

Geologic Resources Inventory Scoping Summary Cumberland Island National Seashore, Georgia

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The Geologic Resources Inventory (GRI) provides each of 270 identified natural area National Park System units with a geologic scoping meeting and summary (this document), a digital geologic map, and a Geologic Resources Inventory report. The purpose of scoping is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and monitoring and research needs. 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 National Park Service held a GRI scoping meeting for the park units of the Southeast Coast Network (SECN) during the week of April 20–24, 2009 at Jacksonville, Florida. These units included Canaveral National Seashore (CANA), Castillo de San Marcos National Monument (CASA), Cumberland Island National Monument (CUIS), Fort Caroline National Memorial (FOCA), Fort Frederica National Monument (FOFR), Fort Matanzas National Monument (FOMA), Fort Pulaski National Monument (FOPU), and Timucuan Ecological and Historic Preserve (TIMU). Cumberland Island National Seashore was discussed on April 20. Bruce Heise (NPS GRD) facilitated the meeting, presented an overview of the GRI program, and led the discussion regarding geologic processes and features at each NPS unit. Stephanie O’Meara (CSU) led the discussion of map coverage relevant to each unit. Randy Parkinson (RWParkinson Consulting) presented an overview of coastal regional geology and barrier island geomorphology. On April 21, 2009, John Fry (NPS CUIS) led a Cumberland Island National Seashore field trip. Participants at the meeting included NPS staff from the park, Geologic Resources Division (GRD), and Southeast Coast Network (SECN) and cooperators from the U.S. Geological Survey (USGS), Florida Geologic Survey (FGS), University of West Georgia (UWG), university of Georgia (UGA), Polk Community College (PCC), and Colorado State University (CSU) (see table 3).

This scoping summary highlights the GRI scoping meeting for Cumberland Island National Seashore including the geologic setting, the plan for providing a digital geologic map, a summary of geologic resource management issues, a list of significant geologic features and processes, and a record of meeting participants.

Park and Geologic Setting

Cumberland Island National Seashore occupies most of Cumberland Island, a largely undeveloped barrier island that has the longest beach (28 km; 17.5 mi) and most upland acreage (6,110 ha; 15,100 acres) of any of Georgia’s barrier islands. The park’s boundaries also include Little Cumberland Island, a small privately-held landmass separated from the rest of Cumberland Island by Christmas Creek. Cumberland River and Cumberland Sound separate Cumberland Island from the mainland. South of the island, the St. Marys River flows into the Atlantic Ocean and separates Cumberland Island from Florida’s Amelia Island. Jekyll Island, the next island to the north, is separated from Cumberland Island by the Satilla River and St. Andrews Sound. The park allows a

maximum of 300 visitors per day, transported to the island via a passenger ferry leaving from St. Mary's, Georgia, although other visitors to the island may arrive by private boats.

Cumberland Island developed as a Pleistocene (1.8 million years to 10,000 years ago) barrier island about 40,000 years ago. Sea level began to drop at the onset of the last Pleistocene glaciations about 120,000 years ago. About 25,000 years ago, sea level lowered to approximately 122 m (400 ft) below modern sea level, exposing the core of Cumberland Island to erosion for 15,000 to 20,000 years. Following the last glacial maximum about 20,000 years ago, continental ice sheets began to melt and global sea level rose. Rising sea level pushed sediment deposits up to the island's interior (Griffin 1982).

The depositional setting of Georgia's coast is related to plate tectonics. Most coastlines may be described as either a "collision" or a "trailing edge" coastline. On the California coast of North America, for example, the North American lithospheric plate is colliding with the Pacific plate. Rapid uplift, young mountain ranges and short rivers characterize these active margins. In contrast, more passive, trailing edge coastlines, such as the eastern U.S. coast, are relatively stable, have a broader continental shelf, and form a "depositional" coast. Barrier islands are frequently found along these depositional coastlines.

Barrier islands are rare along tide-dominated coasts, where tidal range exceeds 4 m (13 ft). Along coastlines such as eastern Florida, where tidal range is small and waves dominate the coastline, barrier islands form long, linear features. A mixed energy environment dominates Georgia's coast where tidal range averages just higher than 1.8 m (6 ft) and wave action associated with seasonal storms and infrequent hurricanes modify the coastline (Henry 2009). Mixed-energy barrier islands tend to be short, wide at one end and narrow at the other. Relatively deep, stable, tidal inlets separate these short barrier islands. Extensive sand shoal systems accumulate at the mouth of tidal inlets, and longshore currents transport the sand to downcurrent recipients.

