FINAL DRAFT

Accreted Land Management Plan

Sullivan's Island, South Carolina

Sullivan's Island, South Carolina

Prepared for:

Town of Sullivan's Island
South Carolina

— DRAFT FINAL —

ACCRETED LAND MANAGEMENT PLAN
Town of Sullivan's Island South Carolina

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COVER: 2006 aerial courtesy of SCDNR

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1.0 INTRODUCTION

The town of Sullivan's Island includes upward of 190 acres of accreted beachfront property, placing it among a handful of barrier islands in South Carolina that have gained sand during the past century (Hayes 1994, Kana and Gaudiano 2001). Historical shoreline studies dating back to the 1970s (eg – Stephen et al 1975) attributed the buildup along Sullivan's Island to Charleston Harbor jetty construction in the late 1800s. Also, an important factor is a plentiful updrift sand supply which periodically bypasses from Isle of Palms to Sullivan's Island by way of Breach Inlet (Nelligan 1982).

Following its construction a century ago, the Charleston jetty trapped sand before it could proceed around the south end of the island. Since then, extensive buildup along the front beach has buried the landward end of the jetty and now allows sand to migrate freely over the weir section and accrete along the western end of the island. Some sections of the beach have accreted over 1,500 feet (ft) since the 1940s.

As accreted land (AL) evolves, a succession of vegetation types occurs that are typical of low-country barrier islands. First to appear are dune grasses and pioneering beach shrubs such as *Iva imbricata* (beach elder). Later stages bring species such as *Yucca* (Spanish bayonet). Waxed myrtle (*Myrica cerifera*) is a dominant transition species that generally becomes established within ten years after the land has accreted. If the land remains free of tidal flooding, primary maritime forest species (palmetto, live oak, cedar, magnolia, loblolly pine) become established. After several decades free from flooding, the maritime forest species grow high enough to blanket the myrtle and other shrubs, leading to a natural die-off of the understory. The type of vegetation in the backshore area offers insight regarding the age of the land:

- Grassed areas are usually very young (measured in a few years).
- Waxed myrtle zones are at least one decade old.
- Forested areas are at least several decades old.

As new land has accreted and vegetation has matured, the character and vistas of the beach front have changed. Views of the ocean have been altered; access has become more difficult; and new habitats have formed. Some aspects are generally favorable such as increased separation between development and damaging waves. Other aspects are problematic, such as blocked views, increased fire hazards, nuisance species, and lowered security along beach-access paths.

Existing Ordinances and Deed Restrictions

In 1991, the town of Sullivan's Island took steps to protect over 90 acres of accreted beachfront property from residential and commercial development by means of ordinance and deed restrictions. This has created a rare conservation and recreation zone along the seaward edge of a populated barrier island. The 90 acres have continued to grow by way of natural accretion and now support a great biodiversity – including maritime grassland, shrub-land forest, and interdunal wetland (and birds of many species) – that is readily accessible to residents and visitors.

Under the existing ordinance, the Town allows contiguous property owners to prune specifically identified shrubs (eg – waxed myrtle) to maintain oceanview corridors. The impacts of such pruning can be beneficial as well as detrimental to associated biological communities and natural, social, and economic resources – depending on the objective. For example, selective pruning encourages horizontal growth of the applicable plant into areas that could be occupied by other plants to create more diversity of species. Expanding understory inhibits movement of animals, increases the density of brush, and provides more fuel for fires during drought conditions. Some believe limiting the height of shrub species increases the vulnerability of the area to storm tides. Others point to the diminishment of property values and, potentially, the local tax base when oceanfront houses become hidden behind stands of maritime forest. Dense vegetation adjacent to a popular suburban beach introduces security and public-safety issues that are generally of less concern along other barrier islands where development is close to the ocean.

With a range of opinions regarding how the accreted land of Sullivan's Island should be managed, the zoning provisions of 1991 are not considered to be adequately science-based (Town of Sullivan's Island 2007). Furthermore, the existing ordinances do not provide for comprehensive conservation management. In addition, a number of conditions have changed since 1991, and therefore, revisions to ordinances and deed restrictions within the AL area are now considered necessary — development has intensified on the island with a majority of year-round residents; there has been a marked increase in the size and density of shrubs and trees; and land-management methods and technologies have advanced.

Accordingly, the town of Sullivan's Island issued a request for qualifications for outside assistance in developing a scientifically-based accreted land management plan (ALMP). In June 2008, the Town retained a Team of professionals from the firms of Coastal Science & Engineering Inc (CSE-Columbia), Sabine & Waters Inc (S&W-Summerville) and Dewberry (Mt. Pleasant) to assist in preparing an ALMP for the oceanfront. The principal purpose of this plan is to outline a set of scientifically-based strategies for conserving the AL and balancing the need for:

Conservation of the area	Preservation of views
Storm protection	Fire safety
Beach access	Habitat diversity

1.1 Accreted Land Management Plan Goals

The town of Sullivan's Island (2007) outlined a number of goals intended to achieve balance among factors ranging from ecological values to aesthetics, access, and recreation for the benefit of all Sullivan's Island residents. These goals were refined in a series of proposed principles for management of the Town's accreted land (Appendix 1) approved by the Town Council on 15 December 2009. The management goals approved by council upon review of the draft findings of the present report and receipt of input from the community (forums on 4 August and 7 December 2009) are summarized as follows. The ALMP should be designed to:

a) Achieve *balance* among ecological values, aesthetic concerns, and recreational and quality of life factors to benefit all Sullivan's Island residents.

b) Maintain healthy, sustainable dune land and developing forests through active management.

c) Apply habitat-appropriate management techniques.

d) Maximize native plant and animal diversity.

e) Limit the spread and establishment of invasive species.

f) Facilitate breezes and vistas where appropriate.

g) Manage the land for future generations by providing protection from storm and tidal impacts.

h) Monitor management actions and modify strategies as needed.

This report serves as a basis for formulating the ALMP, provides an inventory of existing conditions, reviews the natural processes that have produced today's conditions, predicts likely changes over the next several decades as the land evolves, and offers a selection of management strategies for the future. The report addresses the physical processes that have molded and shaped the land, biology, and botany that have transformed the land from active beach to maritime forest and the degree of vulnerability of the land to damaging storm surges, waves, and wave heights. Some specific analyses contained herein include:

- Evaluation of the value of shrub forest in the area.
- Evaluation of the value of the development of maritime forest in the area.
- The present condition of the area and any impact on erosion control, storm protection, recreation, education, and plant and animal species which may use or cannot use the area.
- An inventory of resources to determine any areas of potential compatibility or conflict between environmental values and nearby development.
- Evaluation of the impact of trimming and pruning on the existing shrub forest.
- Evaluation of the need for fire control in the AL area.
- Evaluation of the need for beach-path and dune-walkover maintenance in the area.

The report also reviews public use and safety issues with the AL and outlines recommendations for long-term management.

The Town Council convened a series of public forums in which early drafts of this report were presented to the community so as to provide all interested citizens with a common background and framework for discussion. Then with community input, the final set of management goals was developed. Implementation of the ALMP is anticipated to be an ongoing process into the future, with adjustments to management techniques applied as needed based on regular monitoring of the AL area.

1.2 Organization of the Report

The study Team (CSE–S&W–Dewberry) includes professionals in the fields of coastal geology, coastal engineering, ecology, and forestry management. Each Team member was responsible for key elements of the study. Brief biographies for the Team members are given at the end of the report.

