas, to Bunkie, LA.	Agricultural products, edible oils, and general freight.
Alabama and Gulf Coast Railway	III	Pensacola, FL, to Columbus, AL. Extensions to Mobile, AL, via Norfolk Southern trackage.	Paper industry: logs, woodchips, chlorine, sodium chlorate, hydrogen peroxide, rolled and boxed paper, and kaolin clay.
Burlington Northern Santa Fe Railway	I	Over 32,000 route miles in western U.S. Operate between Houston and New Orleans.	Coal, grains, intermodal, lumber, and chemicals.
Canadian National Railway (formerly Illinois Central Gulf)	I	Over 19,000 route miles in U.S. and Canada. Serves Mobile and New Orleans via north-south route.	Petroleum, chemicals, grain, fertilizers, coal, metals, minerals, forest products, intermodal, and automotive.
CSX Transportation	I	Over 22,000 route miles in eastern U.S. Operate between Florida and New Orleans along I-10 corridor.	Coal, chemicals, autos, minerals, agricultural products, food, consumer goods, metals, forest and paper products, and phosphates and fertilizer.
Kansas City Southern	I	Operates approximately 3,100 route miles in central and southeastern U.S. Serves New Orleans and Lake Charles, LA, Port Arthur and Galveston, TX, and Mexico.	Agriculture, minerals, general merchandise, intermodal, autos, and coal.
Lake Charles Port and Harbor District	Switching	Owned by the Port. Switches traffic for Union Pacific.	Port traffic.
Louisiana and Delta Railroad	III	Multiple branches connected by trackage rights on Union Pacific between Lake Charles and Raceland, LA.	Carbon black, sugar, molasses, pipe, rice, and paper products.
Mississippi Export Railroad		Escatawpa River at Evanston, MS, to port at Pascagoula, MS.	Transloading services for intercoastal and river barges or vessels.
New Orleans and Gulf Coast Railway	III	Westwego, LA, to Myrtle Grove, LA.	Food products, oils, grains, petroleum products, chemicals, and steel products.
New Orleans Public Belt Railroad	Switching	Serves Port of New Orleans along the Mississippi River and Industrial Canal.	Exports: lumber, wood products, and paper. Imports: metal products, rubber, plastics, and copper. Domestic: clay, cement, and steel plate.
Norfolk Southern Corporation	I	Over 21,000 route miles in eastern U.S. Operate from Birmingham to Mobile, AL, and New Orleans, LA.	Agriculture, autos, chemicals, coal, machinery, intermodal, metals, construction material, paper, clay, forest products.
Pearl River Valley Railroad	III	Goodyear, MS, to Nicholson, MS.	Lumber and forest products.
Port Bienville Railroad	Switching	Port Bienville Industrial Park, Hancock County, MS.	Plastic resins and other goods for industrial park tenets.
Sabine River and Northern Railroad	III	Between Buna and Orange, TX.	Wood chips, chemicals, and other raw materials for the paper industry. Finished paper and lumber products.
Terminal Railway Alabama State Docks	Switching	Operates over 75 miles in the Mobile, AL, area, serving the port and local industries.	Port cargo.
Timber Rock Railroad Company	III	De Ridder, LA, west through Merryville to Kirbyville, TX.	Forest products and rock.
Union Pacific Railroad	I	Over 32,000 route miles in western U.S. Operate between Houston and New Orleans.	Chemicals, coal, food, forest products, grains, intermodal, metals, minerals, and autos.

Table 2.5 Domestic and international waterborne tonnage of study area ports, 2003. (Source: U.S. Army Corps of Engineers, Navigation Data Center)

National Rank	Port	2003 Short Tons
1	South Louisiana, Louisiana	198,825,125
2	Houston, Texas	190,923,145
4	Beaumont, Texas	87,540,979
5	New Orleans, Louisiana	83,846,626
9	Texas City, Texas	61,337,525
10	Baton Rouge, Louisiana	61,264,412
11	Plaquemines, Louisiana	55,916,880
12	Lake Charles, Louisiana	53,363,966
14	Mobile, Alabama	50,214,435
23	Pascagoula, Mississippi	31,291,735
24	Freeport, Texas	30,536,657
27	Port Arthur, Texas	27,169,763
	Gulf Coast Study Area Total	**932,231,248**
	National Total	**2,394,251,814**

Table 2.6 Tonnage on study area inland and coastal waterways, 2003. (Source: U.S. Army Corps of Engineers, Waterborne Commerce of the United States, 2003)

Waterways Segments Within Study Area	2003 Short Tons (Millions)
Mississippi River, Baton Rouge to New Orleans, LA	212.9
Mississippi River, Mouth of Ohio to Baton Rouge, LA	185.5
Gulf Intracoastal Waterway, TX-FL	117.8
Mississippi River, New Orleans, LA, to Gulf of Mexico	115.8
Gulf Intracoastal Waterway, Port Allen Route, LA	24.3
Black Warrior and Tombigbee Rivers, AL	21.0
Atchafalaya River, LA	9.8
Tennessee-Tombigbee Waterway, AL and MS	5.2
Red River, LA	4.2
Chocolate Bayou, TX	3.3
Petit Anse, Tigre, Carlin bayous, LA	2.5
Ouachita and Black Rivers, AR and LA	2.2
Bayou Teche, LA	1.4
Subtotal for Waterway Segments Within Study Area	**705.9**
Subtotal for Full Gulf Coast and Mississippi River Systems, including Waterway Segments Within or Connecting to Study Area	**1,650.5**
National Total of All Major Inland and Coastal Waterway Segments	**1,717.0**

Table 2.7 Passenger enplanements and cargo tonnage for select commercial service and industrial airports in the study area, 2005.

Associated City	FAA Code	State	County	Airport Name	Airport Type	2005 Passenger Enplanements	2005 Cargo Tonnage
Mobile	MOB	Alabama	Mobile	Mobile Regional	CS	638,953	582
Mobile	BFM	Alabama	Mobile	Mobile Downtown	IND	0	44,000[a]
Lake Charles	LCH	Louisiana	Calcasieu	Lake Charles Regional	CS	43,250[a]	2[a]
Lake Charles	CWF	Louisiana	Calcasieu	Chennault International	IND	0	75
Baton Rouge	BTR	Louisiana	East Baton Rouge	Baton Rouge Metropolitan, Ryan Field	CS	973,625	5,663
New Orleans	MSY	Louisiana	Jefferson	Louis Armstrong New Orleans International	CS	7,775,147	66,123
Lafayette	LFT	Louisiana	Lafayette	Lafayette Regional	CS	343,301	6,774
Hattiesburg	HBG	Mississippi	Forrest	Bobby L Chain Muni	CS	8,000[a]	
Gulfport	GPT	Mississippi	Harrison	Gulfport-Biloxi International	CS	769,669	
Houston	EFD	Texas	Harris	Ellington Field	CS	53,947	15
Houston	HOU	Texas	Harris	William P. Hobby	CS	8,252,532	7,000
Houston	IAH	Texas	Harris	George Bush Intercontinental/ Houston	CS	39,684,640	387,790
Beaumont/ Port Arthur	BPT	Texas	Jefferson	Southeast Texas Regional	CS	43,038[1]	
Study Area Total						**58,586,102**	**517,418**
National Total						**738,629,000**	**30,125,644**

Source: Alabama airports from http://www.brookleycomplex.com/cargo/statistics.asp. Louisiana airports from the Airports Council International and U.S. DOT BTS T100 data. Texas airports from http://www.city-data.com/us-cities/The-South/Houston-Economy.html. Wilbur Smith Associates. National totals from Bureau of Transportation Statistics (http://www.bts.gov/programs/airline_information/air_carrier_traffic_statistics/airtraffic/annual/1981-2001.html) and Airports Council International.

Note: CS: Commercial Service Airport
IND: Industrial Airport

[1] Estimated.

Table 2.8 Land use of the central Gulf Coast study area as defined by the 1992 National Land Cover Dataset. (Source: National Land Cover Dataset, U.S. Geological Survey)

Land Use Category	Area (Hectares)	Percent of Total
Water	508,735	5.38%
Low-Intensity Residential	250,032	3.00%
High-Intensity Residential	106,637	1.13%
Commercial, Industrial, Transportation	152,744	1.62%
Bare Rock, Sand, Clay	14,126	0.15%
Quarries, Strip Mines, Gravel Pits	3,921	0.04%
Transitional from Barren	92,835	0.98%
Deciduous Forest	492,245	5.21%
Evergreen Forest	1,175,278	12.44%
Mixed Forest	861,726	9.12%
Shrubland	23,096	0.24%
Orchard, Vineyard	5	Negligible
Grasslands, Herbaceous	123,576	1.31%
Pasture, Hay	1,213,343	12.84%
Row Crops	591,105	6.26%
Small Grains	694,855	7.35%
Urban, Recreation Grasses	83,476	0.88%
Woody Wetlands	1,087,093	11.50%
Emergent Herbaceous Wetlands	1,974,788	20.90%
Total	**9,449,615**	

Table 2.9 Top 10 industries in the study area by employment percentage, 2000. (Source: United States Census 2000, U.S. Census Bureau, 2007)

Industry	Percent of Study Area Employment
Retail Trade	11.6
Manufacturing	11.6
Health Care and Social Assistance	10.2
Educational Services	8.9
Construction	8.6
Accommodation and Food Services	6.4
Professional, Scientific, and Technical Services	6.2
Other Services (except Public Administration)	5.2
Transportation and Warehousing	4.8
Public Administration	4.3

Figure 2.1 Map of the study area, which extends from Mobile, AL, to Houston/Galveston, TX. (Source: U.S. Census Bureau; ESRI, Inc.; National Transportation Safety Bureau)

