Geologic Resources Inventory Scoping Summary
Jean Lafitte National Historical Park, Louisiana

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The Geologic Resources Inventory (GRI) Program provides each of the 270 identified natural area National Park System units with a geologic scoping meeting, a digital geologic map, and a geologic resources inventory report. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity to discuss park-specific geologic management issues and, if possible, include a site visit with local experts. The purpose of these meetings is to identify geologic mapping coverage and needs, distinctive geologic features and processes, resource management issues, and potential monitoring and research needs. Outcomes of this scoping process are a scoping summary (this report), a digital geologic map, and a geologic resources inventory report.

The National Park Service held a GRI scoping meeting for Jean Lafitte National Historical Park and Preserve on April 15, 2010, at the French Quarter headquarters building on Decatur Street in New Orleans, Louisiana. Participants at the meeting included NPS staff from the park, Geologic Resources Division, Gulf Coast Network, and Southeast Regional Office, as well as cooperators from the Louisiana Geological Survey and Colorado State University (see table 2). Superintendent Carol Clark welcomed the group and brought attention to the six units of Jean Lafitte National Historical Park and Preserve (fig. 1). During the meeting, Tim Connors (Geologic Resources Division) facilitated the group's assessment of map coverage and needs, and Lisa Norby (Geologic Resources Division) led the discussion of geologic features, processes, and issues. David Muth (Jean Lafitte National Historical Park and Preserve) described the natural and cultural resources in the park, and Richard McCulloh (Louisiana Geological Survey) presented a geologic overview of the park, which addressed the question: "How can you do geologic mapping in a swamp?" McCulloh pointed out that remote-sensing LIDAR (Light Detecting and Ranging) has been a real boon for mapping in coastal Louisiana (see McCulloh and Heinrich 2009). Using LIDAR imagery, geologists focus on changes in color hue corresponding to elevations as fine as 0.3 m (1 ft) above and below sea level; these variations in color and elevation correspond to particular geomorphic features of the delta plain. Features such as natural levees and crevasse splays, which exhibit depositional topography, are depicted on LIDAR imagery.

During the site visit, participants drove to the Barataria Preserve and discussed impacts of Hurricane Katrina en route. Once at the preserve, David Muth led participants along the Bayou Coquille Trail and highlighted the natural levee of the Mississippi River, middens, subsidence as it affects development of wetland species such as bald cypress, legacy logging operations, floating marshes (called "flotant"), and canals and spoil banks from oil and gas activities. Dusty Pate (Jean Lafitte National Historical Park and Preserve) assisted by Kelly Altenhofen (Jean Lafitte National Historical Park and Preserve) guided participants via airboat on a tour that highlighted restoration of canals, post-restoration marsh succession, shoreline stabilization along Lake Salvador and Chenier Grand Coquille, and Bayou Boeuf (a natural, meandering channel).

This scoping summary highlights the GRI scoping meeting for Jean Lafitte National Historical Park and Preserve and includes the park setting, the plan for providing a digital geologic map, descriptions of geologic features and processes and related resource management issues, and a record of meeting participants (table 2). This document and the completed digital geologic map (see "Geologic Mapping for Jean Lafitte National Historical Park and Preserve") will be used to prepare the final GRI report.

Park Setting

National historical parks combine history with associated natural features. In short, they preserve history "in place." "Jean Lafitte"—both the historic figure and legends that surround him—is a fitting name for this park that spreads across southern Louisiana. Jean Lafitte was the most celebrated pirate of the Mississippi River delta "where the marsh's mazes could swallow up men and ships with the ease of a fog bank" (Hallowell 2001, p. 68). Once upon a time, Jean Lafitte navigated the swamps of the Barataria Preserve, roamed the streets of New Orleans' French Quarter, and helped the Americans win the Battle of New Orleans at Chalmette Battlefield. Stories also connect Lafitte to the three Acadian sites (National Park Service 2010b). The Prairie Acadian Cultural Center in Eunice, the Acadian Cultural Center in Lafayette, and the Wetlands Acadian Cultural Center in Thibodaux interpret Cajun culture and history. Expelled from British controlled Nova Scotia in 1755, the French Acadians were transformed into Cajuns as they adapted to the culture and environment of Louisiana.

Together, the six sites of Jean Lafitte National Historical Park tell the story of the Mississippi River delta and its culture. As stated in the park brochure, "It is a world shaped by a dynamic, centuries-old relationship between humans and a still-evolving land. Here a succession of peoples has both altered and adapted to the environment as they interacted with other cultures—changing and being changed." Barataria Preserve, south of New Orleans, protects 9,300 ha (23,000 ac) of natural-levee forests, bald cypress swamp, and floating marsh. Chalmette, east of New Orleans, was the scene of the 1815 Battle of New Orleans. The French Quarter unit interprets the ethnic population of the region and the origins of jazz in the city widely recognized as its birthplace.

Figure 1. Southern Louisiana. Labeled in green on the figure are the six sites of Jean Lafitte National Historical Park and Preserve. The park interprets diverse cultures and delta environments.

Distinguishing subtle changes in the landscape is necessary for comprehending the geology of Jean Lafitte National Historical Park and Preserve. As David Muth pointed out during the site visit, "You can tell you're going downhill because the vegetation changes." Unlike the geology more familiar to scoping participants from Colorado and Utah, geology does not often draw attention to itself at Jean Lafitte. Small changes in elevation equate to distinct depositional environments and habitats (e.g., palmetto grows at higher elevations; water tupelo and bald cypress grow at lower elevations). Although the landforms may be vertically challenged, their lateral extent and the processes that formed them are anything but subtle. In particular, the Mississippi River delta plain, of which Jean Lafitte is a part, is a massive wedge of Holocene alluvial and deltaic sediment extending for almost 320 km (515 mi) along the coast of Louisiana and over 100 km (160 mi) inland (Pearson and Davis 1995). The various delta lobes represent major shifts in the course of the Mississippi River during the Holocene. The Prairie Acadian Cultural Center in Eunice and the Acadian Cultural Center in Lafayette are situated on Pleistocene river terraces and loess (windblown silt), which are older than the Mississippi River delta complex (Heinrich and Autin 2000; Snead et al. 2002; Heinrich et al. 2003).