The report is organized into sections discussing the general setting (2.0), existing conditions (3.0), historical changes (4.0), future changes and land evolution (5.0), applicable land management alternatives (6.0), and management recommendations (7.0). Existing conditions (2008) are described in detail before historical changes to give the reader a basis for understanding coastal processes and for interpreting the nature of the changes that have occurred over the past century or so. Within each section are multi-disciplinary topics such as coastal processes, flora and fauna, storm histories, etc, as applicable. Existing conditions have been used to evaluate relative storm-wave vulnerability using state-of-the-art numerical models (c/o Dewberry). Where appropriate, certain background data, detailed plant inventories, and the basis of the models have been provided in the appendices. A list of references used by the Team has also been provided.

In this report the following acronyms or names are used:

ALMP Accreted Land Management Plan (ie – the overall study).
AL Accreted Land "Study Area" as delineated in Figure 1.1.
Team The preparers of the study including the firms, Coastal Science & Engineering (CSE), Sabine & Waters Inc (SW), and Dewberry (DEW).

1.3 Accreted Land Management Plan Study Area

The area of interest is the ocean shoreline of Sullivan's Island from Breach Inlet to Fort Moultrie (Fig 1.1). The specific section of oceanfront that has accreted begins near Station 14 and ends at approximately Station 29. A tradition at Sullivan's Island has been to name streets extending perpendicular to the oceanfront as "stations," either after the days before roads (when Life Saving Stations monitored the coastline for vessels in distress) or in connection with the trolley stops that ran the length of the island around the end of the 19^{th} century. [Note: Sullivan's Island is US Coast Guard Station 196, built in 1894-1895]. Street "stationing" increases from the west end to the east end of the island.

Sullivan's Island is ~3.1 miles long, bounded by Breach Inlet at the east end and by Charleston Harbor along its west end*****. The shoreline between Fort Moultrie (~Station 14) and Station 29 encompasses about 14,000 ft of oceanfront. Accretion since the mid 1900s has added about 190 acres of high ground between developed property and the present seaward edge of vegetation line.

> [*In this report, **east** and **west** are adopted as the primary alignment of the oceanfront. There are common references in the literature to sand moving from "north to south" along the South Carolina coast. A truer orientation for Sullivan's Island would be from east-northeast to west-southwest as illustrated in Figure 1.1.]

For purposes of the present study, the Team evaluated conditions from Breach Inlet to Fort Moultrie, including sand bars associated with the inlet. The landward limit of the study is generally Atlantic Avenue, the seawardmost access road paralleling the beach. Much of the data in the report is referenced to a survey control line along Middle Street (main access road along the island). Using engineering nomenclature, control line transects begin at 0+00 (western tip of the island) and extend to Breach Inlet (190+00). It is easy to estimate distances with this system by simply omitting the "+" sign. For example, transect 50+00 is ~5,000 ft from the western tip of the island; transect 85+35 would be ~8,535 ft from the western tip, etc. Because the survey control line wraps around the west end of the island and is positioned about 1,000 ft inland, its length will not exactly match the oceanfront lengths. Nevertheless, the control line provides a necessary reference for evaluating historical changes and dividing the shoreline into discrete lengths ("reaches") having similar features.

The majority of beachgoers at Sullivan's Island access the beach by way of paths through the AL study area which begin at each street end. Some paths, such as Station 16, are wide enough for the passage of emergency vehicles; however, most are narrow footpaths (Fig 1.2). Swales between some dune ridges are wet much of the time with standing water and associated "wetlands" vegetation. The western half of the study area is heavily forested, whereas the eastern half has less-mature vegetation.

Some property owners periodically prune vegetation to around 5 ft from the ground, a practice that has been allowed under Town deed restrictions dated 12 February 1991 (Appendix 2). Pruning by swaths seaward of some oceanfront properties has left some sections of the study area with a relatively uniform growth of a single dominant species such as wax myrtle (Fig 1.3). Other areas have a variable canopy of shrubs (eg – groundsel tree, blackberry, peppervine, poison ivy), trees (eg – laurel cherry, eastern red cedar, Chinese tallow), and dune grasses (eg – sea oats, beach morning glory) (Fig 1.3).