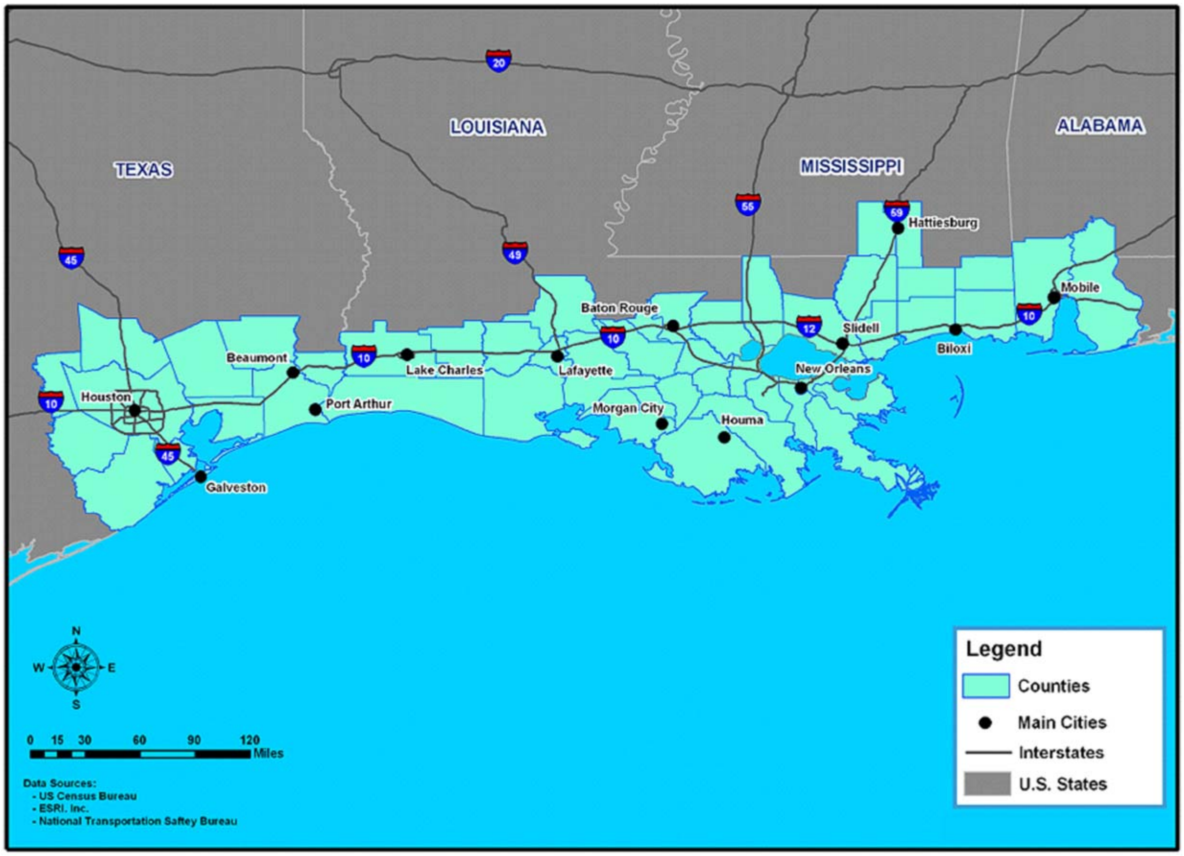


Figure 2.2 Study area counties and Federal Information Processing Standard (FIPS) codes. (Source: U.S. Census Bureau; ESRI, Inc.; National Transportation Safety Bureau)

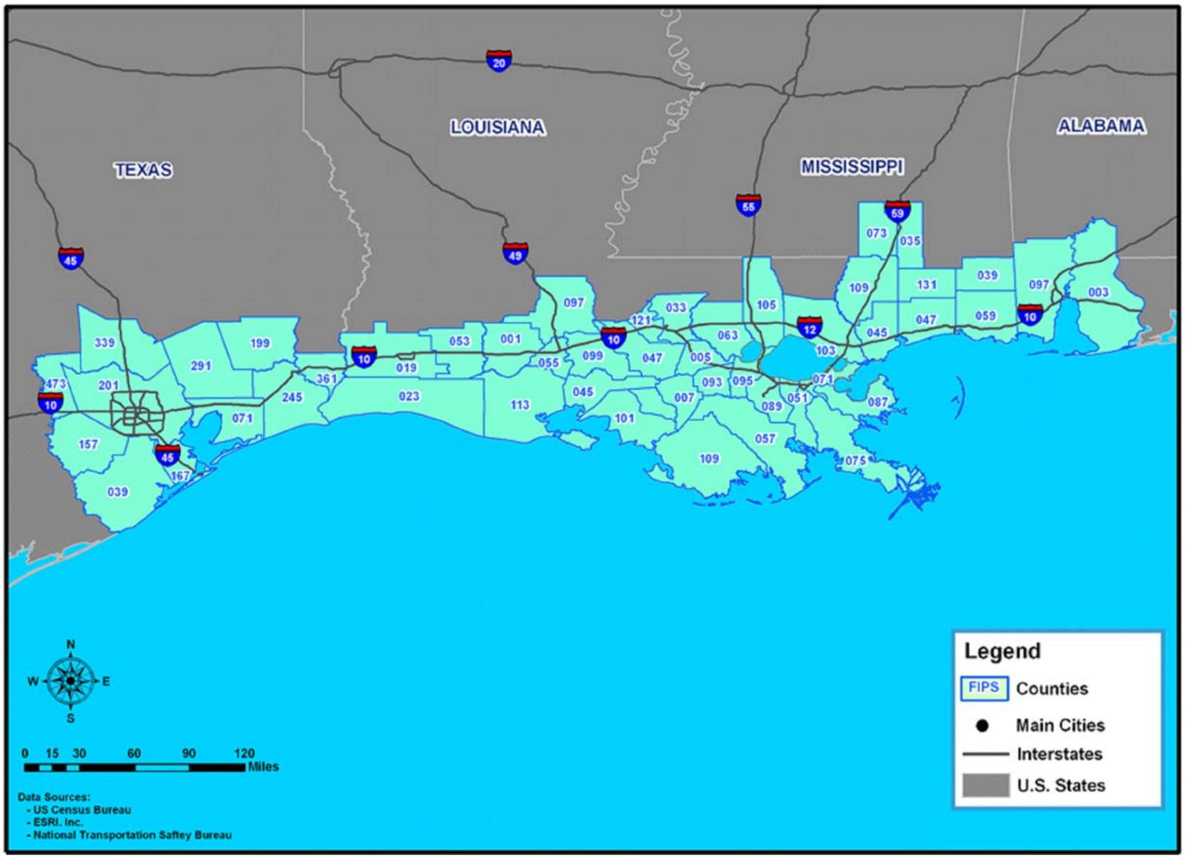


Figure 2.3 Metropolitan planning organizations (MPO) in the study area. (Source: U.S. Census Bureau; ESRI, Inc.; National Transportation Safety Bureau)

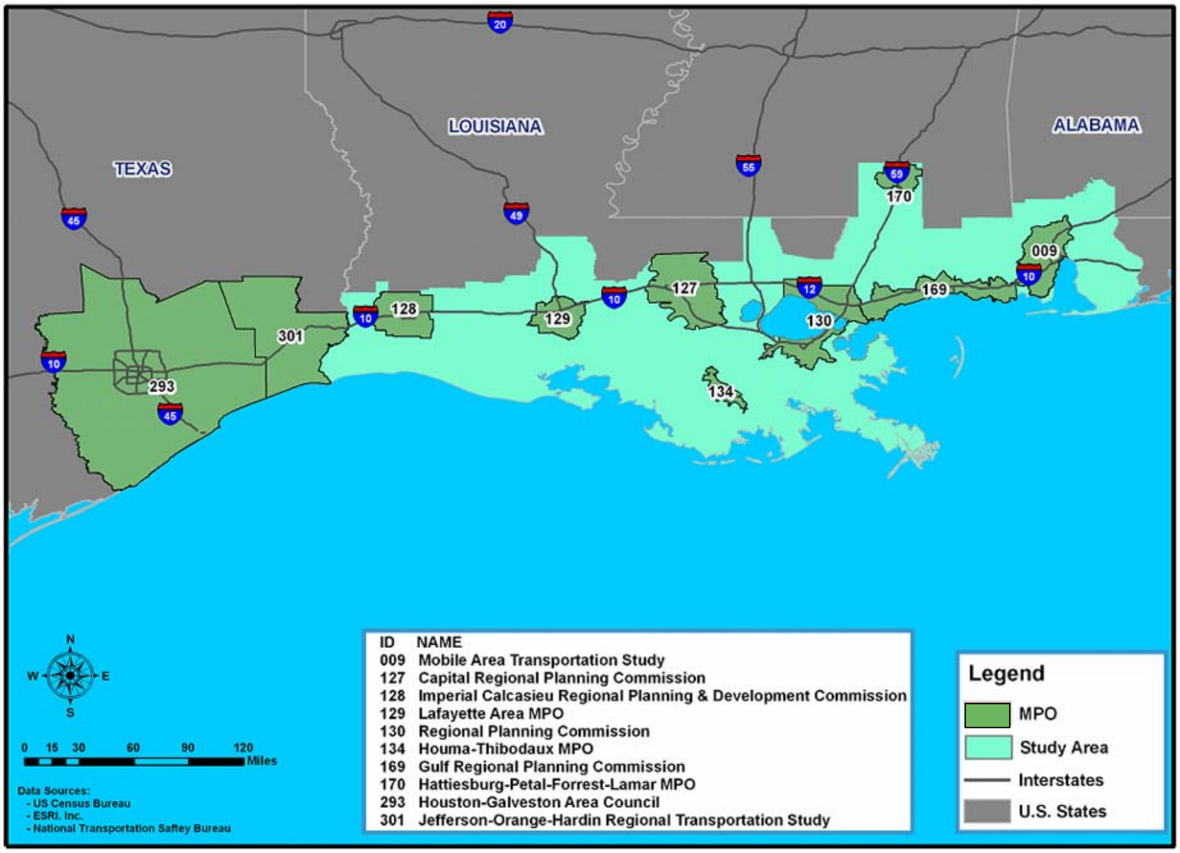


Figure 2.4 Combined truck flows shipped domestically from Louisiana, 1998. (Source: U.S. Department of Transportation Federal Highway Administration, Freight Management and Operations, Office of Operations)