Geologic Mapping for Jean Lafitte National Historical Park and Preserve

During scoping, Tim Connors (Geologic Resources Division) showed some of the main features of the GRI Program's digital geologic maps, which reproduce all aspects of paper maps, including notes, legend, and cross sections, with the added benefit of being GIS compatible. The NPS GRI Geology-GIS Geodatabase Data Model incorporates the standards of digital map creation for the GRI Program and allows for rigorous quality control. Staff members digitize maps or convert digital data to the GRI digital geologic map model using ESRI ArcGIS software. Final digital geologic map products include data in geodatabase and shapefile format, layer files complete with feature symbology, Federal Geographic Data Committee (FGDC)–compliant metadata, an Adobe Acrobat help file that captures ancillary map data, and a map document that displays the map and provides a tool to directly access the help file. Final products are posted at http://science.nature.nps.gov/nrdata/ (August 4, 2010). The data model is available at http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm (accessed August 4, 2010).

The process of selecting maps for management begins with the identification of existing geologic maps in the vicinity of the National Park System unit. During the scoping meeting, participants discuss mapping needs and select appropriate source maps for the digital geologic data or, if necessary, develop a plan to obtain new mapping. Maps can show bedrock or surficial geology, or a combination of the two. Surficial geology dominates in southern Louisiana, so the final digital geologic map for the park will incorporate Holocene deltaic deposits (see "Deltaic Features and Processes" section) and Pleistocene fluvial terraces and loess deposits in Eunice and Lafayette.

In the lower 48 states, large-scale mapping is usually defined as "one inch to 2,000 feet" or quadrangles produced at a scale of 1:24,000 on a 7.5' × 7.5' base. There are thirty-two 7.5' quadrangles on a 30' × 60' (scale 1:100,000) sheet. When possible, the GRI Program provides large-scale (1:24,000) digital geologic map coverage for each unit's area of interest, which is generally composed of the 7.5' quadrangles that contain NPS-managed lands. Maps of this scale (and larger) are useful to resource managers because they capture most geologic features of interest and are spatially accurate within 12 m (40 ft). Jean Lafitte National Historical Park and Preserve has thirty 7.5' quadrangles of interest related to the six units of the park (table 1; figs. 2 and 3). The Louisiana Geological Survey has published 30' × 60' (scale 1:100,000) mapping for many of these quadrangles. The Gulfport, Ponchatoula, Baton Rouge, Crowley, and Ville Platte 30' × 60' sheets are available as published PDFs at http://www.lgs.lsu.edu/deploy/content/PUBLI/contentpage17.php (accessed May 25, 2010). Additionally, the New Orleans 30' × 60' sheet is scheduled for draft compilation in summer 2010 in fulfillment of a STATEMAP cooperative agreement between the U.S. Geological Survey and the Louisiana Geological Survey. As of August 25, 2010, the New Orleans 30' × 60' was not available publically (i.e., via the LGS website). However, discussions with Hampton Peele at the Louisiana Geological Survey revealed that although the digital product is still "in progress," the survey is willing to share these data with park staff as a preliminary map. Dusty Pate (Jean Lafitte National Historical Park and Preserve) can contact Hampton Peele (Louisiana Geological Survey) at the survey to discuss obtaining the data (Hampton Peele, Louisiana Geological Survey, e-mail communications to Tim Connors, Geologic Resources Division, August 6, 2010).

Completing the digital geologic map for Jean Lafitte National Historical Park and Preserve will involve extracting the individual 7.5' quadrangles from the compiled 30' × 60' sheets. To date, only the PDF files are available online and in the public domain. GRI staff would like to obtain these data as GIS files. Discussions between Tim Connors and Hampton Peele indicated that the survey hopes to release the digital GIS data sometime in summer 2010, but this could be delayed due to the Deepwater Horizon oil spill crisis and subsequent other higher priorities of the Louisiana Geological Survey (Hampton Peele, Louisiana Geological Survey, personal communication to Tim Connors, May 5, 2010).

Between the already published 30' × 60' sheets (i.e., Gulfport, Ponchatoula, Baton Rouge, Crowley, and Ville Platte) and completion of the New Orleans 30' × 60' sheet, the only data gaps at the time of scoping for the park's quadrangles of interest were part of the Black Bay 30' × 60' sheet, specifically the portion covering Chalmette Battlefield. Of note is that figure 1 in Heinrich (2005) covers this area. Furthermore, as of May, 26, 2010, Paul Heinrich (Louisiana Geological Survey) indicated that he had nearly completed draft geologic mapping of both the Black Bay and Mississippi River Delta 30' × 60' quadrangle sheets in ArcMap format (Rick McCulloh, Louisiana Geological Survey, written communication, May 28, 2010).

The "Saucier maps" (Saucier 1994) are another important source of data. These maps are serving as a placeholder for completed LGS mapping of the New Orleans and Black Bay 30' × 60' sheets. The U.S. Army Corps of Engineers published these maps and the accompanying text. The maps are smaller scale (1:250,000) but do give coverage for both the New Orleans and Black Bay sheets (fig. 4). Portions of these maps exist in a digital GIS format, and GRI staff has obtained shapefiles from David Thompson (Mississippi Department of Environmental Quality, Office of Geology).

Table 1. Map Coverage for Jean Lafitte National Historical Park and Preserve

Unit Name	Quadrangle of Interest (7.5' quadrangle)	30' × 60' Sheet	Reference/Source	Format
Prairie Acadian Cultural Center	Eunice North	Ville Platte (GMAP[1] 41780)	Snead et al. (2002)	PDF
	Eunice South	Crowley (GMAP 56242)	Heinrich et al. (2003)	PDF
Acadian Cultural Center	Broussard	Baton Rouge (GMAP 41781)	Heinrich and Autin (2000)	PDF
	Lafayette	Crowley	Heinrich et al. (2003)	PDF
Wetlands Acadian Cultural Center	Thibodaux	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
Chalmette Battlefield	Chalmette	Black Bay	Preliminary geologic mapping by Louisiana Geological Survey or Saucier (1994)	Portions of Saucier (1994) in GIS
French Quarter and Barataria Preserve	Indian Beach	Ponchatoula (GMAP 56243)	McCulloh et al. (2003)	PDF
	Spanish Fork	Ponchatoula	McCulloh et al. (2003)	PDF
	Little Woods	Gulfport (GMAP 68647)	Heinrich et al. (2004)	PDF
	Lac Des Allemands	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Hahnville	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Luling	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	New Orleans West	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	New Orleans East	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Martello Castle	Black Bay	Preliminary geologic mapping by Louisiana Geological Survey or Saucier (1994)	Portions of Saucier (1994) in GIS
	Bayou Boeuf	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Des Allemands	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Lake Cataouatche West	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Lake Cataouatche East	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Bertrandville	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Belle Chasse	Black Bay	Preliminary geologic mapping by Louisiana Geological Survey or Saucier (1994)	Portions of Saucier (1994) in GIS
	Delacroix	Black Bay	Preliminary geologic mapping by Louisiana Geological Survey or Saucier (1994)	Portions of Saucier (1994) in GIS
	Gheens	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Catahoula Bay	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Barataria	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Lafitte	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Phoenix	Black Bay	Preliminary geologic mapping by Louisiana Geological Survey or Saucier (1994)	Portions of Saucier (1994) in GIS
	Cut Off	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Bay L'Ours	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*
	Three Bayou Bay	New Orleans	Louisiana Geological Survey (summer 2010)	*In progress*

[1]GMAP numbers are identification codes for the GRI Program's database.