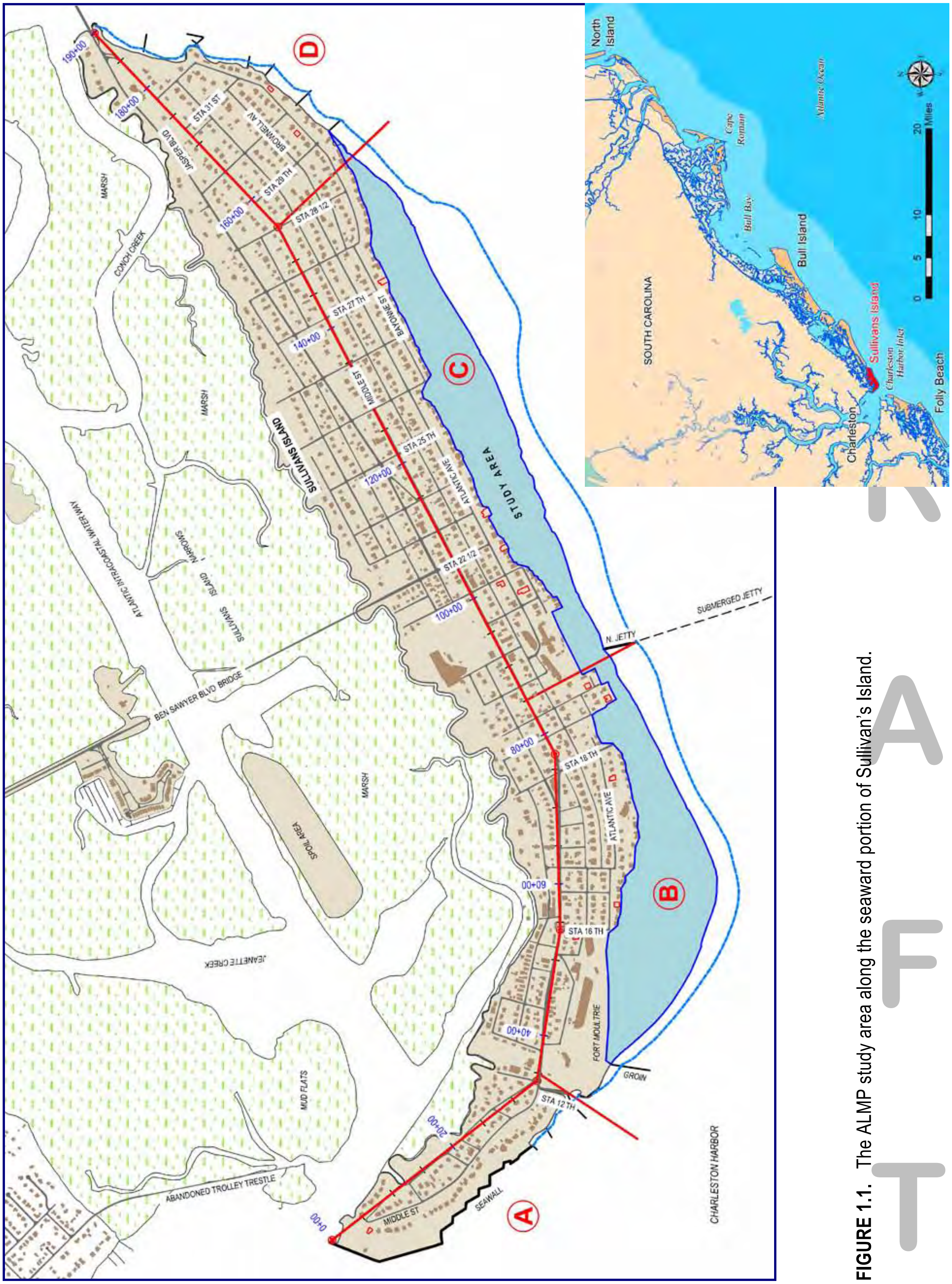


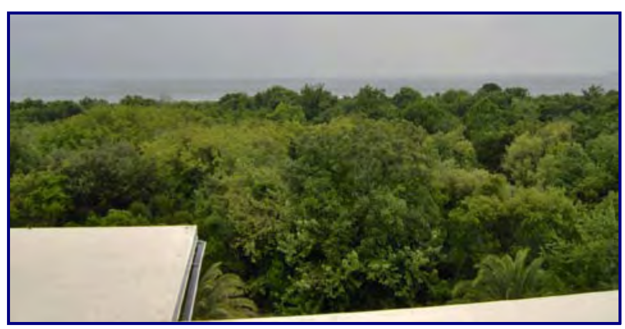
FIGURE 1.1. The ALMP study area along the seaward portion of Sullivan's Island.

FIGURE 1.2. Representative accesses in the study area in 2008: [upper] the heavily wooded west end (Station 16), [center] narrow central section near Station 18, and [lower] the east end around Station 26.

FIGURE 1.3.

The upper infrared aerial photo (SCDNR 2006) shows swaths of vegetation (swaths A, B, C, and D) which have not been pruned, situated between areas which have been pruned.

The ground photos (T Hair, August 2008) show representative areas which have been pruned (center left) and unpruned (center right). The lower right photo is a view of a variable canopy of shrubs, trees, and dune grasses which can be seen in the AL area.



1.4 Site Constraints and Opportunities

Sullivan's Island is in the enviable position of being one of the healthiest barrier islands in South Carolina (Hayes 1994). Large-scale accretion along the majority of the oceanfront over the past century has created a broad dune field seaward of development. This area buffers buildings during storm events, provides a natural edge between the ocean and development, and offers an attractive set of habitats for coastal wildlife. However, the accretion zone has low relief and is subject to overtopping during major storms (Fig 1.4). Dense vegetation in some areas combined with easy public access creates certain public safety issues including increased risk of fire and assaults. The scale of the study area and its inherently variable nature are assets. This offers opportunities for improved access, enhanced dunes and wetlands, and improved habitat for certain species.

The ALMP must take into consideration certain jurisdictional and regulatory constraints as well as the physical, topographic, and vegetative conditions of the site. This section of the ALMP provides a synopsis of regulations and governmental jurisdictions which impact activities within the AL study area.

Applicable Jurisdictions, Regulations, and Controls

The AL study area is subject to certain local, state, and federal jurisdictions and regulations:

- State and local development set backs and control lines under the Beach Management Act (BMA – 1988/1990) by SC Department of Health and Environmental Control (SCDHEC)–Office of Ocean and Coastal Resource Management (OCRM).
- Federal National Flood Insurance Program (NFIP) and local Town flood ordinance.
- Local deed restrictions established by the town of Sullivan's Island (Appendix 2).
- Federal Endangered Species Act (1973) which provides certain protections to rare plants and animals that occur in or utilize a particular area.
- Federal Clean Water Act (1982) regulations which define wetlands and restrict some activities within and near their boundaries.

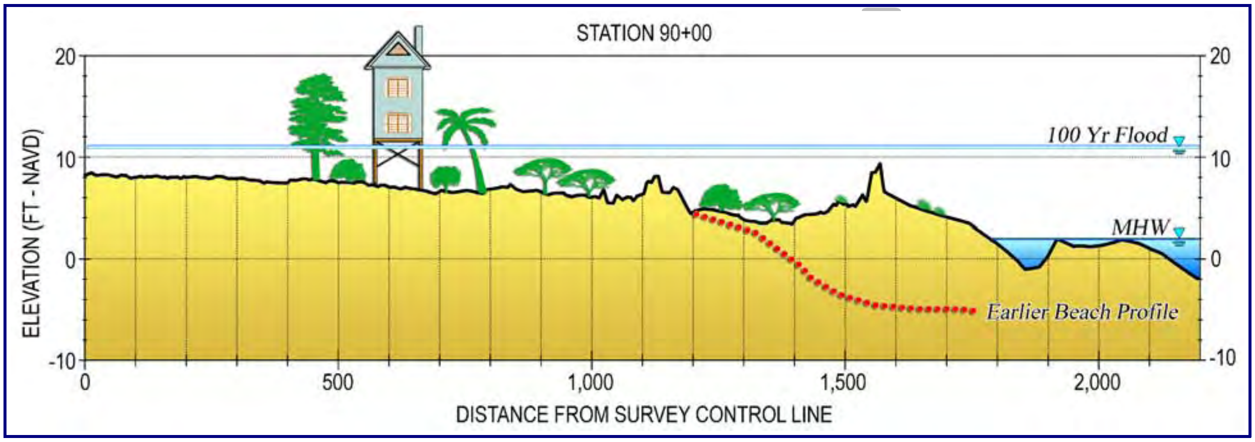


FIGURE 1.4. Representative profile of the AL study area showing the low-relief accreted land and vegetation cover that have evolved seaward of houses during the past several decades. Note the profile scales (in feet) are greatly exaggerated in the vertical. House and vegetation (not to scale) are stylized to help the reader interpret the cross-section. Along many South Carolina beaches, "oceanfront" buildings would be situated close to the foredune (ie – ~1,500 ft seaward of the control line in this example).

Following is a brief description of these jurisdictions and regulatory controls.

Development Control Lines

OCRM establishes jurisdictional lines along the open coast under the BMA of 1988 (amended in 1990). Two lines are established:

> *Baseline*: The approximate seaward dune crest (in the absence of shore-protection structures) ***or*** the most landward shoreline (approximate seaward vegetation line) during the past 40 years. The former applies to the ocean coast away from inlets. The latter applies to inlet-influenced coasts such as Sullivan's Island.
>
> *Setback Line*: A line measured landward of the baseline (a distance equal to 40 times the site-specific erosion rate) ***or*** a minimum of 20 ft landward of the baseline along accreting shorelines.

Figure 1.5 illustrates the present baseline and setback line for Sullivan's Island. Under the BMA, jurisdictional lines are to be updated every ten years or so. The present lines were established in 2009. As shown in Figure 1.5, the baseline and setback line pass through the middle of the AL study area and are seaward of existing development parcels in Reach B and Reach C by ~200–800 ft. The fact that the lines closely parallel each other (20 ft apart) confirms the official determination that most of Sullivan's Island accreted during the past ~40 years.