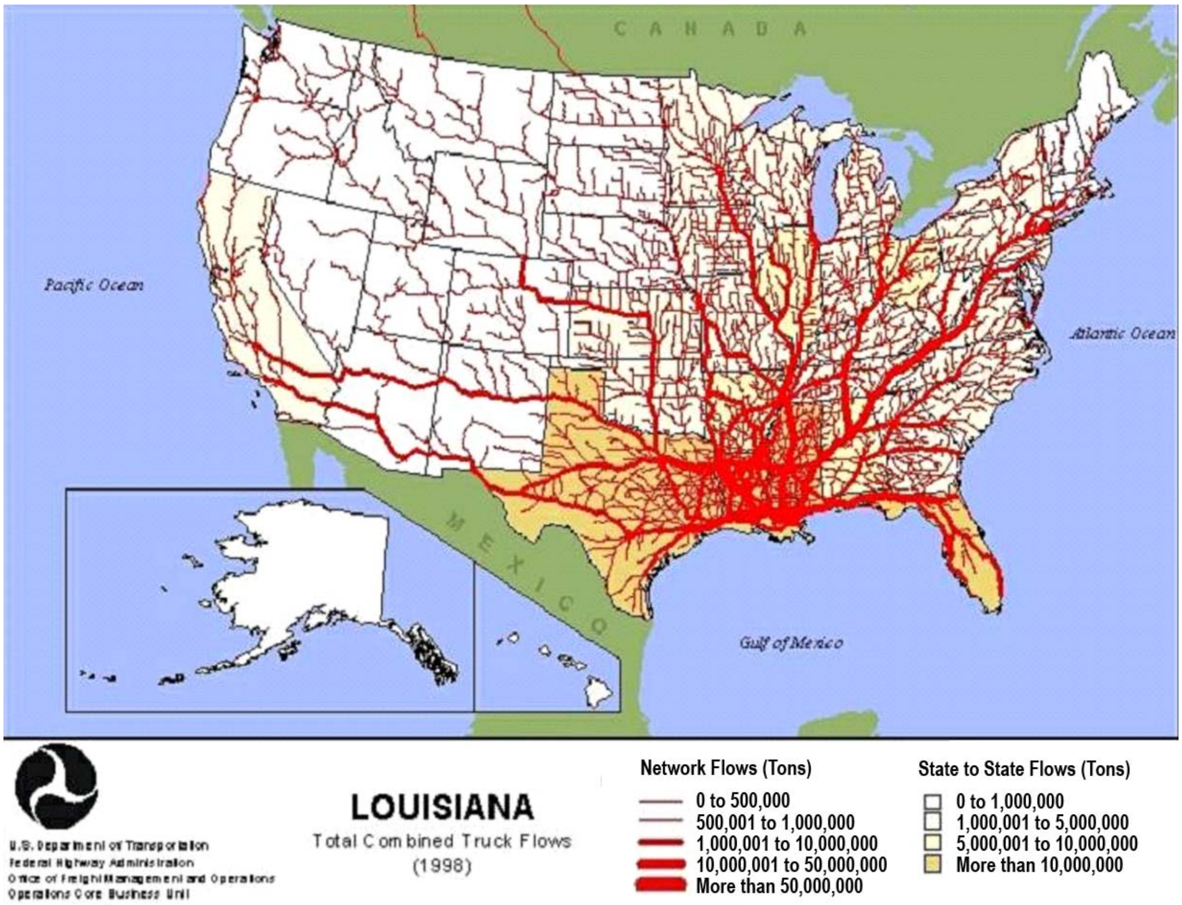


Figure 2.5 Navigable inland waterways impacting the study area, shown as named waterways. (Source: U.S. Department of Transportation)

Figure 2.6 National network of Class I railroads. (Source: Federal Railroad Administration Office of Policy, U.S. Department of Transportation)

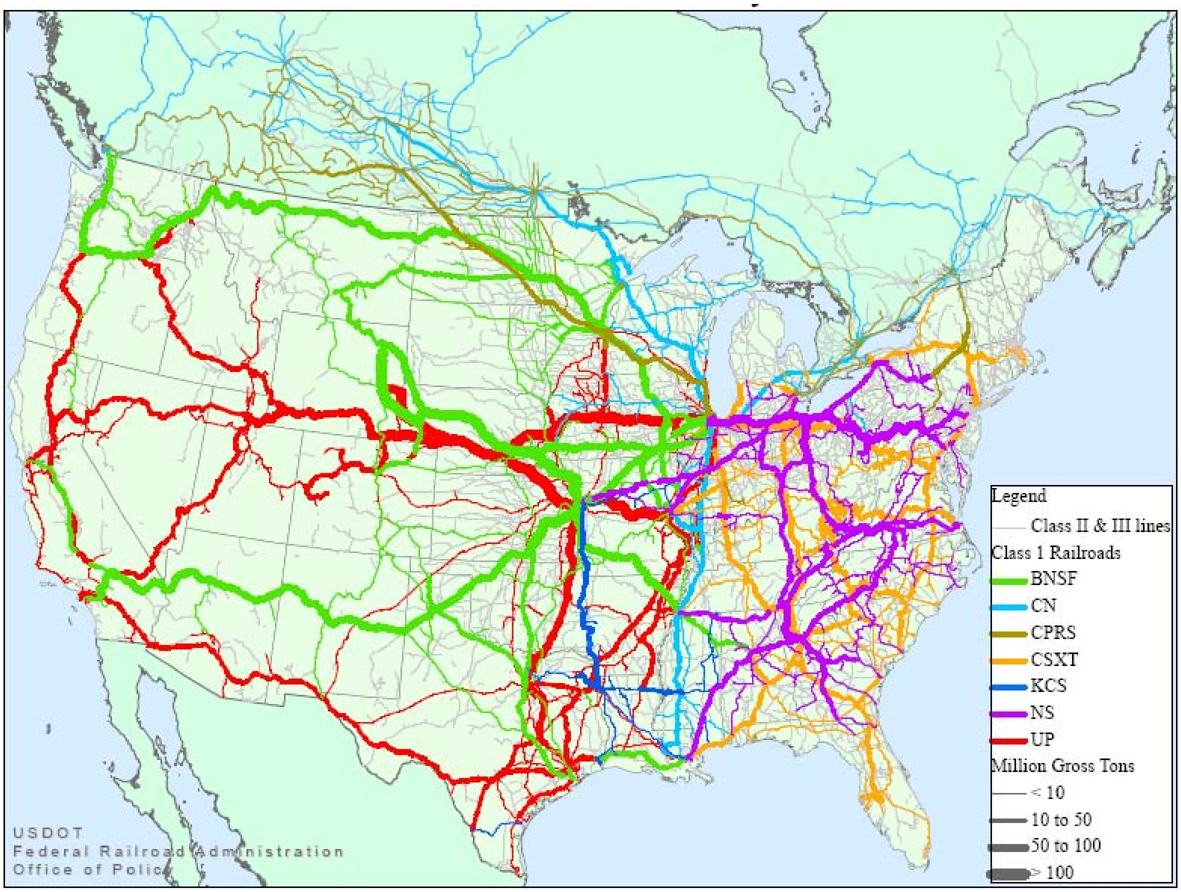


Figure 2.7 Intermodal facilities in the study area. (Source: Bureau of Transportation Statistics, U.S. Department of Transportation)

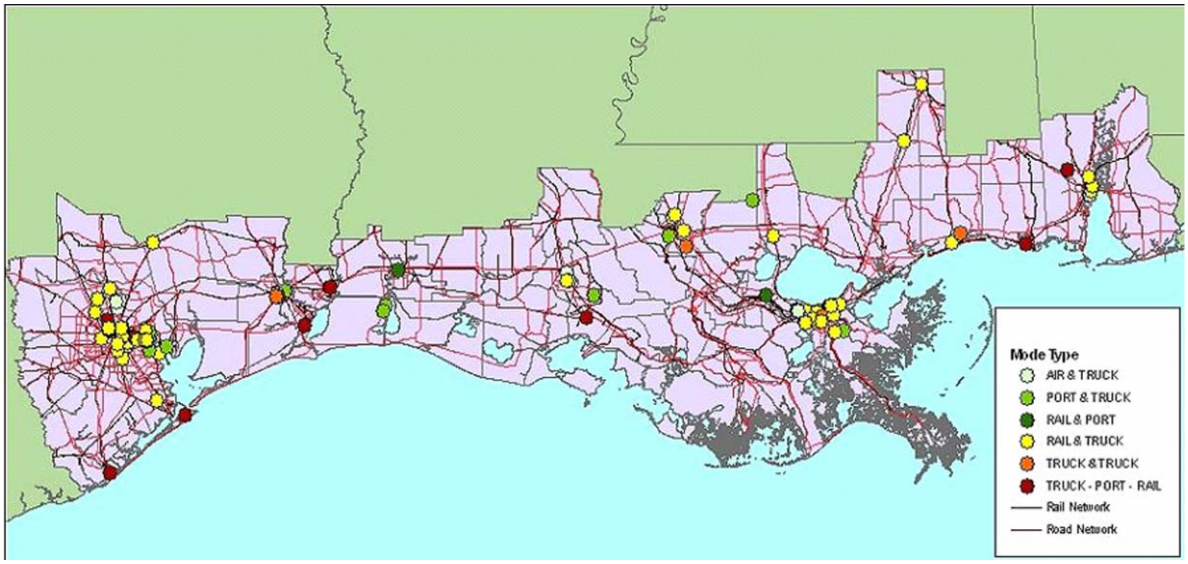


Figure 2.8 Highways in the study area. (Source: Cambridge Systematics analysis of U.S. Department of Transportation data)