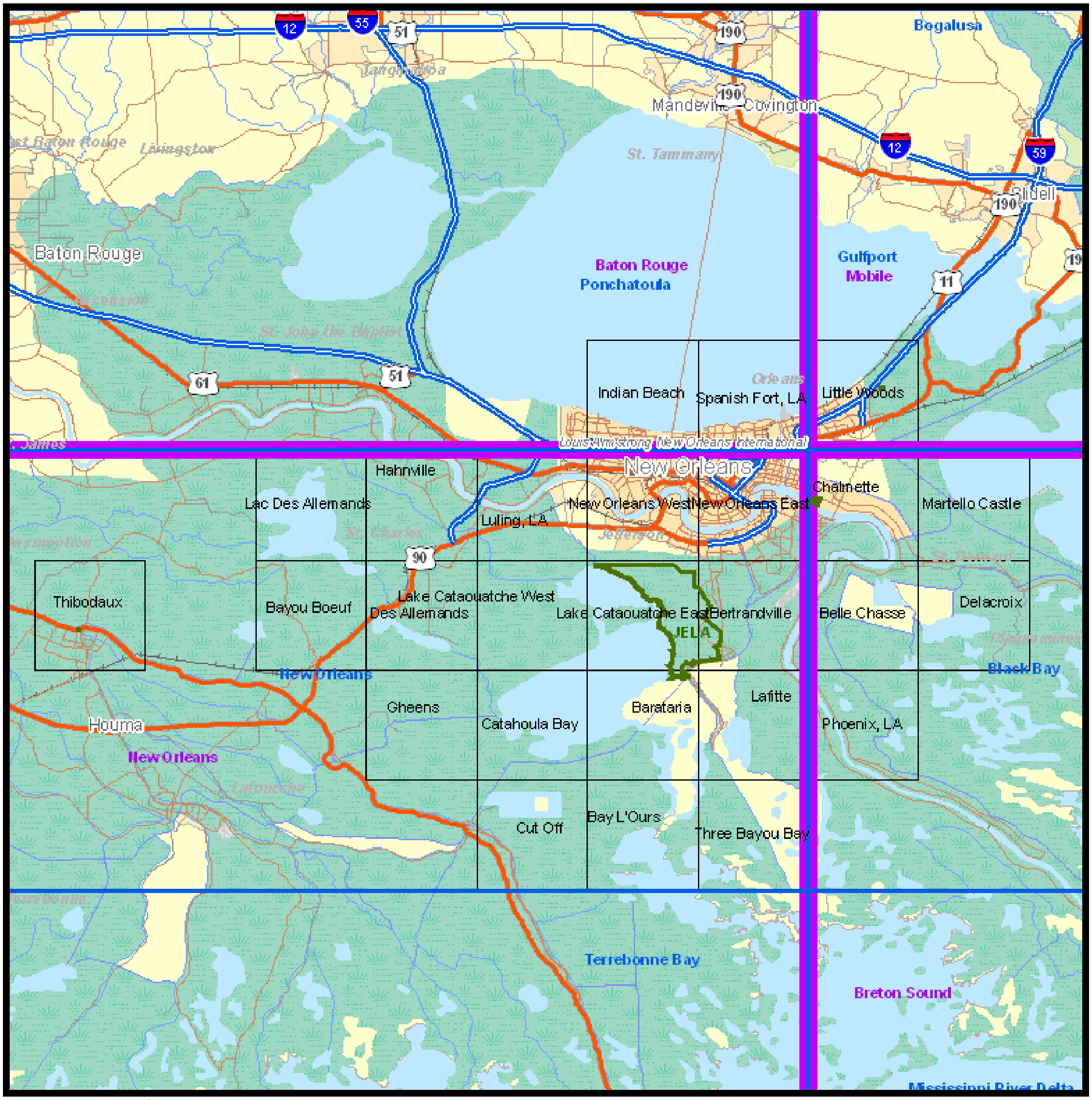

Figure 2. Jean Lafitte National Historical Park and Preserve (east). In the contiguous area around the Barataria Preserve and New Orleans, there are twenty-five 7.5' quadrangles of interest (scale 1:24,000). These quadrangles are outlined and labeled in black on the figure. Four 30' × 60' (scale 1:100,000) sheets—Ponchatoula, Gulfport, New Orleans, and Black Bay—cover the eastern units of Jean Lafitte National Historical Park and Preserve and surrounding areas. These sheets are outlined and labeled in blue on the figure. The 1° × 2° (scale 1:250,000) sheets are outlined and labeled in purple on the figure.