Cumberland Island, one of 8 major islands and island groups along the Georgia coast, is approximately 29 km (18 mi) long (including Little Cumberland Island) and 4.5 km (3 mi) wide at its greatest width. The highest point on the island is approximately 17 m (50 ft) above sea level. The general geomorphology of the island may be subdivided into: 1) an actively changing Holocene (10,000 years ago to present) beach-dune zone, 2) the interior of the island, composed of vegetated Pleistocene beach ridges, 3) tidal inlets that bound the island to the north and south, and 4) the salt marsh/tidal channel area surrounding the back-barrier, or landward portion of the island (Griffin 1982). The original dune shape is preserved on the Pleistocene beach ridges that are largely undisturbed behind the present-day dune fields in central and northern Cumberland Island. These dunes support a mature maritime forest, dominated by live oaks and palmettos, and many small, freshwater ponds. Farther inland, the dune ridges have been so modified by logging, agriculture, and overgrazing by the island's horses that their original character is not easily discerned.

Georgia tidal marshlands include saltwater wetlands that predominate in the 5- to 8-km-wide (2- to 5-mi-wide) areas between the barrier islands and the mainland and the brackish to freshwater wetlands that extend inland along the estuaries for an additional 16 km (10 mi) or so (Henry 2009). Erosional remnants of Pleistocene and Holocene barrier islands and back barrier deposits are scattered throughout the tidal marshlands.

The Pleistocene and Holocene deposits overlie Pliocene (5.3 – 1.8 million years ago) and Miocene (23 – 5.3 million years ago) sedimentary rocks that are buried only 12-20 m (39-66 ft) below sea level. A thin 6-10 m (20-33 ft) layer of Pliocene river deposits overlie Miocene limestone that formed in an open ocean environment at a time when sea level was higher and the shoreline much farther inland (Griffin 1982). The Pliocene and Miocene formations have been age-dated using fossils of organisms buried during sedimentation.

Regional Geology and Barrier Island Geomorphology (Randy Parkinson)

Cumberland Island National Seashore, Fort Pulaski National Monument, and Fort Frederica National Monument are part of Georgia's Coastal Plain, one of five major northeast-southwest trending geologic zones that define the landscape in the southeastern United States. From northwest to southeast, these geologic zones include the Appalachian Plateau, Ridge and Valley, Blue Ridge, Piedmont, and Coastal Plain provinces. The Coastal Plain is a broad and gently sloping landscape that consists of nearly horizontal sedimentary layers that were deposited, eroded, and modified over the past 100 million years and continues to be modified even today. Barrier islands, tidal creeks, and extensive marshlands mark the eastern edge of the province. To the west, the "Fall Line" represents the boundary between the Coastal Plain and Piedmont provinces. The Fall Line, identified on topographic maps by a series of waterfalls, marks an abrupt change in elevation between the low-lying plains and the rolling topography and foothills of the Piedmont. The Piedmont and the other elevated provinces formed from tectonic events spanning 250 million to 1 billion years ago. The provinces continue to undergo erosion and supply sediment via rivers and streams to the Coastal Plain and its barrier islands.

Linear features identified on the Coastal Plain represent previous coastlines and barrier islands associated with major fluctuations of sea level over the past 400,000 years. Sea level fell during periods of glacial advance and rose during interglacial periods when glaciers melted. Sea level began to rise about 20,000 years ago and rose rapidly until about 6,000 years ago when the present barrier islands along the eastern seaboard formed. The rapid rise in sea level drowned previously existing barrier islands. About 3,000 years ago, coastal features stabilized so that although sea level continues to rise and the coastline continues to retreat landward, the barrier islands, wetlands, lagoons, and other coastal features have maintained their geomorphic integrity.