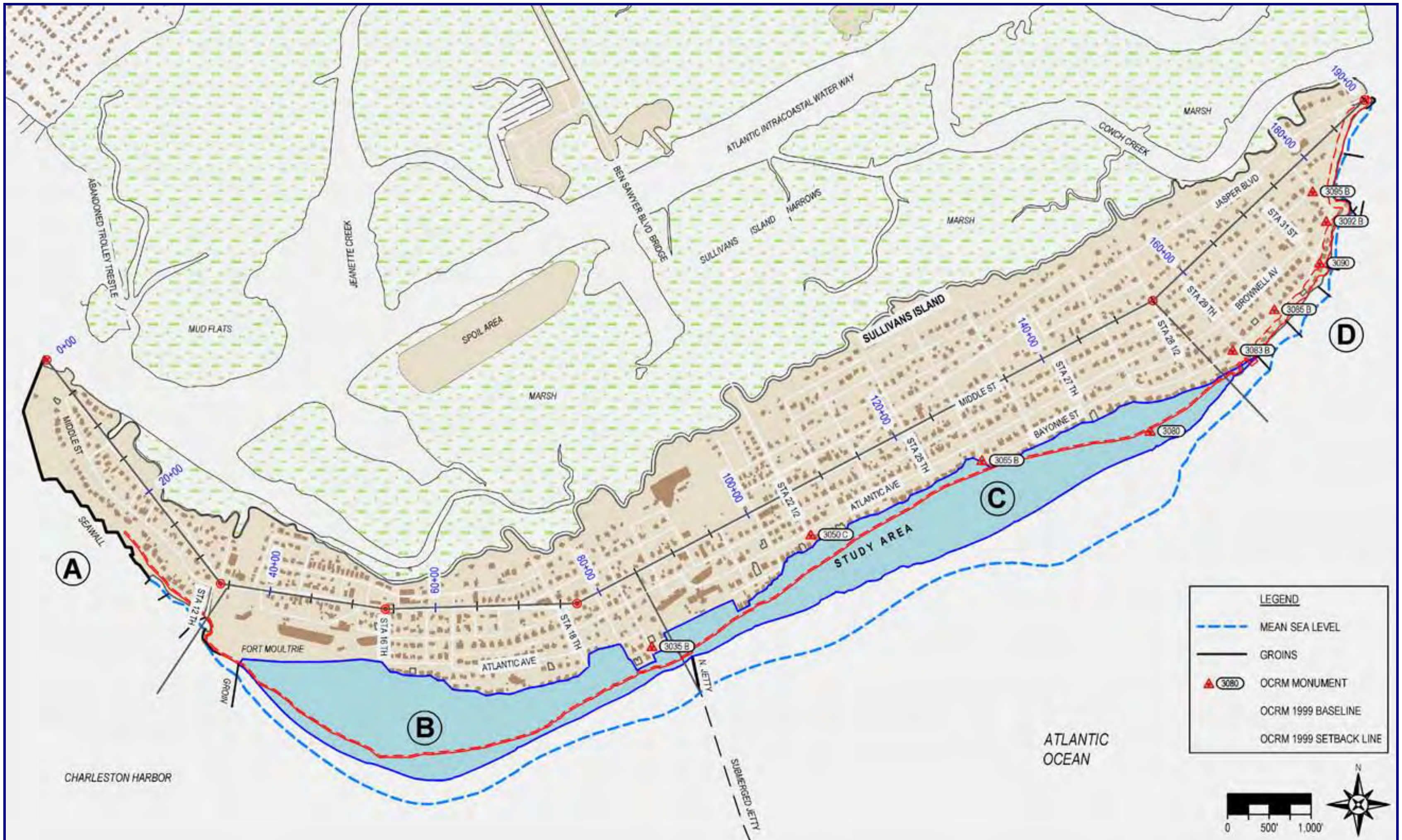


FIGURE 1.5. Jurisdictional baselines and setback lines under the BMA for the oceanfront along Sullivan's Island. The lines are revised every ~10 years by OCRM based on the erosion and accretion trends for the area. Under the BMA, the lines may move seaward over time due to natural accretion or beach nourishment. Local governments may impose additional restrictions (establish more landward development control lines) at their discretion.

In the case of Sullivan's Island, the lines are well seaward of existing development along the AL study area. However, at Breach Inlet, the lines encroach certain properties because of prior shoreline positions, erosion, or limited beach and dune width. An implication of the development control lines for the ALMP is that certain activities may be allowed, without state permit, landward of the setback line. This could potentially include alterations to vegetation and topography for the benefit of the community, enhanced storm-surge protection, fire control, or public access and safety.

National Flood Insurance Program (NFIP)

The National Flood Insurance Act of 1968 established the NFIP, enabling property owners in participating communities to purchase flood insurance along the coast. Sullivan's Island participates in the NFIP and enforces NFIP regulations through their locally adopted flood ordinances. The Federal Emergency Management Administration (FEMA) administers the NFIP and establishes the technical basis and controlling elevations for development under the program. Among the regulations of the NFIP, first-floor elevations of habitable structures must be constructed at or above the 100-year base flood elevation (BFE). Along the open coast, an additional component (the action of waves) is incorporated into the building requirements for habitable structures via V-zone flood boundaries. [Note: A summary of the NFIP can be found at http://www.fema.gov/about/programs/nfip/index.shtm.]

Because of its importance to Sullivan's Island, a part of the ALMP relates to a review of impacts to flood levels and wave hazards under existing and anticipated future conditions by means of state-of-the-art models developed by FEMA.

Deed Restrictions

To protect a portion of the Sullivan's Island AL study area, the Town placed deed restrictions on a 90-acre portion of the property. Ordinances and deed restrictions are set forth in Appendix 2 of this report. Among the deed restrictions are:

- No buildings with roofs.
- No asphalt, concrete, or nonporous pavement.
- No power lines, conduits, stations, or pads (some easements accepted).
- No sewer lines or water lines, pipes, or lift stations.
- No commercial activities.

The deed restrictions allow the Town Council "unrestricted authority to trim and control the growth of vegetation for purposes of mosquito control, scenic enhancement, public and emergency access to the Atlantic Ocean, and providing views of the ocean and beaches to its citizens." (Appendix 2, Item 2).

Threatened and Endangered Species

The Endangered Species Act (ESA) [7 USC §136; 16 USC § 460 et seq (1973)] was established in 1973 to provide for the conservation of plants and animals in threat of extinction as well as their habitats. As of 2008, there were 1,574 endangered species listed and 351 threatened species. The listed species include birds, mammals, fish, reptiles, insects, crustaceans, and plants, 40 percent of which are plants.

The ESA defines an endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range" [16 USC § 1532(6)]. A threatened species is "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" [16 USC § 1532(20)]. Though endangered and threatened species have different definitions, they are afforded the same protection under the ESA.

The ESA charges the US Fish and Wildlife Service (USFWS) with the task of maintaining a list of threatened and endangered species, with assistance from the US National Oceanic and Atmospheric Administration (NOAA) and the National Marine Fisheries Service (NMFS). Section 7 of the ESA requires any federal agency to consult with USFWS and NOAA to ensure that an action authorized, funded, or carried out by that agency is not likely to jeopardize the continued existence of a listed species or result in the destruction of the critical habitat for the species. Furthermore, Section 9 of the ESA prohibits unauthorized taking, possession, sale, and transport of listed species by any person. If a species recovers to the point that it no longer meets the requirements for threatened or endangered status, it may be de-listed. This has happened recently for the American alligator and the bald eagle.

Table 1.1 presents a list of animal and plant species that have state or federal legal protection and are either known to occur or which may possibly occur in the AL study area. Those that were seen in the AL area during our Team's surveys are in bold. Further information regarding species listed in Table 1.1 may be found in Appendix 3.

TABLE 1.1. Animal and plant species having federal and state legal protection and are either known to occur or which may possibly occur in the AL study area.