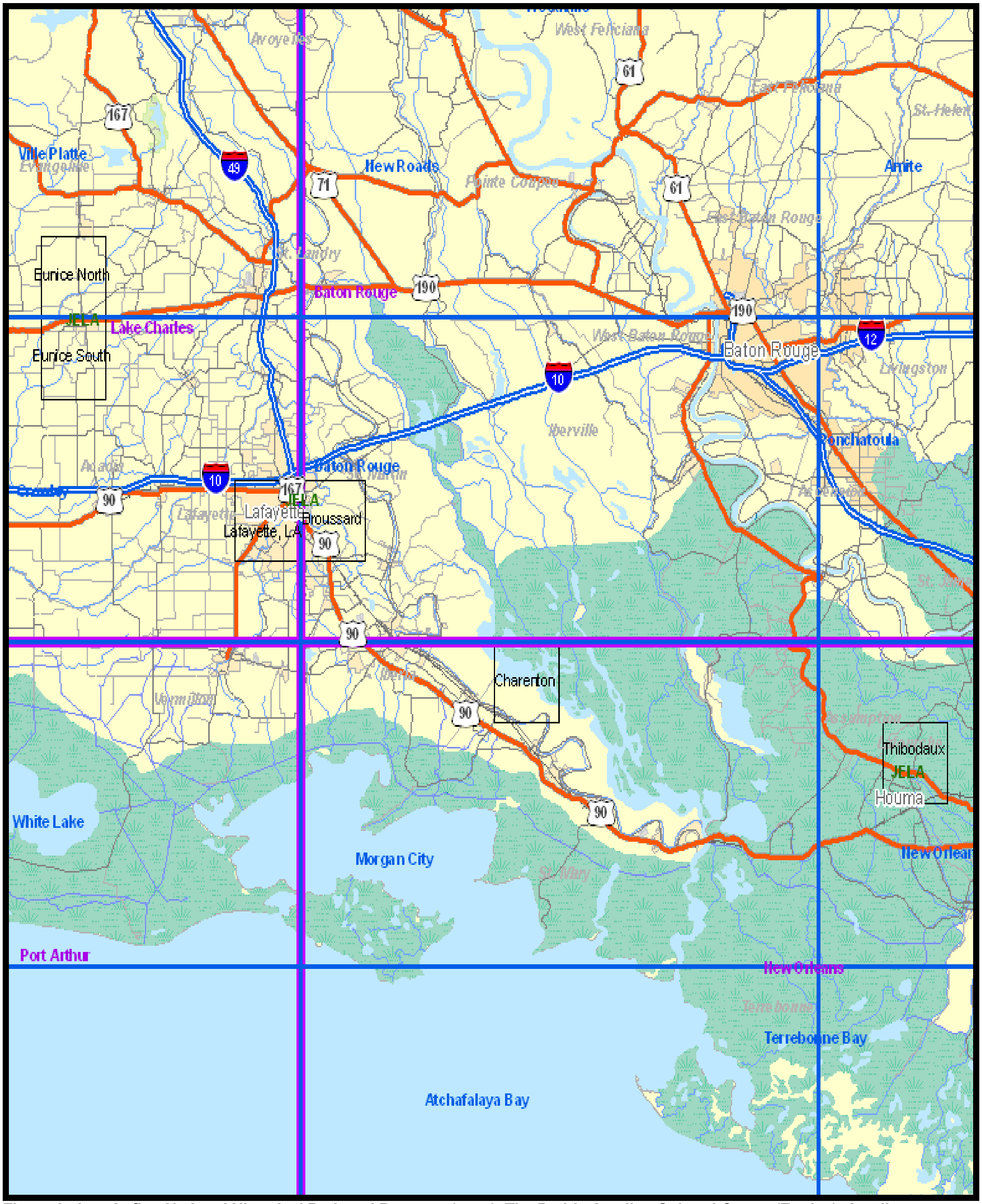

Figure 3. Jean Lafitte National Historical Park and Preserve (west). The Prairie Acadian Cultural Center (Eunice), Acadian Cultural Center (Lafayette), and Wetlands Acadian Cultural Center (Thibodaux) lie to the west of New Orleans and the Barataria Preserve. The 7.5' (scale 1:24,000) quadrangles of interest for these units are labeled and outlined in black in the figure; 30' × 60' (scale 1:100,000) sheets are represented by blue outline and blue text. The 1° x 2° (scale 1:250,000) sheets are shown in purple outline and purple text. The Charenton 7.5' quadrangle is no longer considered a quadrangle of interest.

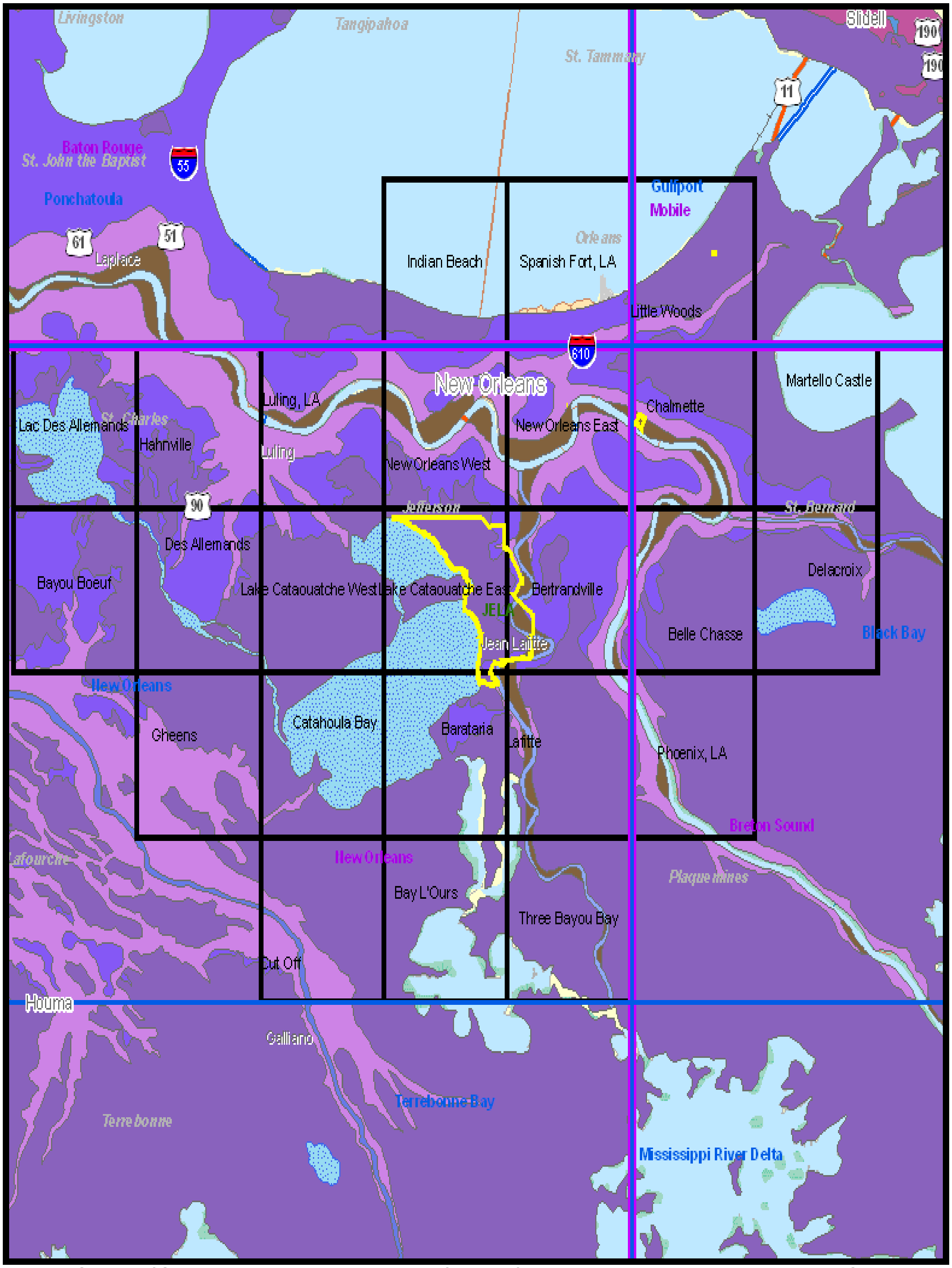

Figure 4. Overlay of Saucier (1994) on the eastern sites of Jean Lafitte National Historical Park and Preserve. Saucier (1994) covers the New Orleans and Black Bay 30' × 60' sheets at a scale of 1:250,000.