To form, barrier islands require an abundant sediment supply, moderate to high wave energy, micro- to meso-tidal ranges of less than 4 m (13 ft), rising sea level, and a broad continental shelf. Barrier island morphology is controlled by both tidal range and wave height. Wave dominated barrier islands, such as those along the east coast of Florida, are long and straight. Short, crenulated barrier islands along Florida's panhandle and southwest coast are tide dominated. The short barrier islands along the Georgia coast result from a mixed wave and tidal energy.

Three conceptual models have been proposed for the origin of barrier islands: 1) dune drowning, 2) spit elongation, and 3) shoal emergence. Dune drowning occurs with a relative rise in sea level, which may inundate a mainland ridge of coastal dunes, thus forming a lagoon between the most seaward dune ridge and the mainland. Stable sea-level conditions and/or an abundant sand supply

are conducive to the development of barrier islands by spit elongation. In the spit elongation model, longshore currents transport sand along the coast, and the sand is deposited on the flanks of headlands or at the downdrift ends of existing barrier islands. As these relatively thin spits of sand elongate, they form barriers that block embayments and form lagoons. Eventually, tidal inlets may separate the spits from the headland, forming a barrier island. Shoal emergence results when erosion and redistribution of sediment on the sea floor promotes the upward growth of a submerged sand bar. Shoal emergence is aided by a relative fall in sea level and a local surplus of sand that can maintain the barrier above the ocean's surface.

Barrier islands can be subdivided into a back barrier region, dune system, and beach (fig. 1). A lagoon or estuary separates the barrier island from the mainland. Flood-tidal deltas form on the incoming tide while the outgoing tide produces ebb-tidal deltas. During storms, washover fans distribute sediment into the back barrier and push the barrier island landward.

Sea level rise is a major driving force with regards to barrier island sustainability. With relative sea level rise (transgression), barrier islands migrate landward. Vertical cross-sections through present barrier island systems show this landward migration over time. Buried beneath today's beaches, for example, are yesterday's lagoon and mainland environments. Currently, the margins of North America are being subjected to coastal erosion. Understanding barrier island morphology and its dynamic association with sea level rise, tides, and wave energy may be used to project future coastline patterns

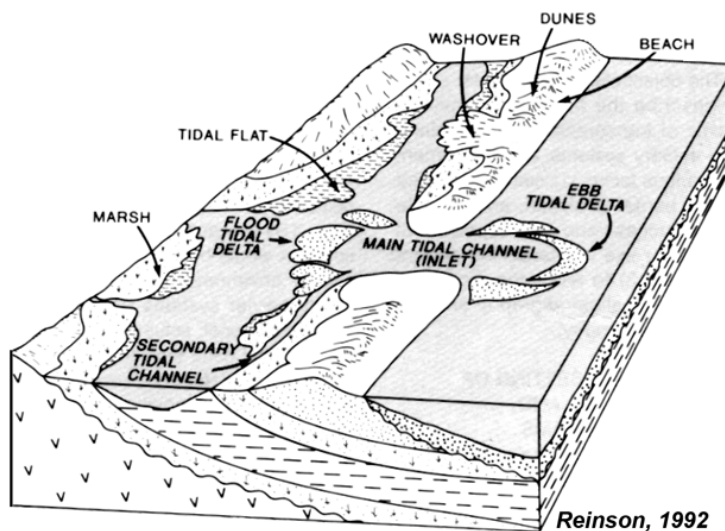


Figure 1. Common coastal environments associated with barrier islands. Schematic from Reinson (1992).

Cumberland Island Field Trip (John Fry)

On Tuesday, April 21, 2009, John Fry (NPS CUIS) led a field trip around Cumberland Island National Seashore to point out some of the geological issues and features that were discussed at Monday's meeting. The stops and associated features are summarized in the following table.