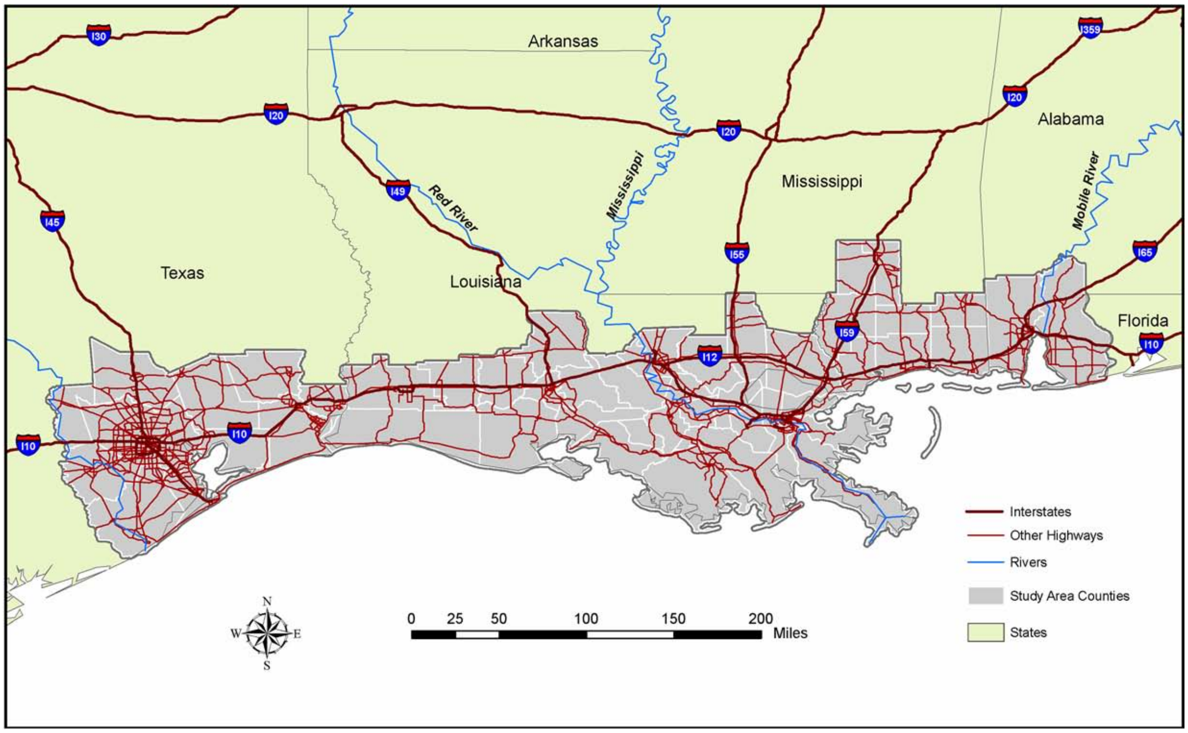


Figure 2.9 Total and truck annual vehicle miles of travel (VMT) on nonlocal roads, 2003. (Source: Cambridge Systematics, from 2004 Highway Performance Monitoring System database for Gulf Coast study supplied by the Bureau of Transportation Statistics, U.S. Department of Transportation)

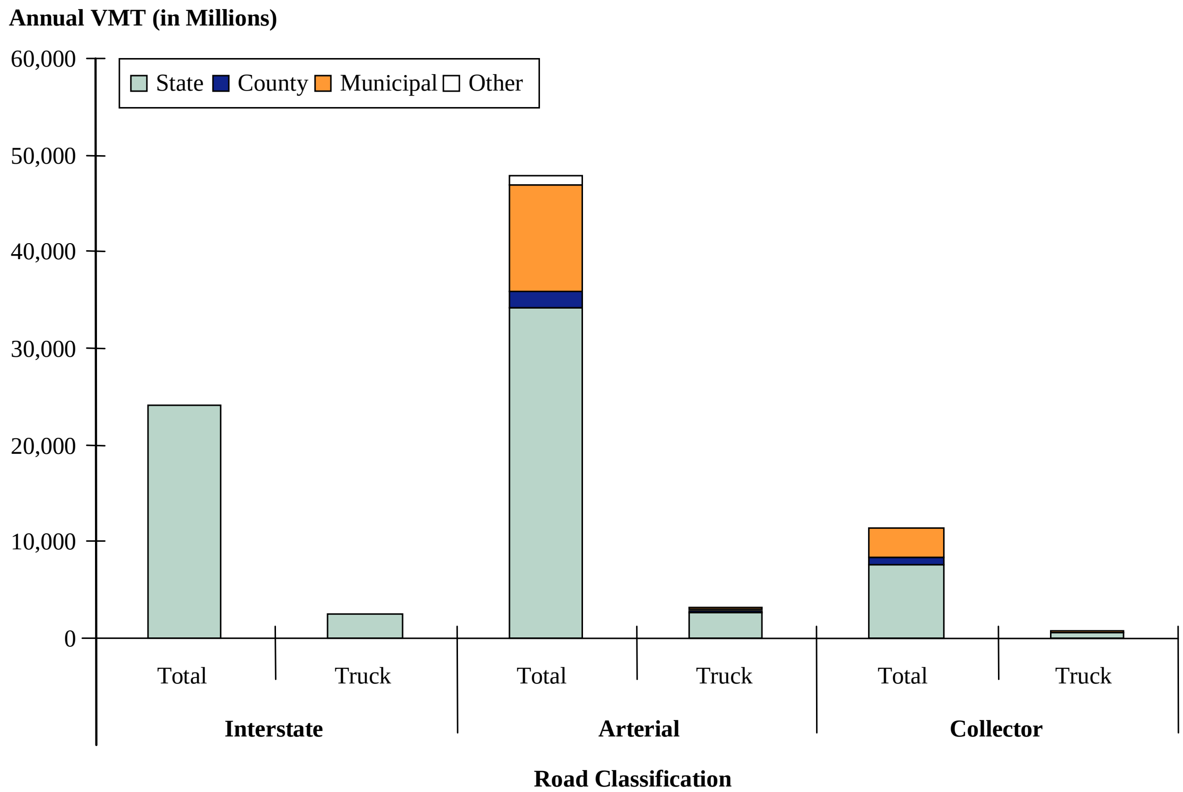


Figure 2.10 Nonlocal bridges in the study area (National Bridge Inventory [NBI] latitude and longitude location). (Source: Cambridge Systematics analysis of U.S. Department of Transportation data)

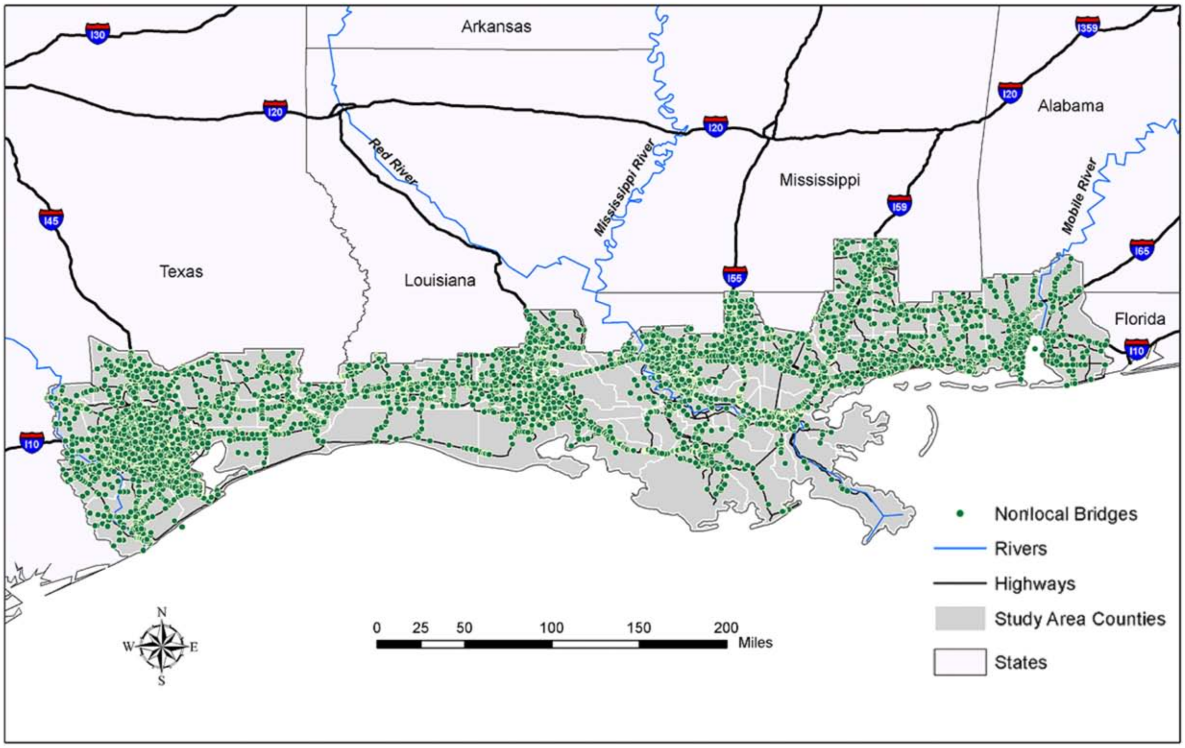


Figure 2.11 Freight railroad traffic density (annual millions of gross ton-miles per mile) in the study area. (Source: Bureau of Transportation Statistics, U.S. Department of Transportation)