Geologic Features, Processes, and Issues

The scoping meeting for Jean Lafitte National Historical Park and Preserve provided the opportunity to develop a list of geologic features and processes occurring at the park, which will be further explained in the final GRI report. Many of these features and processes have associated issues of management concern. The two main resource management issues at the park are reclamation (of oil and gas and other sites of development that predate the park) and shoreline erosion/land loss. These issues are discussed first as part of the “Disturbed Lands” section and followed alphabetically by other features and processes in the park.

Disturbed Lands

Disturbed lands are those parklands where the natural conditions and processes have been directly impacted by mining, oil and gas production, development (e.g., facilities, roads, dams, abandoned campgrounds, and trails), agricultural practices (e.g., farming, grazing, timber harvest, and abandoned irrigation ditches), overuse, or inappropriate use. The NPS Disturbed Lands Restoration (DLR) Program, administered by the Geologic Resources Division, usually does not consider lands disturbed by natural phenomena (e.g., landslides, earthquakes, floods, hurricanes, tornadoes, and fires) for restoration unless the areas are influenced by human activities.

The following human activities have resulted in disturbed lands at Jean Lafitte National Historical Park:

- The closing of the tributaries of the Mississippi River. Beginning in Colonial times and culminating with Bayou Lafourche in 1904, the closing of tributaries has prevented river water and sediments from entering the upper Barataria Basin.
- The confinement of the main channel of the Mississippi River within artificial levees. This prevents overbank flooding. Since the early 18th century, artificial levees have controlled spring floods and since 1927 none have breached the constructed levee system and allowed water into the Barataria Basin.
- The massive network of canals that connects the upper basin to the Gulf of Mexico. This increased tidal volume, tidal reach, and salinities, while decreasing the retention of freshwater and sediments.
- The subsurface removal of oil and gas and freshwater. This may cause subsidence and increased movement along faults, although the importance of the role of hydrocarbon production in overall Gulf Coast subsidence is controversial (see “Shoreline Erosion and Land Loss” section).
- Oil and gas and other development activities. The construction of levees, canals, and dredged channels, which accommodate pipelines and provide access for drilling, have altered geomorphology and fluvial processes.
- Back levees construction. Developed to create storm–water drainage basins and provide hurricane protection to communities within the basins, back levees have interrupted sheet flow of water and nutrients from the upper parts of natural levees to fringing wetlands. Rainwater collected within these drainage basins is collected through interior drains and canals and carried over fringing levees by large pumping stations, which concentrate drain water and pollutants, and discharge them into canals that serve as conduits through fringing wetlands. Fifteen pumping stations discharge drain water from surrounding communities into the waters of the park.

- Placement of dredge material. This has created unnatural high ground in the form of spoil banks that interrupt sheet flow, sediment transport, and nutrient transport.
- Dredging of lake-bottom shells and mining of shell beaches. This has removed large quantities of clam shells from the system, resulting in degradation of the hard lake bottom and beach substrate.
- The introduction of exotic species (e.g., nutria and feral pigs). This has decreased plant vigor and soil cohesion.

Canals

The primary disturbance at Jean Lafitte National Historical Park and Preserve is canals—77 km (48 mi) of them. Starting in the 1700s, drainage outlets and navigation passages were cut through the wetlands in the area to drain agricultural fields; create navigation routes for small watercraft, which included cutting off meander bends; and to access bald cypress (*Taxodium distichum*) as timber. In more recent years, oil and gas exploration has made even greater alterations: cutting canals, dredging channels into the underlying sediment, and depositing spoil in linear piles called spoil banks along the sides of the canals. Urban development also created canals to facilitate drainage of planned (later defunct) subdivisions. Not only have these canals converted marshes and swamps into open water and spoil banks, but the resulting checkerboard of canals has altered the natural hydrology of the area, which further erodes the remaining wetlands.

During the site visit to the Barataria Preserve, scoping participants walked on the spoil bank (Marsh Overlook Trail) of the Kenta Canal, which had been built as part of a logging operation, as well as traveled via airboat on the open waters of the Kenta Canal. At the Marsh Overlook where participants loaded the airboat, they viewed Pipeline Canal, which spans all the way to One Shell Square in downtown New Orleans; the view illustrates the length of some of these canals. Interestingly, the building at One Shell Square is the tallest building in Louisiana and is framed at this vantage point by the spoil banks of Pipeline Canal.

Additional disturbances include the Gulf Intracoastal Waterway (GIWW) on the southern boundary of Barataria Preserve and the Bayou Segnette Waterway, which is inside the preserve and runs roughly parallel to the eastern shorelines of Lakes Cataouatche and Salvador. The wakes of tug and barge traffic using these waterways erode adjacent wetlands in the preserve. Furthermore, the Gulf Intracoastal Waterway fundamentally changed the area's hydrology by creating an east-west conduit for water perpendicular to the natural line of flow (Coburn 2010). Also, like the dredging of other canals, spoil material from the waterways have created a barrier to sheet flow, which limits the transport of water, sediment, and nutrients. In addition to restricting flow, spoil banks cause ponding behind the elevated berm, which stresses marsh vegetation and leads to a reduction in the production of peat. Spoil banks are also prime habitat for exotic Chinese tallow (*Triadica sebifera* (L.) Small) (see "Hurricanes" section).

The primary objective of canal reclamation is to restore wetland functions and values. Some of the canals are historic or maintained for navigation, and are, therefore, not slated for reclamation. However, park managers have identified 32 km (20 mi) of non-historic, abandoned canals in need of reclamation. Of these, the park has received funding to reclaim 5.6 km (3.5 mi), which began in June 2010. Reclamation plans call for removing the spoil banks and depositing the sediment and vegetation into the canals. The canals will then revert to marsh habitat by natural processes, re-creating freshwater wetlands (National Park Service 2009).