Table 1. Cumberland Island field trip stops

Field Trip Stop	Associated Geologic Issue, Feature, Process
1. Ferry ride to Cumberland Island	Back-barrier erosion: Inlet channel is about 60 m (200 ft) from the west shore; boat wake results from submarines, tugs, and pilot boats
2. Ice House Museum dock & historic seawall	Overview: Maximum 300 visitors/day by ferry; visitors stay mostly on southern part of island; 5 historic districts with buildings on National Historic Register; various ownerships on island; political interests Back-barrier erosion: Most significant geologic issue on the island; Pleistocene clay layer beneath the historic seawall helps protect the shore; cobbles on beach have been eroded from the seawall. Back-barrier erosion occurs at about 0.5 to 1 m (1.6 to 3.3 ft) per year Cutbank erosion at the end of the seawall has undercut trees, which have toppled onto the shore; cutbank here is approximately 2.4 m (8 ft) high and results from natural meandering channel processes and boat wake; erosion has exposed shell middens, Previous buffers to erosion that have been removed from the system include oyster banks and long grasses, which have been cropped close by the island's horses. Horses have also cut a path to the beach, which allows for channelized runoff and increased erosion
3. Dungeness Ruins	Carnegie mansion: Arson-caused fire destroyed building Tabby (oyster shell concrete) building Artesian wells: 3 in area; 1 flows into the duck pond; when the mill on the mainland shut down, the wells started flowing again and burst the pipes in the house due to the increased pressure; depth to the water table is about 6 m (20 ft) Old Carriage house Grazing horses: free ranging horses date from 1788; no horses on island after the Civil War; genetic study showed that current horses are 20 th century stock
4. "Dead Raccoon" Tidal Creek (informal name for creek south of Plum Orchard turn off)	Channelized stream: Channel takes a right angle turn southeast of the road; channelized when area was used for agriculture (rice, cotton, etc.) Dikes: Need restoration but the area is now a functioning wetland
5. Brickhill River/Plum Orchard Mansion (Carnegie)	Cutbank meander of Brickhill River Back-barrier bank erosion Abundant boat traffic on weekends Sea wall and riprap protecting an old shed near the steep bank; erosion is causing an edge effect (undercutting) around the hardened structure (common effect with riprap) Exposed oyster beds (low tide) suggests high tidal energy Historic duck pond threatened by back-barrier erosion: A 1 m (3 ft) high by 3 m (9 ft) wide dike separates the fresh water pond from the Brickhill River and tidal influence
6. South Cut Trail	Frazier's road (1970): Channelization and causeway problems; without causeway, area would be open marsh; needs restoration but can't due to "special use" permit that allows road access; road is in a designated wilderness area
7. Private Dock north of Brickhill Bluff	Cutbank erosion Meander cutoff: Sediment is beginning to clog the mouth of the creek, making a difficult passage for pleasure boats; owners want to move the dock but NPS can't allow the dock to be moved because the location would be in designated wilderness; looking at other options (dredging?)
8. Cumberland Wharf Ruins and bluff above ruins	Mass wasting of bluff: Blocks of Pleistocene semi-consolidated nearshore-shoreface sandstone; midden layer near top of bluff; Pleistocene shoreface evidence of higher sea level in past; clay layer between sandstone beds may be a paleosol (old soil) Oyster bank off shore Good illustration of fluvial fetch (the area of the river's surface over which a constant and uniform wind generates waves)
9. Drive to beach	Paleodunes: North from stop 8 on way to The Settlement Seeps and artesian wells Arrive at Beach/Dune Complex
10. Long Point	Active shoaling and new dunes forming Sediment composed of sand and shell fragments (future grainstones and packstones) Sedimentary structures include ripples, dunes Heavy mineral segregation
11. Beach at South Cut Trail dune crossing marker	Lake Whitney outflow: Drains an interdune area Main north-south trending dune ridge Heavy minerals and tannin make colorful patterns in stream bed Dune height almost reaches tree height (approximately 15 m (50 ft) above beach)
12. Sweetwater Lake Complex (inland from stop 11)	Approximately 8 km (5 mi) long lake complex Perched on Pleistocene clay layer
13. Dune north of Duck house Trail dune crossing marker	Expansive dune field; abundant hummocks, some vegetated; ridgeline to east; dune ripples; heavy mineral segregation; dead trees lying in sand (future trace fossils)
14. Jetty	Extends 4 km (2.5 mi) seaward Carnegie extended jetty towards Dungeness Dock because sand was being lost at the south end of the island; south end has been growing, but growth rate has slowed since 1950 Sedimentary structures include cross-bedding; ghost crab burrows (future trace fossils); shells and sand (future grainstones and packstones)
15. Dredge spoil piles	Sharks' teeth

Geologic Mapping for Cumberland Island National Seashore

During the scoping meeting, Stephanie O'Meara (CSU) briefly displayed some of the main features of a GRI digital geologic-GIS map, which includes source map 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-GIS map model using ESRI ArcGIS software. Final digital geologic-GIS map products include GIS data in geodatabase and shapefile format, layer files complete with feature symbology, FGDC-compliant metadata, an Adobe Acrobat PDF help document that captures ancillary map data, and an ESRI ArcGIS ArcMap document file that displays the map, and provides a tool to access the PDF help document directly from an ArcMap document. Final data products are posted at <http://science.nature.nps.gov/nrdata/>. The data model is available at <http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm>.