Common Name	Scientific Name	Federal Status	State Status
Bald Eagle	*Haliaeetus leucocephalus*	Protected	Endangered
Wood Stork	*Mycteria americana*	Endangered	Endangered
Kirtland's Warbler	*Dendroica kirtlandii*	Endangered	Not Listed
Least Tern	***Sterna antillarum***	**Not Listed**	**Threatened**
Wilson's Plover	***Charadrius wilsonia***	**Not Listed**	**Threatened**
Piping Plover	***Charadrius melodus***	**Threatened**	**Threatened**
Rafinesque's Big-eared Bat	*Corynorhinus rafinesquii*	Not Listed	Endangered
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	Endangered	Endangered
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	Endangered
Loggerhead Sea Turtle	*Caretta caretta*	Threatened	Threatened
Green Sea Turtle	*Chelonia mydas*	Threatened	Threatened
Shortnose Sturgeon	*Acipenser brevirostrum*	Endangered	Endangered
Seabeach Amaranth	*Amaranthus pumilus*	Threatened	Threatened

Wetland Regulation

The Federal Water Pollution Control Act [renamed the Clean Water Act (CWA) in 1982] includes a multitude of regulations designed to protect the nation's waters. These include river and estuarine protection, ensuring clean drinking water, and prevention of freshwater wetland destruction. The CWA places jurisdiction over some waters in the hands of the US Army Corps of Engineers (USACE).

Section 404 of the CWA requires a permit from the USACE for the discharge of fill material into navigable waters of the United States, including wetlands. Activities in wetlands for which permits may be required include:

- Placement of fill material.
- Ditching activities when the excavated material is sidecast.
- Levee and dike construction.
- Mechanized land clearing.
- Land leveling.
- Most road construction.
- Dam construction.

Some wetlands that are subject to jurisdiction by USACE may fall under the jurisdiction of the state of South Carolina. OCRM is tasked with protecting the quality of the coastal environment and promoting the economic and social improvement of the coastal zone. The South Carolina Coastal Zone Management Act of 1977 gives OCRM jurisdiction in all seven of South Carolina's coastal counties, including Charleston County. Though there is some controversy concerning OCRM's authority over federal nonjurisdictional wetlands, discharge of fill material into wetlands may require additional permitting from OCRM. [See Appendix 4 for more information, including wetland definition, wetland impacts, and permitting.]

Exotic Invasive Species

There are a number of federal and state laws related to exotic invasive species (eg – Title 46 of the 1976 Codes of Laws updated through 2007). The Department of Natural Resources (DNR) provides guidelines and management recommendations. Despite controls on their import and use, some plants imported from other parts of the world have escaped cultivation and have disrupted native ecosystems. These "exotic invasive" plants all share several common characteristics – they grow quickly, propagate easily, resist native pests, grow in a wide range of soils, can invade undisturbed habitats, and have traits considered attractive enough to encourage further distribution by people (Jubinsky 2002). Appendix 5 contains information regarding management of these species and other common invasive species of the southeastern United States.

Physical and Topographic Controls

The ALMP is necessarily constrained by the physical boundaries of the AL site and its relationship to the ocean and adjacent development. Physical processes such as winds, waves, tides, and currents have created the AL area via the introduction, deposition, and reshaping of littoral sediments. While sandy sediments dominate, there are also accumulations of finer grained sediments in some swales, which provide opportunities for more diverse species to occupy the AL area. As long as sediment continues to accumulate seaward of the beach, accreted land will remain stable. However, the relatively low elevation will leave it exposed to storm surges.

Hurricanes, like *Hugo* (1989), will potentially reshape the topography of the accreted land. Surges and waves associated with major storms tend to flatten the dunes and fill in the swales between dunes. Because of its strategic position between the ocean and existing development, the AL area provides a critical line of defense over which the hazards of storm waves can be attenuated. The effectiveness of the AL area in absorbing waves and protecting the development and infrastructure of Sullivan's Island is directly related to its elevation and width. Therefore, the ALMP should take into account the accreted land's important shore-protection function.

Vegetative Controls

The temperate climate of South Carolina, sandy sediments that dominate the AL study area, and the relatively harsh effects of salt spray all limit the types of plants that can grow in this setting. However, given its scale, the AL is wide enough to allow a range of distinct habitats to thrive. More salt-tolerant vegetation occupies the seaward edges and serves as a shelter to more diverse freshwater species along interior sections of the AL area.

As the present report describes in detail in Section 3, some portions of the AL area are low swales that support freshwater wetland species. Fine-grained sediments have accumulated and serve to retain fresh water. An associated consequence is an increase in mosquitos compared with barrier islands lacking comparable accreted land seaward of development.

An underlying vegetation control is time. There is a natural progression of plants in this setting once land has accreted. Progressing from grasses to shrubs and ultimately to mature maritime forest requires about one century. Therefore, the youngest portions of the AL are not expected to have mature trees today, but there is a likelihood some of these areas will support a diverse forest decades from now. This inexorable process provides opportunities for as well as constraints on the ALMP.

An additional consideration relevant to the ALMP is the presence of invasive species which, if left unchecked, may become the dominant plant type in some areas. Such species include Chinese tallow (*Sapium sebiferum*), cattails (*Typha* spp), Chinese privet (*Ligustrum sinense*), autumn olive (*Eleagnus umbellata*), Japanese honeysuckle (*Lonicera japonica*), and wisteria (*Wisteria* sp). The control of invasive vegetation can be accomplished by utilizing biological control agents (insects and pathogens), herbicides, mechanical manipulation, or combinations of these methods (Jubinsky 2002).

1.5 Alternative Management Measures

There is a spectrum of management measures possible for the accreted land, ranging from doing nothing to large-scale manipulation of topography and vegetative cover. The Town recognizes that a conservation management plan may be directed toward a range of objectives and that the final plan will depend on which objectives are emphasized (Town of Sullivan's Island 2007, pg 3). The Team prepared this document (ALMP) according to the scope of services with the intent of:

- Describing existing conditions.
- Analyzing the relative value of habitats and species in the area.
- Demonstrating the evolution and history of the accreted land.
- Projecting likely changes into the future.
- Predicting the outcomes of certain management alternatives, such as trimming and pruning of the shrub forest or selective application of controlled burns.
- Analyzing public health and safety issues in connection with management alternatives.
- Developing the final ALMP after review and consideration by the Town of the data provided herein.

The final plan draws on input from the community and reflects a consensus regarding which objectives are emphasized. To facilitate community review and discussion, the Team considered four broad management alternatives:

1) Do nothing and leave the AL to evolve naturally.
2) Continue present practices such as shrub pruning, maintenance of the beach-access paths, etc.
3) Implement more extensive vegetation controls to enhance habitat diversity and associated modifications of vistas.
4) Modify the topography of the land in conjunction with vegetation management so as to increase protection during major storms.

Each of the general alternatives has implications regarding the evolution of the AL area and certain specific issues. For example, doing nothing could ultimately lead to loss of ocean views, possible reductions in the tax base, continued vulnerability of houses and community infrastructure to storm surges, and increased public safety issues. However, doing nothing is inexpensive and will lead to expansion of certain forest habitats that attract back-barrier wildlife.

Present practices of pruning and brush clearing along access paths have generally been limited in scope and have been implemented by individual property owners or the Town. The report outlines the positive and negative consequences of present practices, such as preservation of views, maintenance of dense understory cover, expansion of one dominant shrub species, ongoing cost of pruning, and potential increase in fire hazard.

The Team evaluated the potential impact of more extensive vegetation controls such as removal of shrubs and replacement with grasses along broad corridors to provide greater variety of habitat, improve vistas, and reduce potential fire hazards. Controlled burning is one management measure that can lead to greater habitat diversity while reducing the density of understory vegetation. Expanded efforts at controlling the spread of invasive species or understory vegetation potentially reduce associated problems with rodents while improving habitat for certain birds such as painted buntings. Changes in vegetation have potential impacts on wave attenuation during storm surges.