Nonnative Species

In addition to Chinese tallow, which invades disturbed areas, two large exotic animals impact the resources at Jean Lafitte National Historical Park and Preserve: nutria, or coypu, and feral pigs. These voracious eaters cause considerable erosion and the loss of organic matter that builds up peat soil. Nutria (*Myocastor coypus*)—a semi-aquatic rodent native to South America—inhabit the wetlands in Barataria Preserve where they feed on marsh and swamp vegetation. The animals prefer to eat the stems of plants, but will consume entire plants, and dig for roots and rhizomes to feed on, especially in winter. This behavior can lead to the destabilization of soil and erosion of wetlands. This activity also decreases the filtering capacity of wetlands and leads to loss of habitat for native wetland species. Feral pigs (*Sus scrofa*) consume an abundance of plant matter including grasses, forbs, berries, roots, and bulbs. They also feed on ground dwelling insects, worms, reptiles, amphibians, fish, small mammals, and carrion, including other pigs (National Park Service 2010c). Wild pigs spend much of their time rooting or digging with their noses in search of these food items. This behavior significantly increases the rate of erosion. Furthermore, pigs rooting near stream banks can cause the soil to loosen and wash away during rains, degrading water quality and negatively impacting aquatic species (National Park Service 2010c).

Oil and Gas Exploration

Most exploration of oil and gas in the vicinity of Jean Lafitte National Historical Park and Preserve occurred in the 1950s and 1960s, and most of the wells were "dry" (i.e., did not host economically producible quantities of oil and gas). However, several pipelines, some within canals, transport hydrocarbons through the Barataria Preserve. Resource managers at Jean Lafitte have GIS (point) data from the State of Louisiana for all the oil and gas wells in the vicinity of the park, as well as pipeline data from the National Mapping Pipeline System. Additionally, the Geologic Resources Division completed an inventory of wells in the 1990s. At present, there is one producing field in Lake Salvador and another north of the preserve.

Oil and gas exploration has the potential to create negative impacts on park geology and hydrology. As discussed in the "Disturbed Lands" section, impacts occur as a result of dredging. Additionally, potential impacts include the following: fluid withdrawals and associated subsidence (see "Shoreline Erosion and Land Loss" section); the introduction of fill material to create roads and drilling locations; and spills of oil, water, drilling fluids, and other contaminants associated with production. Past oil and gas exploration at the preserve, ongoing production adjacent to the preserve, and ongoing hydrocarbon transportation in pipelines and on roads and waterways, both inside and adjacent to the preserve, raise the risk of spills at the park. Specific locations include the refinery near the Chalmette Unit and a 45,000-L (12,000-gal), FEMA storage tank at a radio tower site on an inholding in the preserve. In 2009, a 750-L to 7,570-L (200-gal to 2,000-gal) spill (probably much closer to the low end) occurred at the FEMA site (Dusty Pate, Jean Lafitte National Historical Park and Preserve, written communication, July 6, 2010.) Most recently, on April 20, 2010, five days after the scoping meeting, the Deepwater Horizon oil rig exploded and sank in the Gulf of Mexico, and a few days later began leaking oil from the wellbore on the floor of the gulf. As of July 28, 2010, none of Jean Lafitte's six sites were directly in the path of the Deepwater Horizon oil spill. The Barataria Preserve unit is the most vulnerable site because it is linked to the Gulf of Mexico via waterways. However, no oil from the spill has been observed in the preserve. Oil has fouled the shoreline of the Barataria Waterway about 19 km (12 mi) south of the preserve boundary and has penetrated marshes on the north edge of Barataria Bay, about 24 km (15 mi) south of the preserve. Booms are in place and cleanup is underway. Park staff members continue to monitor the situation and work with experts to prepare defensive actions (National Park Service 2010d).

Shoreline Erosion and Land Loss

Manipulation of the hydrology of the Barataria Basin has resulted in excessive erosion of the Lake Salvador shoreline. As a result, natural (e.g., wetlands) and cultural (e.g., middens) resources are rapidly being lost. If left unabated, shoreline retreat will erode most of the floating marsh at the preserve in the next few centuries (Pranger 2002). Although the entire shoreline of Lake Salvador is undergoing erosion, various substrates "resist" erosion better than others. For instance, on the shell beach of Chenier Grand Coquilles, erosion is 1.5 m (5 ft) per year, while in areas of shoreline composed of organic peat, the rate of erosion is 9 m (30 ft) per year (National Park Service 2003). During Hurricane Katrina (2005), 305 m (1,000 ft) of erosion occurred in one day.

In an effort to protect the shoreline along Lake Salvador, the National Park Service in partnership with the U.S. Army Corps of Engineers constructed shoreline revetment in the form of a dike (geotextile-rock barrier) along 2,890 m (9,500 ft) of the shoreline along the western edge of the Barataria Preserve's boundary. In addition, restoration efforts placed three artificial islands at Chenier Grand Coquille to protect the midden from erosion. The dike and islands have become covered with native vegetation, helping these features blend in with the natural and cultural landscape. The dike's profile protrudes only slightly above the average water level, allowing sediment to be captured behind the rocks when overtopped by waves. The dike is laid on a geotextile material which prevents differential settling and slows subsidence.

Subsidence

As a result of subsidence, the Mississippi River delta plain is losing land, primarily wetlands, at an average rate of more than 60 km^2 (23 mi^2) per year with higher pulses during hurricanes (Wanless 2008). The term "subsidence" as commonly used lumps under one name a host of diverse effects potentially resulting from a complex suite of influences. McCulloh et al. (2006) outlined the complexity of the issue in Louisiana Geological Survey Public Information Series 11.

Natural causes of subsidence include tectonics, compaction, and biological processes. Fault-bounded blocks of land situated on salt deposits slip towards the Gulf of Mexico. Sediment loading on the shelf causes crustal downwarping. The overlying weight of thick sequences of sediment causes compaction/subsidence. Plants "consume" carbon, which results in compaction of organic material.

Potential human causes of subsidence include the withdrawal of subsurface fluids, namely oil and gas resources (Gagliano et al. 1981). This withdrawal has resulted in subsidence rates of up to 4 cm (1.6 in) per year in some areas. Coupled with global sea level rise, this equates to 10 mm (0.4 in) of relative sea level rise in parts of southern Louisiana. In addition, dewatering of swamps and marsh lands causes clays and peats to oxidize and compact, adding to subsidence levels. For peats, dewatering not only reduces volume directly, but permits atmospheric oxygen to react with the constituent organic matter, giving off carbon dioxide. By the time oxidation is recognizably occurring, the volume already has undergone severe reduction from dewatering and compaction, but the release of carbon dioxide leads to additional volume loss (Rick McCulloh, Louisiana Geological Survey, written communication, May 28, 2010). An outcome of subsidence is saltwater intrusion, which kills freshwater marsh vegetation, thereby limiting the amount of peat produced and the amount of land created.