When possible, the GRI Program provides large scale (1:24,000) digital geologic map coverage for each park's area of interest, which is often composed of the 7.5-minute quadrangles that contain park lands (fig. 2). 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). The process of selecting maps for management begins with the identification of existing geologic maps (table 2) and mapping needs in the vicinity of the park. Scoping session participants then select appropriate source maps for the digital geologic data or develop a plan to obtain new mapping, if necessary.

Table 2. GRI Mapping Plan for Cumberland Island National Seashore

Covered Quadrangles	Relationship to the park	Citation	Format	Assessment	GRI Action
Cumberland Island North	Intersects the park boundary	New detailed geomorphic mapping	digital	Specify mapping product similar to the geomorphic map produced for CANA by Parkinson, R.W and Schaub, R., 2007	Await digital data from new mapping and convert to the NPS GRI data model if necessary
Kingsland NE	Intersects the park boundary	New detailed geomorphic mapping	digital	Specify mapping product similar to the geomorphic map produced for CANA by Parkinson, R.W and Schaub, R., 2007	Await digital data from new mapping and convert to the NPS GRI data model if necessary
Cumberland Island South	Intersects the park boundary	New detailed geomorphic mapping	digital	Specify mapping product similar to the geomorphic map produced for CANA by Parkinson, R.W and Schaub, R., 2007	Await digital data from new mapping and convert to the NPS GRI data model if necessary
Harrietts Bluff	Intersects the park boundary	New detailed geomorphic mapping	digital	Specify mapping product similar to the geomorphic map produced for CANA by Parkinson, R.W and Schaub, R., 2007	Await digital data from new mapping and convert to the NPS GRI data model if necessary
Fernandina Beach	Intersects the park boundary	New detailed geomorphic mapping	digital	Specify mapping product similar to the geomorphic map produced for CANA by Parkinson, R.W and Schaub, R., 2007	Await digital data from new mapping and convert to the NPS GRI data model if necessary

- *Geologic map of Cumberland Island, Georgia* (plate 1). Two mapped units: Holocene, undifferentiated and Pleistocene – Satilla Formation.
- *Classes of land-surface forms and natural vegetation*. Cumberland Island, Georgia (plate 2). Eight mapped units: beach, foredune, backdune and other active dunes, stabilized and partially stabilized dunes, inter-dune meadows, salt marshes, freshwater marshes and ponds and interior forest.

The GRI will attempt to locate a copy of this publication and have Linda York, NPS Southeast Region coastal geologist, review it for accuracy and adequacy.

It was agreed that the Swann, 1981 map contained more useful detail than other existing maps. However, the level of detail and subdivision of geomorphic units as identified in the NPS publication, Coastal Mapping Protocols* (and mapped for Canaveral National Seashore, among others) was not attained by this map. John Fry, chief of resources at CUIS, stated that the higher level of detail would be beneficial for park management, particularly for his successors.

A detailed geomorphic map of CUIS would require new mapping that leverages from recent LIDAR data, as well as from recent vegetation maps of the Cumberland Island area. USGS Coastal Geologist Jim Flocks agreed to investigate what LIDAR coverage might be already available. Depending on the level of GRI funding, a solicitation for bids for a new map of the park could be announced in 2010 on the Federal Business Opportunities website, FedBizOpps.gov. Standards for the map product will be detailed in the solicitation but would likely include delivering a product similar to the detailed geomorphic mapping produced in the GRI Geology-GIS Geodatabase Data Model format for the GRI at Canaveral National Seashore.