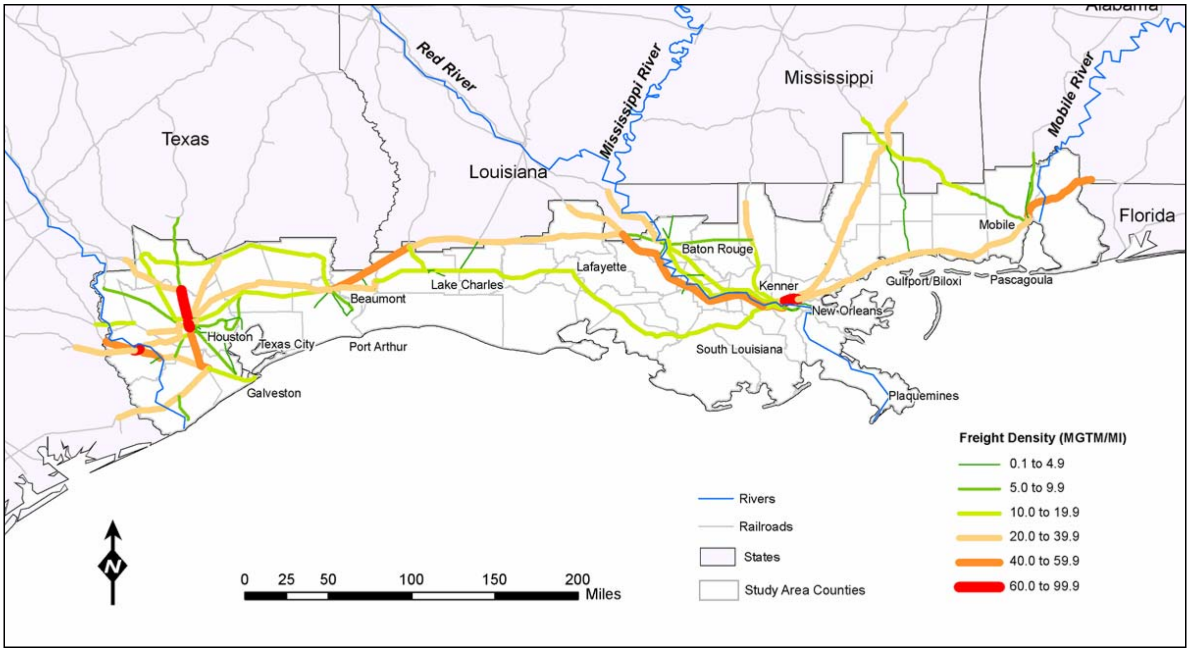


Figure 2.12 Sunset Limited route map, Houston, TX, to Mobile, AL, segment. (Source: Amtrak)

Figure 2.13 Freight handling ports and waterways in the study area. (Source: Cambridge Systematics analysis of U.S. Army Corps of Engineers data)

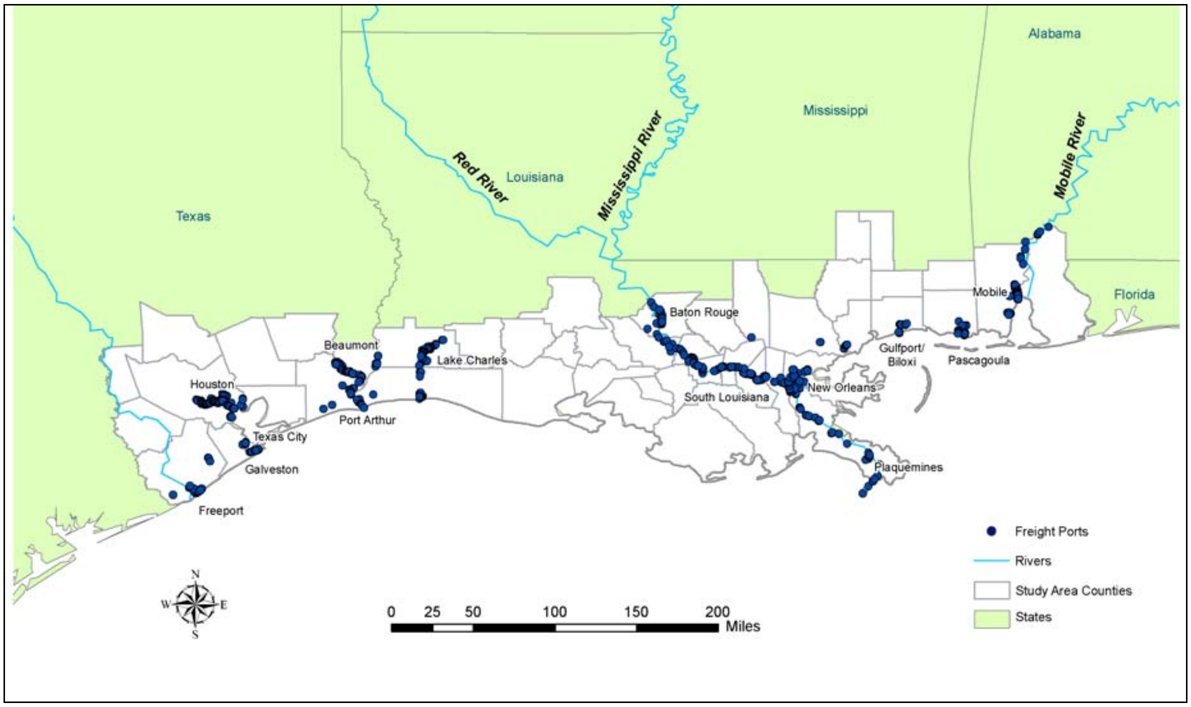
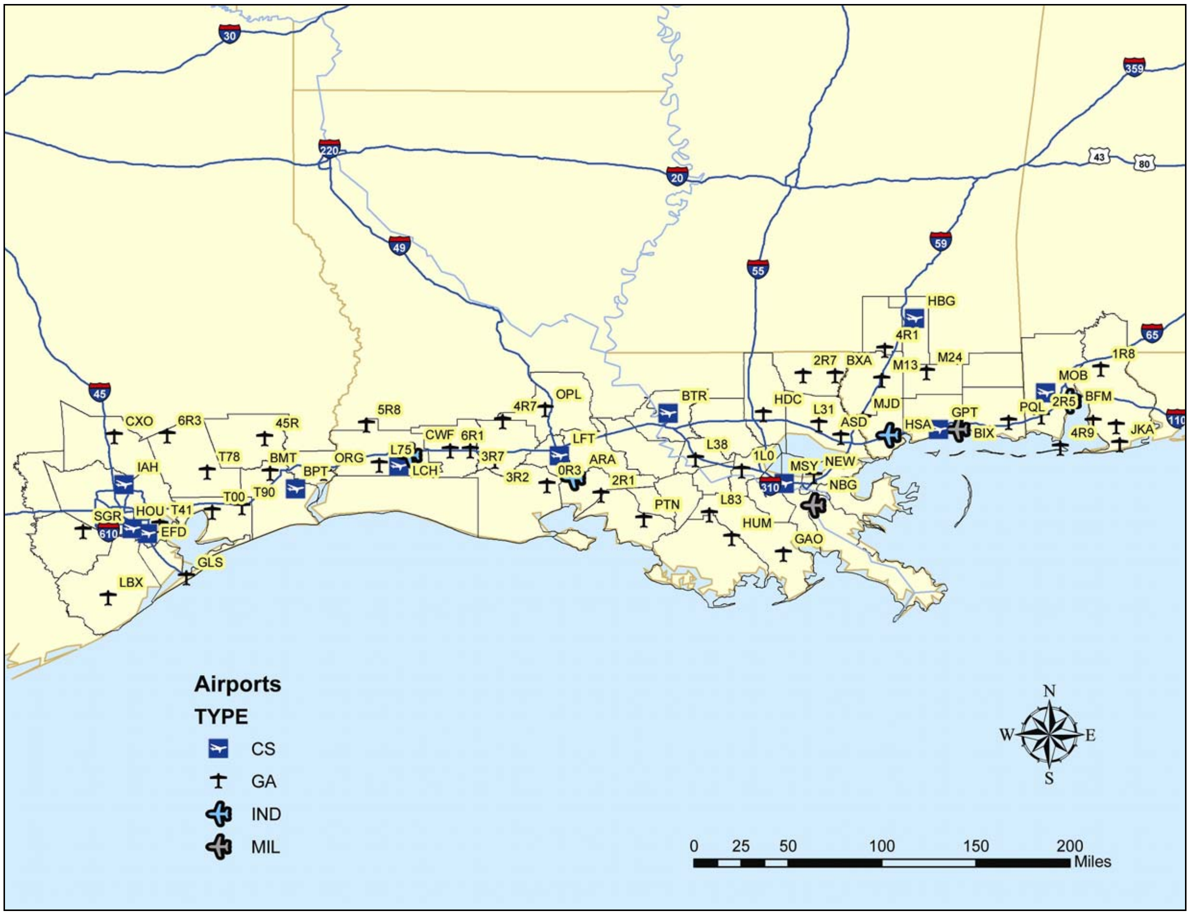


Figure 2.14 Barge tow on the Mississippi River.
(Source: U.S. Army Corps of Engineers)

•

Figure 2.15 Study area airports. (Source: Bureau of Transportation Statistics, U.S. Department of Transportation)



Note: CS: Commercial Service
GA: General Aviation
IND: Industrial
MIL: Military

Figure 2.16 Surface geology of the southeastern United States. White line denotes inland extent of the Gulf Coastal Plain, and grey area is Holocene alluvium. (Source: U.S. Geological Survey, 2000a)

Figure 2.17 Relative elevation of counties in the study area (delineated in blue). All areas shown in bright orange are below 30–m elevation. (Source: U.S. Geological Survey)