Compounding subsidence is the loss of sediment to the delta system. Upstream dams trap sediment, levees prevent overbank flooding, and jetties at the mouth of the river funnel sediment off the continental shelf into deep, marine waters. As a result, floodplains are not receiving fresh inputs of sediment, and the delta is not building up or into the gulf.

As bleak a picture as subsidence paints, park staff pointed out that compared to other national parks, the natural resources at Jean Lafitte National Historical Park and Preserve possess two processes for keeping up with global sea level rise. Parks with coastal marshes that evolved with relatively low inputs of sediment and nutrients, such as those in Everglades National Park, have a limited ability to build land by vertical accretion. Parks with barrier islands such as Padre Island National Seashore that use seaborne sediment input to keep land above sea level have little room to maneuver landward in the face of rapid sea level rise. If the Mississippi River and its delta are reconnected as some investigator suggest (e.g., Baumann et al. 1984; Day et al. 2007; Wanless 2008), Jean Lafitte, and, more importantly, the delta ecosystem, have the ability to counter global sea level rise using three processes: (1) the vertical land-building capabilities of flotant through the accretion of organic soils; (2) the ability of rooted wetland systems in the delta environment to capture sediment and add organic material through nutrient enrichment from river water; and (3) the re-distribution of heavier sediment input from upstream, which will result in soil platforms at the mouths of distributary channels scaled to remain above sea level.

Deltaic Features and Processes

This Mississippi River delta plain is a dynamic landscape that covers 25,000 km^2 (9,650 mi^2) and combines fluvial, coastal, and lacustrine features and processes. Typically, GRI scoping discussions separate these three geologic functions, but at Jean Lafitte National Historical Park and Preserve, they are inextricably combined in a deltaic landscape of water, wetlands, and ridges formed as a series of overlapping delta lobes. The geologic history of the park is primarily a chronology of delta lobe formation and subsequent abandonment. As illustrated in Day et al. (2007), the chronology is as follows:

1. Sale-Cypremont delta lobe (4,600 years before present)
2. Teche delta lobe (3,500–2,800 years before present)
3. St. Bernard delta lobe (2,800–1,000 years before present)
4. Lafourche delta lobe (1,000–300 years before present)
5. Plaquemine delta lobe (750–500 years before present)
6. Balize delta lobe, which includes the Mississippi “bird foot” delta (550 years before present)

This chronology varies somewhat from Spearing (2007), which includes the Maringouis (7,500 to 5,000 years ago) and Atchafalaya (50 years ago to today) delta lobes. The Barataria Preserve and New Orleans sites are part of the St. Bernard and Plaquemine lobes.

Deltaic features at Jean Lafitte include freshwater tidal lakes (e.g., Lake Salvador), bayous (slow-moving streams that are tidally influenced in Louisiana), natural levees and flanking substrate, crevasses and crevasse splays (where the river broke through the natural levee and deposited sediment, creating higher ground), and ridge and swale topography (complex, low-relief accretion on point bars). In addition, the floating marshes in the Jean Lafitte area are the most extensive in the world. Experts such as Chris Swarzenski (U.S. Geological Survey), Tom Doyle (National Wetland Research Center), and Charles Sasser (LSU Department of Oceanography and Coastal Sciences) have studied these marshes and other wetland types, which are defined by salinity (see Sasser et al. 2008).

The delta plain also features barrier islands and barrier headlands, inactive barrier islands and beach trends overtaken by accreting marsh ("cheniers"), offshore sand deposits from earlier delta lobes now eroded away, salt domes, and active tributary channels. In addition, scoping participants mentioned mudlumps as a distinctive deltaic feature. Mudlumps are mounds of clay that are extruded from deep deposits being buried by tons of new sediment at the mouth of the river; they range in size from less than an acre to several tens of acres. However, Rick McCulloh (Louisiana Geological Survey) is unaware of any mudlumps occurring at Jean Lafitte National Historical Park and Preserve because their surface distribution is limited to areas not far seaward of the surface termini of the Mississippi River bird foot–delta distributaries in the open Gulf (Rick McCulloh, Louisiana Geological Survey, written communication, May 28, 2010). Saucier (1994) described many of these deltaic features and the processes that formed them.

Geothermal Features

Scoping participants noted that geothermal energy as a future energy source has the potential to cause further subsidence via groundwater withdrawal. The geothermal gradient in southern Louisiana is higher than normal, and "geopressure" creates elevated water temperatures. Elevated water temperatures can be used in aquiculture, enhancing production rates of freshwater and marine species (Boyd and Lund 2003). Aquiculture is currently a "hot topic" for southwestern Louisiana (Horst 2008). At present, however, this industry does not affect park resources.

Hurricanes

While hurricanes have long shaped the Louisiana coastline, the 2005 hurricane season was extraordinarily active, destructive, and costly. A record 27 named storms, which included 15 hurricanes, 7 of them major, killed more than 1,500 people (1,100 in Louisiana) with thousands more displaced or missing, and caused more than $200 billion in damage in the United States. An unprecedented three hurricanes had sustained winds of more than 249 kph (155 mph)—the equivalent of a category 5 hurricane on the Saffir-Simpson hurricane scale, though not at landfall. Storm surge from Hurricane Katrina—estimated in the 9- to 11-m (30- to 35-ft) range at Waveland, Mississippi, northeast of New Orleans—contributed greatly to the damage, but numerous other storms impacted park resources (Beavers and Selleck 2006). Hurricanes, with Hurricane Katrina in particular, are a primary interpretive theme at the visitor center in the French Quarter.

In August and September 2005, Hurricanes Katrina and Rita struck Jean Lafitte National Historical Park and Preserve with the Barataria Preserve being particularly hard hit. The storms damaged trails and buildings at the preserve. In addition, about 60% of the preserve's big trees blew down or were damaged. Scoping participants noted the open canopy along the Bayou des Familles ridge and Highway 45/Barataria Boulevard as they drove to the preserve for the site visit. At Chalmette Battlefield, floodwaters reached 6 m (20 ft) deep, destroying much of the cemetery wall (Forbis 2006). The French Quarter visitor center suffered roof damage and power outage but sustained less damage than other areas in New Orleans because it sits on higher ground. Twenty-one park staff members lost their homes as a result of the storm, and "blue roofs" became a common sight as FEMA put blue tarps over damaged roofs as a temporary fix. Six weeks after the storm, power was turned back on in limited un-flooded areas of New Orleans, including the French Quarter. The Acadian Cultural Center in Lafayette, the Wetlands Acadian Cultural Center in Thibodaux, and the Prairie Acadian Cultural Center in Eunice were not damaged by the storms, and the National Park Service used these sites as staging areas for disaster recovery teams (National Park Service 2010a).