The Team used the existing variety of habitats to test alternative configurations during storm surges (Section 5). This provides the community with a more quantitative basis for determining whether removal of dense shrub or tree vegetation increases the vulnerability of development to damaging storm surges.

The final broad alternative considered relates to manipulation of the existing topography. The Team evaluated the degree of protection afforded by the existing elevations in the AL area and potential improved protection if a beneficial dune is constructed. The purpose of this analysis was to determine whether a relatively small dune could provide better storm-surge protection and reduce potential damages to oceanfront structures.

The various management alternatives were also considered with respect to the applicability along various portions of the AL. For example, the Team's review of existing conditions shows considerable variation between the western half and eastern half of the AL area. Section 4 describes the historical evolution of the AL and helps explain why there are distinct differences from one section to another. Present differences in vegetative cover suggest that the final

ALMP should consider site-specific management approaches which favor different objectives rather than a single set of regulatory controls and guidelines for the entire area.

Each broad alternative will involve costs whether it is actual outlay to change vegetation and the land or an aesthetic cost or potential reduction of property values if nothing is done. It is beyond the scope of the ALMP to outline costs of all alternatives. Instead, the Team has attempted to offer broad guidelines regarding quantities and costs under a limited selection of alternatives. Detailed cost estimates will necessarily depend on the alternative approach(es) favored by the community. As part of the Team's work, a list of potential outside funding sources was developed. The AL offers a unique opportunity for barrier-island habitat management near an urban center. Nature trails, an interpretive center, and a related wildlife park may attract sponsors while also funding certain management activities within the AL area.

The challenge for the community is to identify a set of objectives for the AL and prioritize their implementation. With diversity of habitats (as will be described in the next sections) comes a great range of management alternatives. The Team has prepared this report to help the community understand the origin of the accreted land, its present condition, and the likely changes to expect over the next several decades. With this background, the community can narrow the choice of management options and develop an ALMP that serves as a model for other barrier-island communities.

2.0 SETTING AND HISTORY

07/15/2010

This section of the ALMP describes the geography, geology, coastal processes, and ecology that have shaped development of Sullivan's Island, the accreted land, and its natural history. The AL area owes its existence to a surplus of sand arriving at the coast. A basic understanding of the processes responsible for the island's evolution and growth are central to the formulation of a rational, scientifically-based ALMP. Fortunately, there have been numerous studies on the origin of the South Carolina coast to draw upon and consider in the context of management plans for Sullivan's Island. Section 2 offers a primer on barrier-island ecology, a subject which is at the core of the ALMP. As detailed in Section 2.4, barrier islands are distinctive ecosystems, subject to extreme physical, environmental, and chemical conditions. To be successful, the ALMP must be adapted to the unique ecology of the island and the natural evolution of its fauna and flora.

2.1 Geography and Development

Sullivan's Island is one of a long chain of barrier islands along the South Carolina coast. It flanks the north side of the entrance to Charleston Harbor and provides storm protection to a broad expanse of salt marsh and tidal tributaries between Mt. Pleasant and the Atlantic Ocean (Fig 2.1). It is bounded to the east by Breach Inlet and Isle of Palms. Its ocean shoreline extends westerly and north into Charleston Harbor. The island's strategic location at the entrance to Charleston Harbor made it a natural site for fortifications dating back to the earliest settlement of Charleston (1600s–1700s). Fort Moultrie (a national monument) is the principal remaining battlement on the island. During World War II, concrete observation bunkers were also placed along the island for purposes of guarding Charleston Harbor.

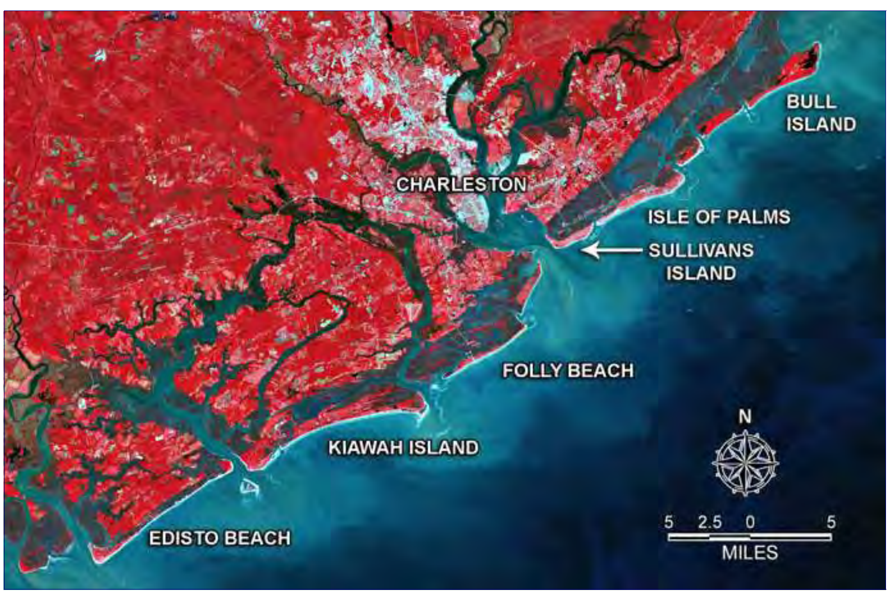


FIGURE 2.1.

The central South Carolina coast around Charleston showing the series of barrier islands that protect the mainland and marshes.

Sullivan's Island is strategically positioned at the east side of the Charleston Harbor entrance.

[2006 infrared image courtesy of SCDNR and RPI]

DRAFT

Today, Sullivan's Island is a residential development with primary and vacation houses occupying most of the high ground (Fig 2.2). The island's sandy and armored shoreline is ~3.8 miles long (including the margins along Breach Inlet and Charleston Harbor). Highland area comprises ~885 acres of platted property plus an estimated 190 acres***** in the accreted land (AL) study area. Recent census lists a population of 1,878 in 1,045 houses on the island (source: www.city-data.com). Approximately 800 houses (77 percent) are occupied with resident owners in over 70 percent of them and resident renters in the remainder.

The island's convenience to Charleston and its longer history of occupation, compared with most other South Carolina barrier islands, makes Sullivan's Island a well-established community. Commercial development is generally limited to small businesses and restaurants. There are no hotels or resorts on the island, and the town is incorporated with its own police force and fire department.

Access to the island is by way of a causeway and the Ben Sawyer Bridge over the Intracoastal Waterway that took the place of a trolley system and trestle bridge which serviced the island as early as the late 1800s. For many years, the bridge to Sullivan's Island and a bridge over Breach Inlet were the only direct vehicle access to Isle of Palms. Traffic congestion, severe on summer weekends, was relieved by the opening of the Isle of Palms connector in 1993.

Access to the oceanfront is via cross-streets ("stations") and pathways. Station numbers increase from west to east. Fort Moultrie is situated between Stations 12 and 16; the center of the island (Ben Sawyer Bridge) is near Station 23. The AL study area extends to Station 29. An ~3,000-ft-long shoreline segment flanks Breach Inlet. The main channel for Breach Inlet runs generally north-south and is oblique to the strand of Isle of Palms and Sullivan's Island. Houses along Breach Inlet are positioned close to the channel and are generally protected by revetments and groins.****** Along the AL study area, most oceanfront houses are presently situated 400–1,200 ft from the shoreline.