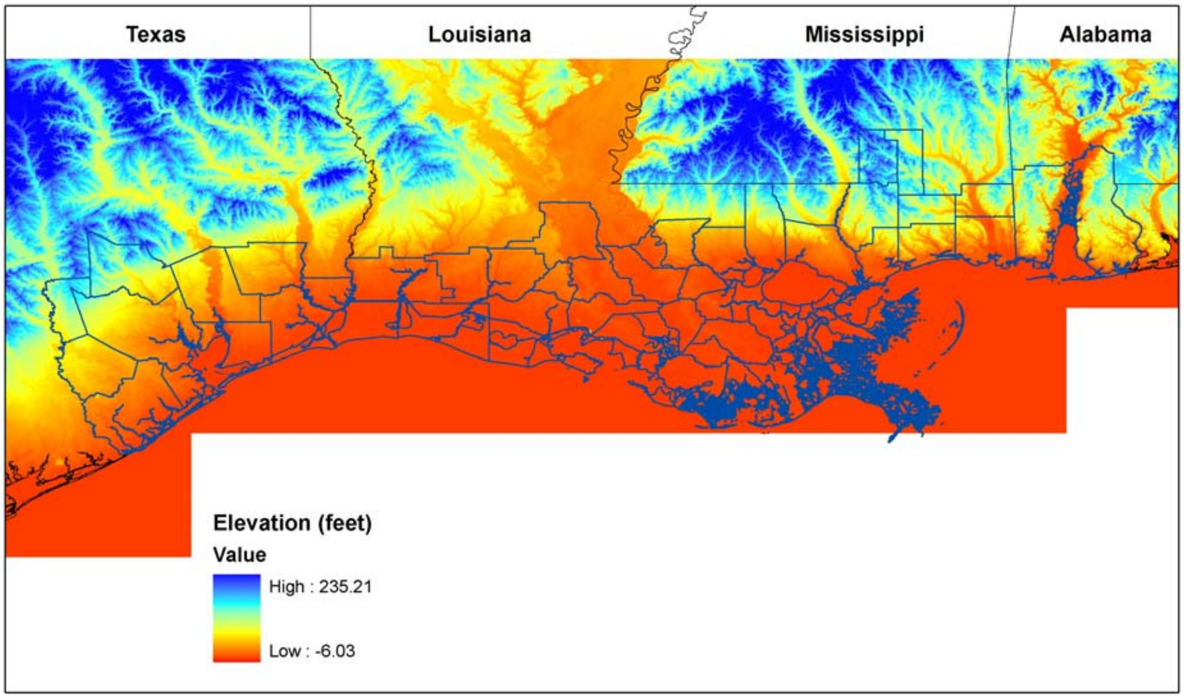


Figure 2.18 Map of terrestrial ecoregions within and adjacent to the study area. (Modified from Bailey, 1975)

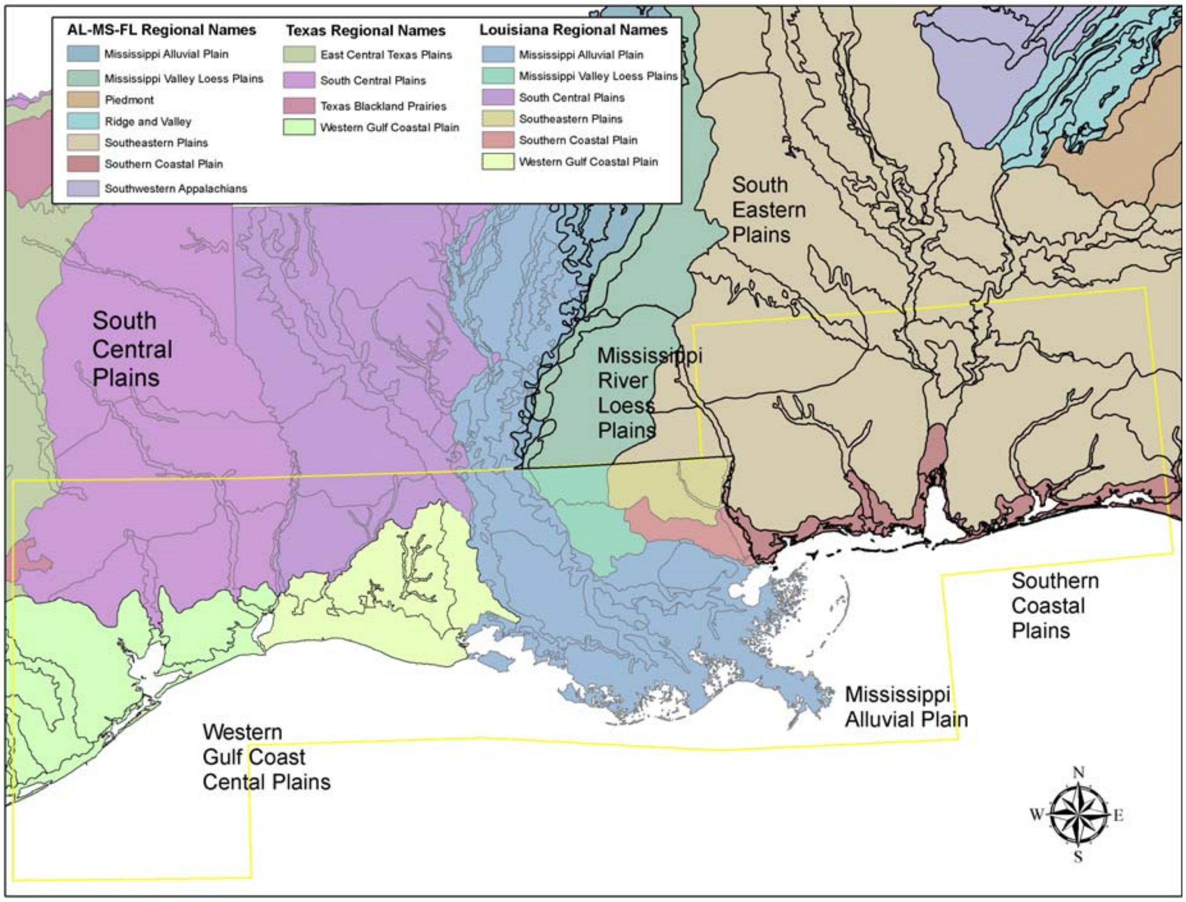


Figure 2.19 U.S. Census Bureau Metropolitan Statistical Areas within the study area. (Source: U.S. Census Bureau; ESRI, Inc.; National Transportation Safety Bureau)

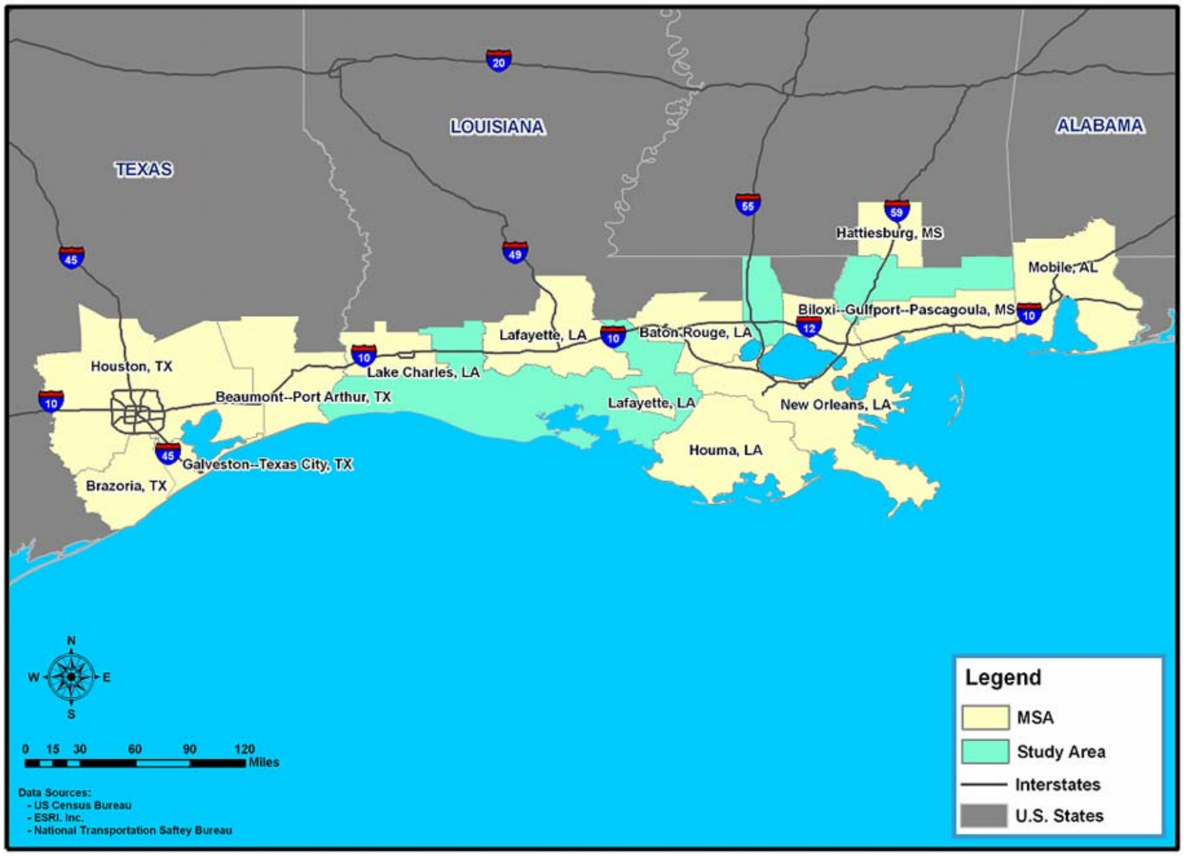


Figure 2.20 Population density in the study area, 2004. (Source: U.S. Census Bureau; ESRI, Inc.; National Transportation Safety Bureau)