*found at: <http://www.nature.nps.gov/geology/coastal/newsletters/finalreportWEB.pdf>

Geologic Resource Management Issues

The principal geologic resource management issue discussed during the scoping session and on the field trip was back-barrier erosion. Other geologic resource management issues involve aeolian (windblown), fluvial (river), lacustrine (lake), and coastal processes. Disturbed lands and climate change also present issues for management. The ubiquitous horses that roam unchecked on the island exacerbate many of the geologic issues facing resource management.

Back-barrier Erosion

Back-barrier erosion, or erosion occurring west of the island's Pleistocene core, is caused by multiple sources (Jackson et al. 2007). Boat wake from ship traffic and recreational boating erodes the southern shoreline, which is approximately 60 m (200 ft) from the channel leading to the Kings Bay Naval Submarine Base. Channel dredging to keep the channel open for ship traffic causes shoreline and bank erosion. Channelized streams, stream piracy, meander cut-offs, sedimentation, wake from private boat traffic, and tidal flux in the Cumberland River and associated tidal creeks are dynamic processes that continue to impact the back-barrier erosion and shoaling patterns along the western shore and marsh area of the island. Natural processes resulting in meander cut-offs and stream piracy also are an issue with regards to park infrastructure. For example, some docks are becoming useless and will require relocation because shoaling and sedimentation is restricting

navigation. Waves and tidal currents undercut the bluff in the Terrapin Point area, causing mass wasting (slumps) and bluff retreat. Riprap and other man-made structures, such as rock and timber retaining walls, constructed to harden, or stabilize, the shoreline have worsened erosion in some areas. Some of the structures are designated historic structures and cannot be altered.

Feral horses and hogs accelerate back-barrier erosion by trampling vegetation, exposing bare soil to erosion, and by reducing the buffering affect of shoreline vegetation through overgrazing.

Other Geologic Issues

Aeolian issues. Grazing horses, vehicles (including occasional ATV use), and storms may destabilize dunes. The root masses of sea oats (*Uniola paniculata*) trap and anchor sand in back dune areas and are so critical in back dune construction that they are protected by Georgia law (Griffin 1982). In many areas of Cumberland Island, however, back dune vegetation has been destroyed by feral horses, feral hogs, and cows so that these huge dunes have been pushed westward by the prevailing winds into the maritime forest. Dune migration is an ongoing process. Dune stability and migration are important with regard to shore bird nesting sites, threatened and endangered (T&E) species, and sea turtle nesting. Non-native vegetation grows in some disturbed areas.

Mass wasting. Bluff collapse and slumping in the Terrapin Point area may destroy archaeological sites.

Lacustrine (lake) issues. Eutrophication, the process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth, is occurring in many of the island's lakes. While not a specific geologic problem, eutrophication is often accompanied by increased sedimentation. In the past, there was concern about dune migration and the possibility that migrating dunes would infill water bodies and alter habitat. Horses wading in lake sediments increase turbidity and so negatively impact the lake's wildlife habitat.

Coastal issues. Natural coastal processes are negatively impacted by the jetty at the south end of the island. The jetty was constructed as a barrier to the southward downdrift transport of sand and to keep the tidal inlet open for ship traffic. The southern tip of the island (Pelican Banks) is growing, while across the inlet, Fort Clinch State Park on Florida's Amelia Island is losing sand. Florida would like to transport the sand on Pelican Banks to Fort Clinch State Park. Increasing coastal development, especially marinas, puts environmental pressure on shoreline erosion and vegetation. Storms increase shoreline erosion and may destroy turtle nests. Sea level rise has similar effects. Extensive grazing of the marshes by horses has significantly reduced the buffering effect of the marshes with regard to wave action and tidal currents.

Disturbed lands. Although largely undeveloped, Cumberland Island has a long history of human activity. Roads, channelized streams, dredge spoils, dikes, levees, irrigation ditches, and shoreline armoring are present throughout the island. Some of these man-made structures are now in designated wilderness areas or on the National Register of Historic Places. Artesian wells on the island need to be plugged. Horses, more than any other animal on the island, disturb the land and negatively impact the island's ecosystem.

Mineral exploration and development. In the past, dredge spoils were used for road material.