Another storm-related impact is the invasion of nonnative species. Nonnative Chinese tallow, for example, is tolerant of many environmental conditions and grows rapidly in disturbed areas. Prior to Hurricane Katrina, the thick forest canopy helped protect the preserve from these exotic species (Walters 2006). Currently, park managers have $1 million of NPS funding to treat Chinese tallow.

Geologically, hurricanes accelerate coastal processes so that during the few hours of storm passage, the degree of erosion and deposition in coastal systems equals what would normally take months or even years. The high winds and wave energy caused by Hurricane Katrina resulted in extensive shoreline loss. The Lake Salvador shoreline along the Barataria Preserve's southwest side suffered shoreline retreat of approximately 305 m (1,000 ft) of erosion in one day (David Muth, Jean Lafitte National Historical Park and Preserve, personal communication, April 15, 2010). Portions of flotant were torn apart and other areas were compacted like an accordion. Post–Hurricane Katrina aerial photographs revealed areas of marsh that were ripped apart and are now open water (Walters 2006).

Beneficial aspects of hurricanes include (1) the introduction of freshwater and nutrients via runoff, which reduce salinity and enhance coastal productivity (Connor et al. 1989), and (2) the re-suspension and deposition of sediment on wetland surfaces, which helps to offset relative sea level rise and is, thereby, important for the sustainability of marshes (Baumann et al. 1984; Cahoon et al. 1995).

Paleontological Resources

As Dusty Pate pointed out during scoping, "We don't have any rocks." In southern Louisiana, bedrock and surficial deposits are synonymous. Not surprisingly, in such a geologic locale, fossils are rare. Kenworthy et al. (2007) completed a baseline paleontological inventory for the park but reported no paleontological specimens in the park's museum collection and little potential for future discovery of paleontological resources. However, the Pleistocene river terraces at the Eunice and Lafayette sites do have potential for fossil resources, and loess (also exposed at Eunice and Lafayette) is very fossiliferous elsewhere, yielding gastropods and mammoth remains in Vicksburg, Mississippi, for example.

Because of oil and gas exploration in the area, there is an extensive library of geologic cores and well logs housed at the Louisiana Geological Survey in Baton Rouge (D. Muth and R. McCulloh, Jean Lafitte National Historical Park and Louisiana Geological Survey, personal communication *in* Kenworthy et al. 2007, p. 26). Some of these subsurface samples include fossils that are used as stratigraphic indicators, although none are yet known from within the park. For instance, Frazier (1967) used macroinvertebrate shells and plant material to date the various delta lobes. Yet, according to Kenworthy et al. (2007, p. 26), "there is little chance for observable paleontological material within the Barataria, Chalmette, French Quarter, and Thibodeaux units due to the young age of the sedimentary deposits and lack of exposures."

Seismic Features and Processes

Louisiana lies in an area of low seismic risk (Stevenson and McCulloh 2001). Although shaking was felt in Irish Bayou during a 1987 "earthquake," there is some controversy as to whether this was in fact a seismic event (Rick McCulloh, Louisiana Geological Survey, written communication, May 28, 2010). A resource for seismic activity (and this event in particular) is Don Stevenson at the Westinghouse Savannah River Company (donald.stevenson@srs.gov) (Rick McCulloh, Louisiana Geological Survey, written communication, May 28, 2010)

Data gathered from oil and gas exploration, including seismic surveys conducted throughout the Gulf Coast region, originally provided evidence for the existence of most of the faults in southern Louisiana. Woody Gagliano has used seismic-exploration data to infer fault trends (e.g., Gagliano 1999a,b; Gagliano et al. 2003a,b; Gagliano 2005a,b,c; Coastal Environments, Inc. 2007); many of these trends are considered controversial as surface faults, however. Surface displacement on faults is minor; for instance, a reported minor yet observable displacement on the Baton Rouge fault resulted from the Alaska earthquake in 1964 (Durham 1964).

Fault traces, however, create other surface expressions such as breaks in levees, the location of lakes, subsidence rates (greater on one side of the fault than the other), and marsh loss. Mechanisms used to explain the formation of these faults include overloading in areas of voluminous sedimentation, differential compaction of deposited sediments, abnormally high fluid pressure, and gravity sliding (Stevenson and McCulloh 2001).

Unique Geologic Features

"Unique geologic features" are often mentioned in a park's enabling legislation; these features are of widespread geologic importance and may be of interest to visitors and worthy of interpretation. Many unique geologic features at the Barataria Preserve are deltaic features (see "Deltaic Features and Processes" section). In addition, geoarchaeology is worthy of mention as a unique geologic feature for the park. The distribution of archaeological sites across the deltaic landforms in coastal Louisiana helped formulate the geologic history of the area and suggested a chronology for these landforms (Kniffen 1936; Russell 1936). Deltaic processes drove cultural patterns: prehistoric peoples inhabited higher ground (e.g., natural levees and crevasse splays). Geologists used the evidence left by these inhabitants (e.g., pottery shards and shell middens) to date the relative age of these landforms; this information could also be used to infer rates of subsidence. Using geoarchaeology, Paul Heinrich (Louisiana Geological Survey) continues the work of these early survey geologists and has mapped the contact between the base of Holocene and the top of Pleistocene in coastal Louisiana; this information (e.g., Goodwin et al. 1991; Heinrich 1991) will be useful for preparing the "Geologic History" section of the final GRI report for Jean Lafitte.

In addition, humans were geomorphic agents themselves; that is, "they ate themselves to higher ground," and in the process created middens such as the ones along Bayou Coquille and at Chenier

Grand Coquille. Past cultures consumed and deposited the shells of primarily brackish water clam (*Rangia cuneata*) (National Park Service 2003). During the field trip, David Muth informed participants that these middens could be 6 m to 9 m (20 ft to 30 ft) high (no small feat at sea level) and cover more than 0.4 ha (1 ac). Most of the middens are now gone or greatly reduced in size, having been mined for shell material, which was used to make lime for mortar, or lost to dredging or erosion (see "Disturbed Lands" section).

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