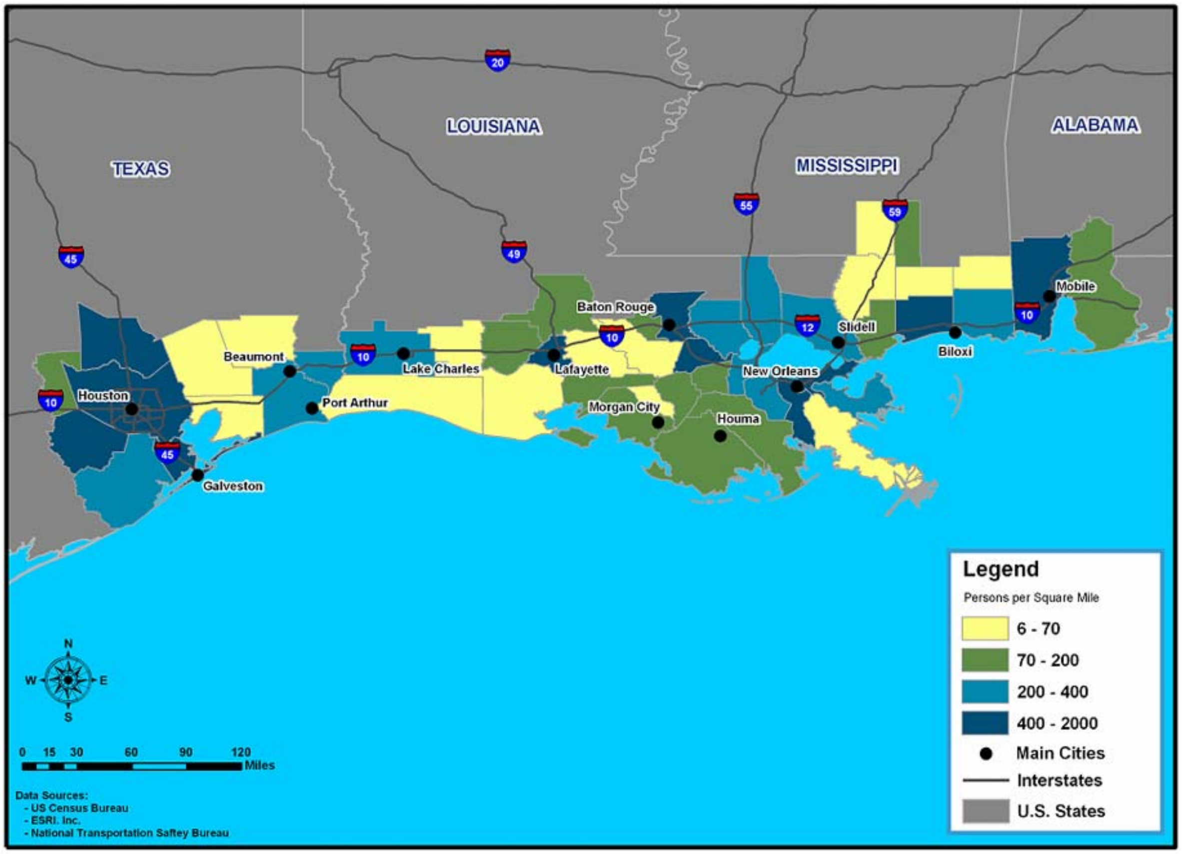


Figure 2.21 Estimated population change in the study area, 2000 to 2005. (Source: U.S. Census Bureau; ESRI, Inc.: National Transportation Safety Bureau)

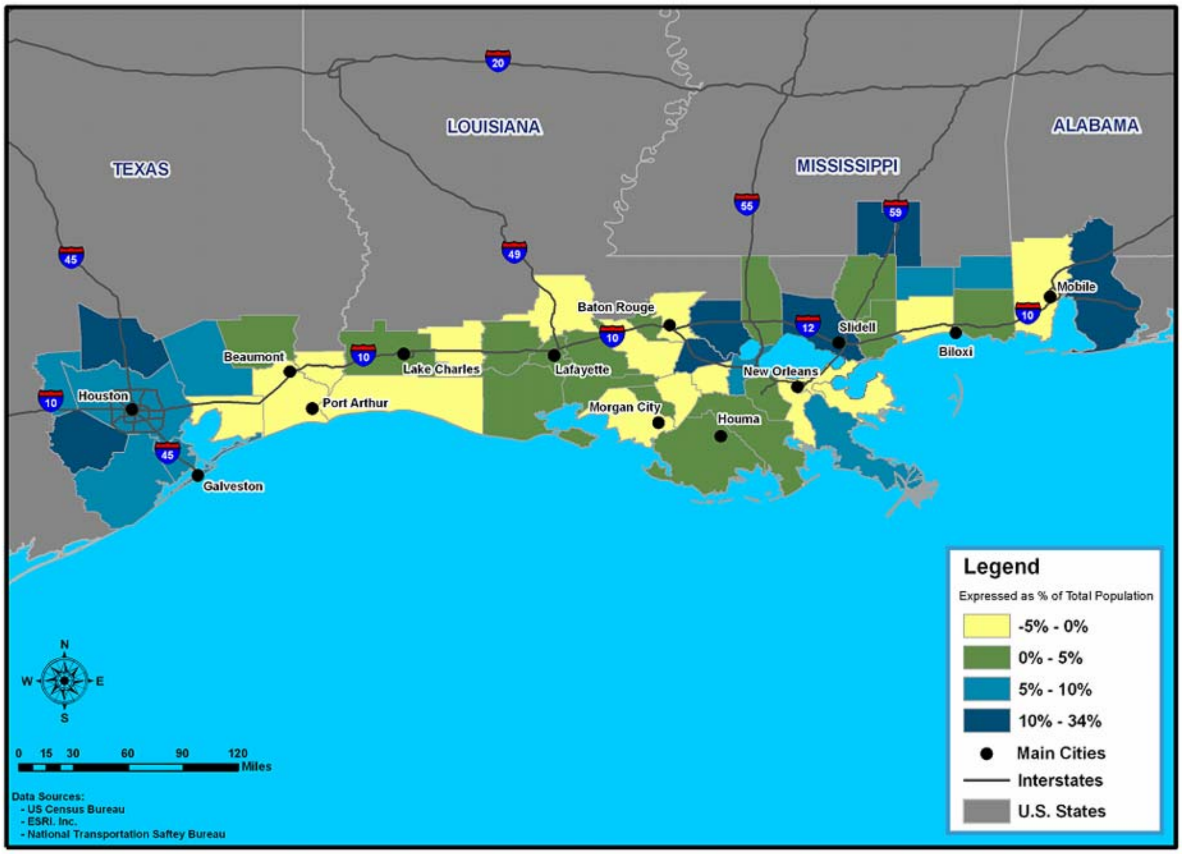


Figure 2.22 Mean travel time to work in the study area. (Source: U.S. Census Bureau; ESRI, Inc.; National Transportation Safety Bureau)

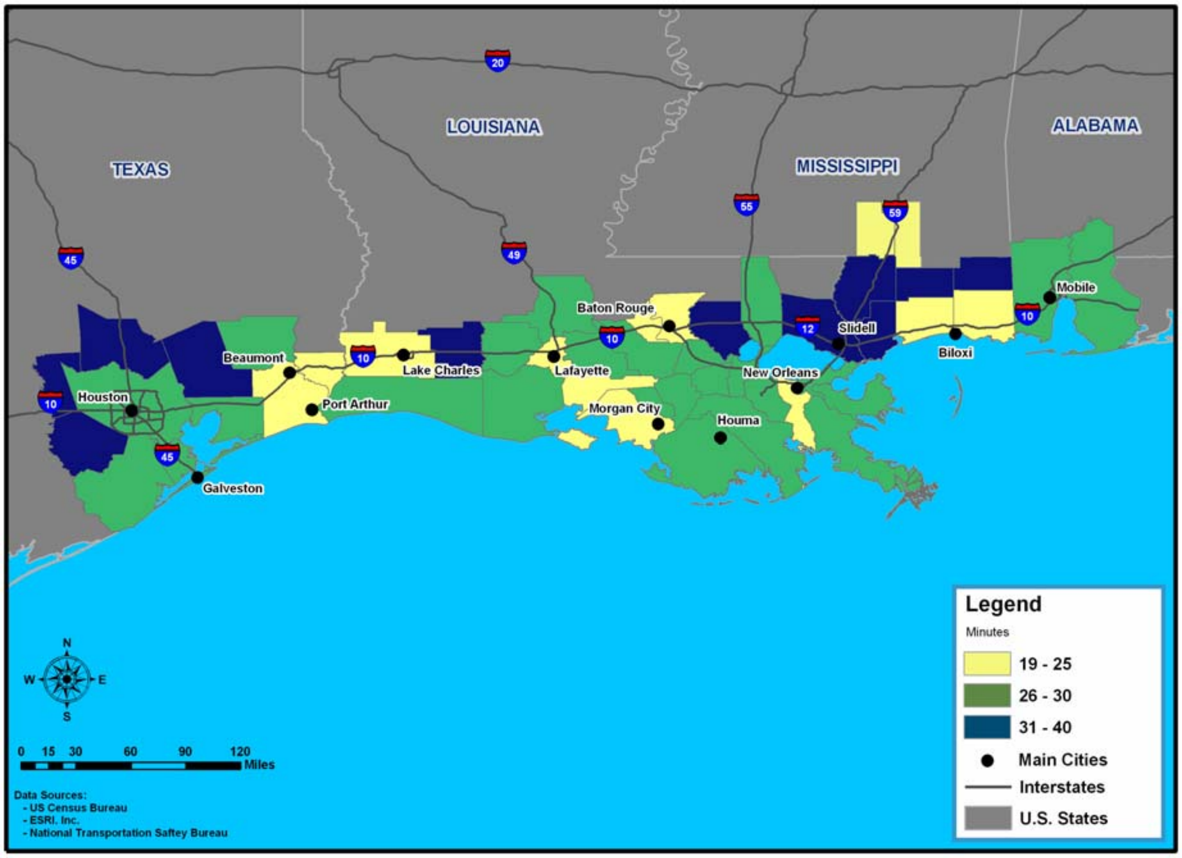


Figure 2.23 Manufacturers' shipments in thousands of dollars, 1997. (Source: U.S. Census Bureau; ESRI, Inc.; National Transportation Safety Bureau)