Climate change. The major issue with regard to climate change is the increased erosion from storms due to the increase in storm intensity. With sea level rise and the decrease in marshland vegetation due to grazing, fluvial fetch is expected to increase, which will produce higher energy wave impact to infrastructure, such as docks, and cause flooding in the St. Mary's River.

Features and Processes

The scoping session for Cumberland Island National Seashore provided the opportunity to develop a list of geologic features and processes, which will be further explained in the final GRI report. Please note that the National Park Service monitoring manual (R. Young and L. Norby, editors. *Geological Monitoring*. Special paper. Geological Society of America, Boulder, CO.) is currently in press and will contain information on monitoring of geologic features and processes found in NPS coastal units. These features at Cumberland Island National Seashore include:

- *Aeolian (windblown features).* The most prominent landforms on Cumberland Island are the north-south trending sand dunes. The dune system includes primary (foredunes) and secondary dunes (back dunes), interdune meadows and wetlands (Sweetwater Lakes complex), and remnant (paleo) dune and swale topography.
- *Caves and karst.* No major cave or karst features are present although there is a thin calcareous layer in the subsurface that produces a few small sinkholes.
- *Fluvial.* Stream channel morphology and associated fluvial features and processes include stream meanders and meander-cutoffs, stream piracy, cut banks, back-barrier tidal channel flux, and association with marshland vegetation.
- *Hillslope processes.* Cumberland Island is cored by Pleistocene deposits, which crop out as bluffs in the northern back-barrier region. Undercutting of the bluffs by wave and tidal energy causes bluff collapse and slumping.
- *Lacustrine (Lake).* Cumberland Island contains many lakes with some ranging up to several acres in size. Lake Whitney is the largest fresh water lake on the island.
- *Coastal.* The Cumberland Island beach zone includes the dune ridge, the berm, the beach face, and the low-tide terrace. An offshore trough and sand bar develop in the surf zone. Waves, tides, and longshore currents contribute to the construction and destruction of the beach zone. Tidal inlets border the island to the north and south. An extensive salt marsh and tidal creek system has developed in the protected intertidal waters behind Cumberland Island. Construction of the jetty at the southern end of the island began in 1881 and finished in 1904. The jetty acts as a sediment trap, and approximately 3 sq km (200 ha; 494 acres) of sand has been added to the south end of Cumberland Island.
- *Seismic.* A fault might run along Cumberland Island, but it is not well-defined. The potential for seismic activity (i.e. earthquakes) is minimal although a historic earthquake in Charleston, South Carolina rang the bell in St. Augustine and was probably felt in the Cumberland Island area.
- *Paleontological resources.* Pliocene-age vertebrate fossils including shark teeth, ray plates, and turtle plates may be found in the spoils material dredged out of Cumberland Sound (Griffin 1982).

Larry West (NPS SECN) suggested consulting the recently published *Paleontological Resource Inventory and Monitoring* report for the SECN to review the paleontological resources in the monument (Tweet et al. 2009). The following information is from that report

Although not in a formal museum collection, teeth of the extinct shark *Carcharodon megalodon* and other specimens are kept at Cumberland Island National Seashore. A tortoise specimen from Cumberland Island exists in the Florida Museum of Natural History collections. Two other Cumberland Island National Seashore specimens reside at the Southeast Archeological Center (SEAC). The first is a fossil bone (lot CUIS 32032) collected from Slave Cabin Ruins #15. The second specimen (lot CUIS 45461) is an unidentified fossil collected from the Dungeness Wharf Midden (Tweet et al. 2009).

- *Age dates.* The fossils on Cumberland Island have been generally age-dated as Pleistocene, but specific age-dates for the fossils have not been reported. The Silver Bluff/Princess Anne unit that is exposed on the back side of the island has been identified as Pleistocene, but the unit may include Pliocene deposits, also. More research is needed to determine the age of this deposit.
- *Type sections:* Although exposed on Cumberland Island, neither the Silver Bluff unit or Princess Anne Formation have their type section on the island. The type section for the Princess Anne Formation is in the village of Princess Anne, Princess Anne County, Virginia. Silver Bluff has been abandoned as a lithostratigraphic term and is now considered to be an informal unit representing a terrace or shoreline complex.

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Table 3. Scoping Meeting Participants

Name	Affiliation	Position	Phone	E-Mail
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