*****There are various estimates for the accreted land area. The study Team calculates this value from the highlighted area in Figure 2.2, which extends from platted lots to the seaward vegetation line.

******Groins are shore-protection structures built out from the shoreline to trap sand and deflect channels away from high ground. Six groins occur along the Breach Inlet shoreline outside the AL study area.

FIGURE 2.2. Infrared aerial orthophoto of Sullivan's Island (2006) showing the AL study area. [Source: SCDNR]

2.2 Climate of Sullivan's Island

The climate of Sullivan's Island is typical of coastal regions of South Carolina and is influenced by warm water of the Gulf Stream (Bellis 1995). It is a mild subtropical climate and remains relatively humid all year with prevailing winds from the west. Prevailing winds tend to be modified locally by the sea-breeze/land-breeze system associated with daily heating and cooling of the land. During the summer, the temperatures are typically upper 80s to lower 90s, occasionally reaching into the 100s with very high humidity and storms coming from the west and south. In the winter, average temperatures are in the 50s occasionally drop into the 20s with most storms approaching from west and south. Average annual rainfall is 49 inches with most precipitation from May to September. Hurricane season is June 1 to November 30, although the occurrence of hurricanes is very low (USDA 1971).

2.3 Geology and Coastal Processes

Sullivan's Island is geologically young, having formed within the past ~5,000 years (Nelligan 1982). Coastal plain barrier islands form by the accumulation of sandy sediments pushed up by waves. The gentle slopes of the continental shelf are subject to ocean waves and tides propagating from deep water. Shelf width and shape control the tide range to a certain extent and principal winds control wave direction. These physical processes combine to mold and shape sediments into the land forms along the coast.

The original source of sediments along the South Carolina coast is erosion of the Appalachian Mountains and discharge via numerous coastal plain rivers (Hayes 1994, Hayes and Michel 2008). However, this has been ongoing for over 200 million years. Considered over century to millennial time scales, the primary sources of sand on the coast are deposits already in the neighborhood, particularly the sand bodies that comprise today's barrier islands and inlet deltas (Hayes 1994, Kana and Gaudiano 2001).

Role of Sea Level

The general position of the shoreline between the coastal plain and continental shelf has moved cyclically in relation to the rise or fall of sea level. During the past half million years, mean sea level has fluctuated over 100 meters (m) in elevation (~330 ft) (Fig 2.3). Its present level is considered a "high stand" and is similar to levels 120,000 and 320,000 years ago (Imbrie and Imbrie 1979). About 20,000 years ago, sea level in the Charleston area was nearly 120 m (~400 ft) lower. Cycles of sea-level change have been correlated with global average temperatures and the expansion and contraction of continental glaciers. The most recent ice age tied up massive volumes of water over northern Europe, Asia, and North America. During periods of expansive glaciation, sea level is lower.

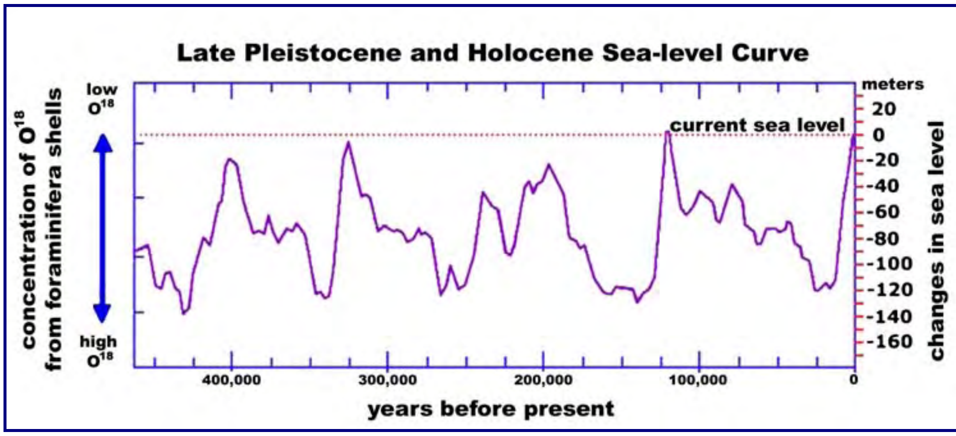


FIGURE 2.3. Global cycles of sea-level change over the past half-million years as interpreted by Imbrie and Imbrie (1979). The present position of sea level is considered a "high stand," similar to levels about 120,000 and 320,000 years ago.

As the curve in Figure 2.3 shows, sea level rose rapidly starting about 15,000–20,000 years ago. Researchers from South Carolina and Georgia, among other places, evaluated the recent rise and determined that sea level reached within 5–10 ft of its present level about 5,000– 6,000 years ago (eg – Colquhoun and Brooks 1986). Hayes and Michel (2008) (Fig 2.4) prepared an interpretation of minor sea-level fluctuations over the past several millennia. These are of interest because any tendency for a rise leads to inundation of the land. Conversely, a minor fall in sea level tends to shift the coastline offshore by some distance, depending on the slope offshore.

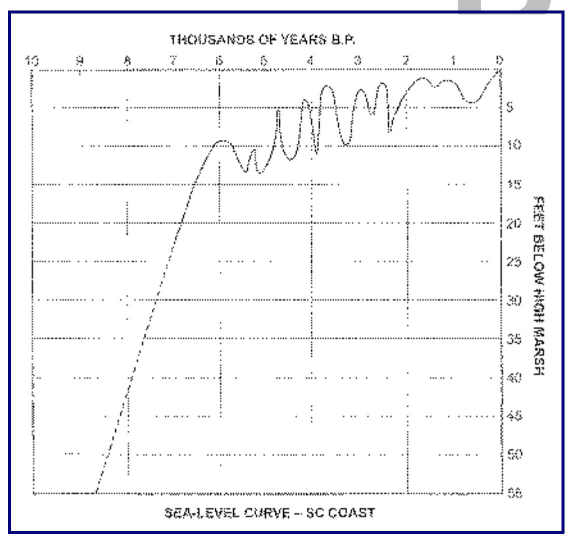


FIGURE 2.4. Fluctuations in sea level along the South Carolina coast over the past 6,000 years based on research by Colquhoun and Brooks (1986) as interpreted by Hayes and Michel (2008). [Courtesy of RRPI and Pandion Books, Columbia, SC – after Hayes and Sexton 1989]

Present-day Sullivan's Island and its sister barrier islands formed within the past ~5,000 years. Interestingly, they parallel an ancient shoreline that marks the mainland of Mt. Pleasant (Fig 2.5). Geologists place the age of the Mt. Pleasant shore at about 120,000 years old (Pleistocene Age), coincident with the previous high stand (see Fig 2.3). Between 120,000 and 5,000 years ago, sea level fell and the South Carolina coast moved dozens of miles out on the continental shelf. When sea level returned to its high-stand position, sands accumulated as barrier islands, and the low area between Sullivan's Island and the Mt. Pleasant escarpment