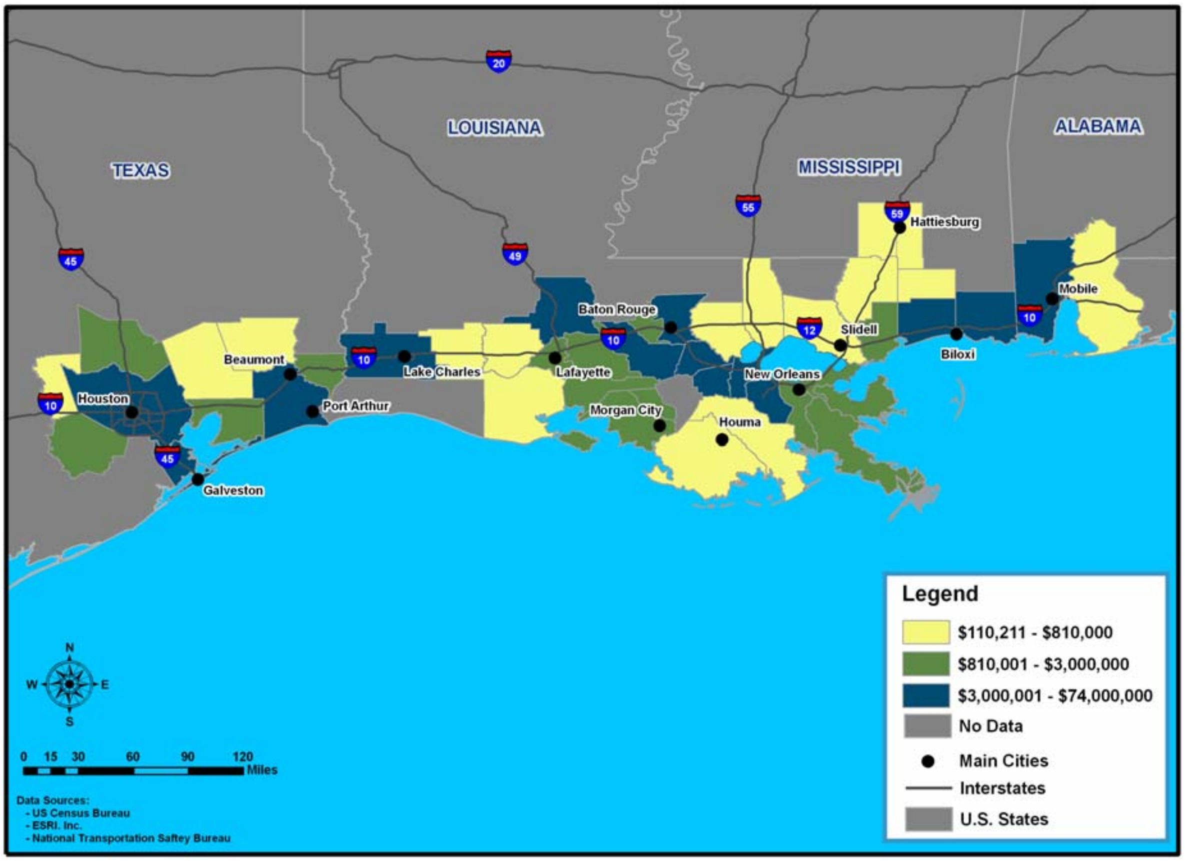


Figure 2.24 Social vulnerability index for the study area. (Source: U.S. Census Bureau; ESRI, Inc.; National Transportation Safety Bureau)

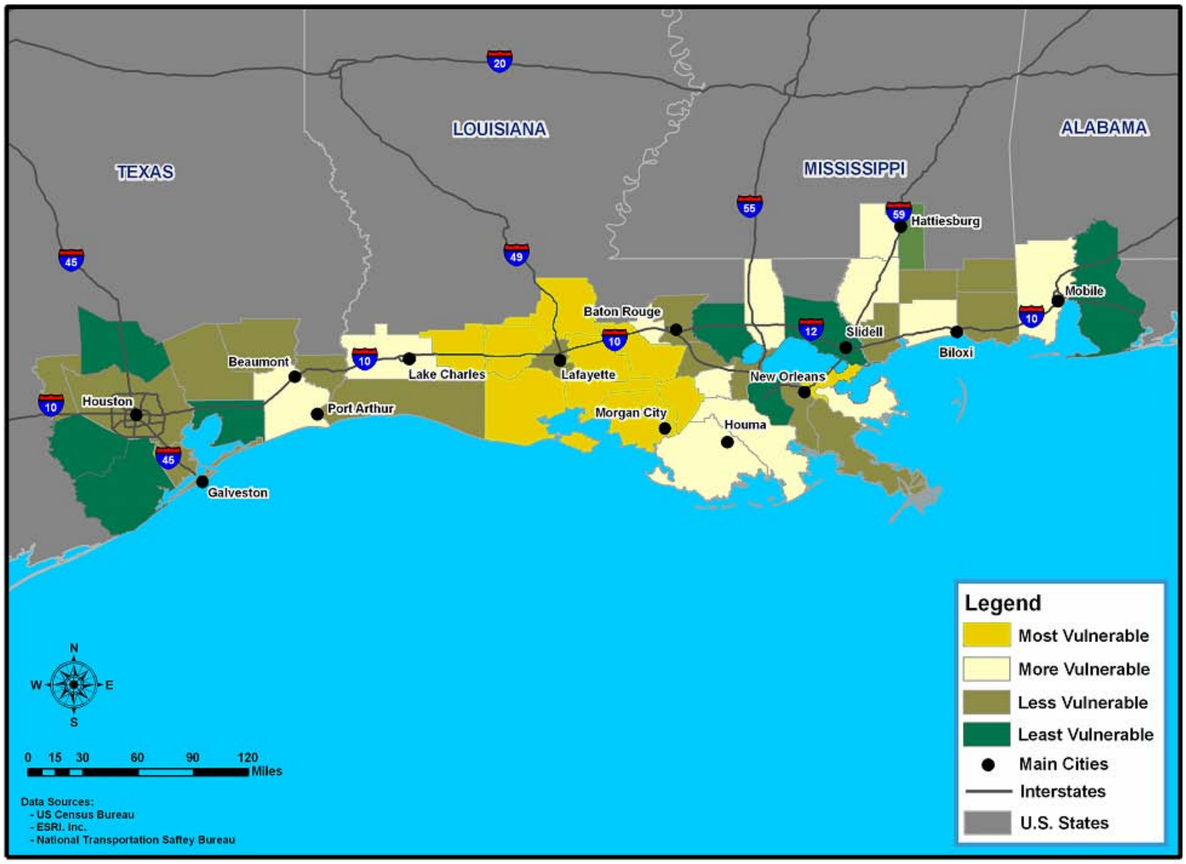


Figure 2.25 Persons in poverty in the study area. (Source: U.S. Census Bureau; ESRI, Inc.; National Transportation Safety Bureau)

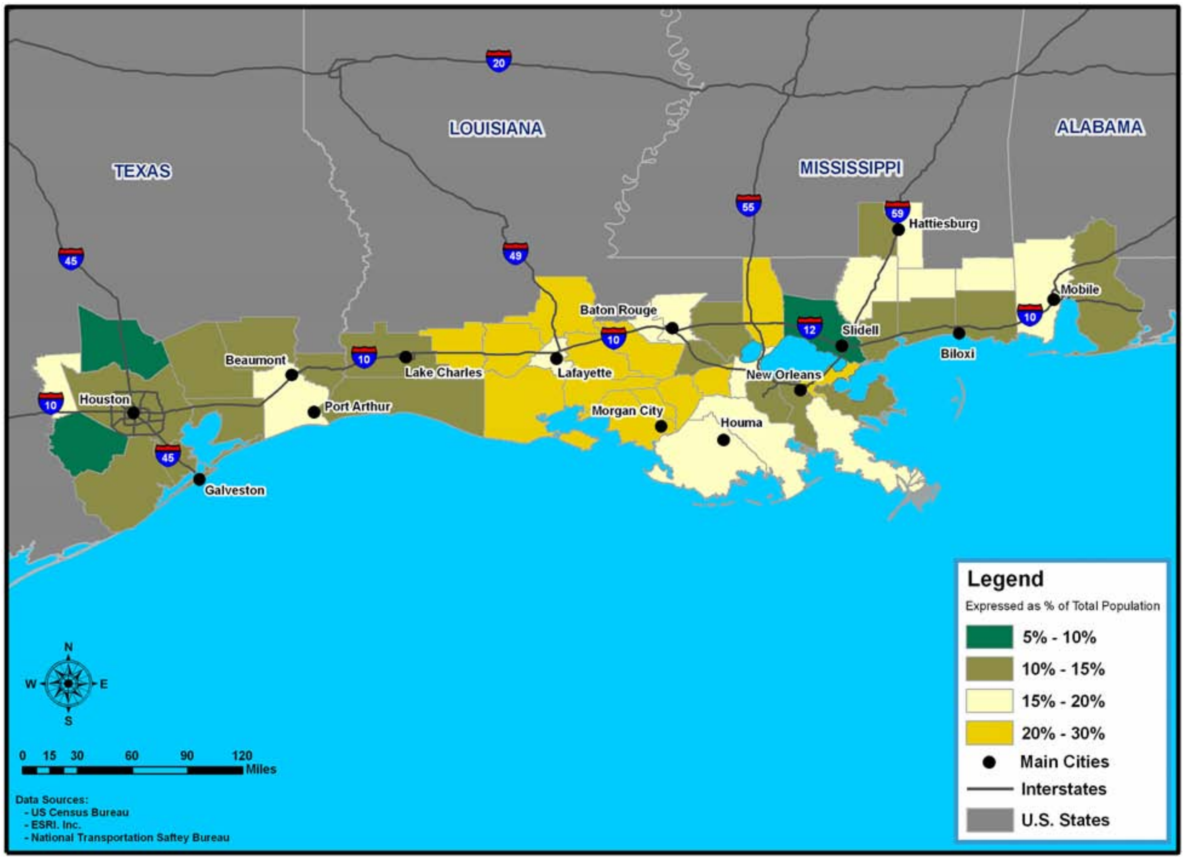


Figure 2.26 Persons aged 65 and older in the study area. (Source: U.S. Census Bureau; ESRI, Inc.; National Transportation Safety Bureau)