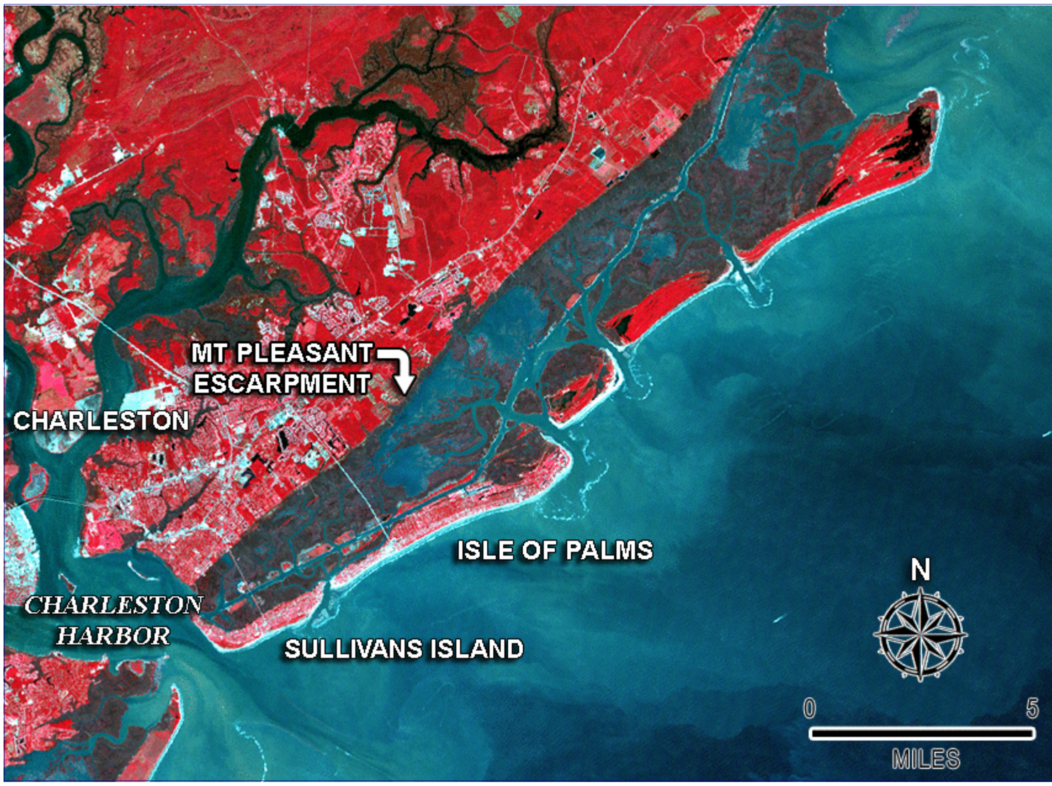


FIGURE 2.5. False-color aerial photo of the barrier islands east of Charleston Harbor. High ground is bright red, whereas tidal wetlands are dark red to purple. Note the distinct break between high ground and marsh along the mainland. This is the Mt. Pleasant escarpment thought to match the South Carolina shoreline of ~120,000 years ago when sea level was similar to today's. [2006 image courtesy of Research Planning Inc and SCDNR]

allowed deposition of mud, leading to formation of the marsh-tidal creek system that is seen today. Many of today's inlets between the barrier islands are situated in the river beds of ancestral channels that drained across the coastal plain when sea level was lower. Lands formed within the past 10,000 years are referred to as Holocene or Recent Age.

Sea-Level Rise (SLR)

During the past century, Charleston has experienced sea-level rise (SLR) of the order 24 centimeters (cm) (0.8 ft) (Barth and Titus 1984). A portion of this rise is attributed to global warming (leads to glacial melting and thermal expansion of the ocean) and about half is due to local subsidence of the land. This is important because it means Sullivan's Island has already been subject to some measure of SLR over the past century.

There has been growing concern that global warming is accelerating due to increased burning of fossil fuels, release of carbon dioxide into the atmosphere, and the associated greenhouse effect (Barth and Titus 1984, NRC 1987). Since the National Academy of Science (NRC 1987) published scenarios of likely sea-level rise through 2100 (Fig 2.6), there has been extensive research and measurement of global temperatures and mean tide levels. The Intergovernmental Panel on Climate Change (IPCC 2007) provides a consensus range of modeled SLR during the 21st century from 20 cm to 59 cm (0.8 ft to 1.95 ft). This does not take into account local land subsidence or sudden accelerated melting of glaciers.

The main point for Sullivan's Island is that a sea-level rise of 2–3 ft over the next century is considered highly probable. This would be a doubling or tripling of the 20th century rate. Such a scenario is reflected in the lower curves of Figure 2.6. The implications of SLR on the ALMP are discussed in more detail in Section 5 of the present report.

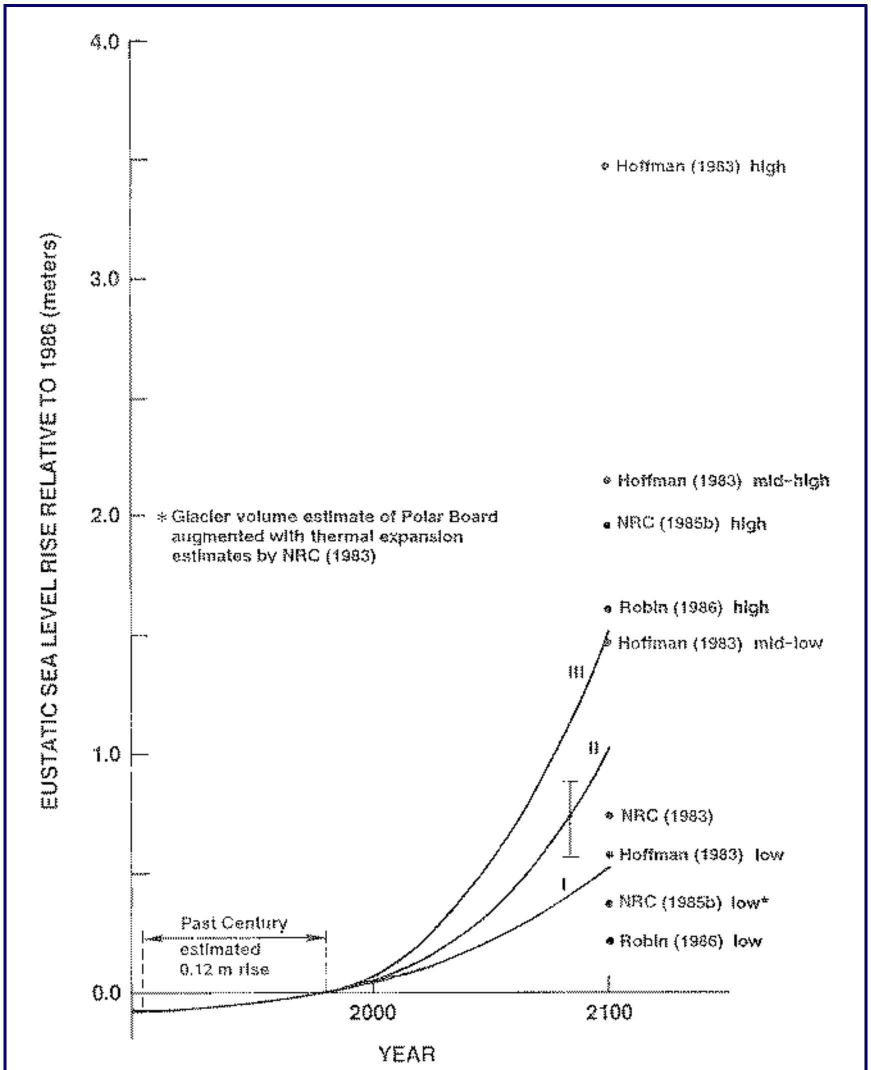


FIGURE 2.6.

Global sea-level rise (SLR) scenarios developed by various researchers as summarized by the National Academy of Sciences (from NRC 1987).

SLR in Sullivan's Island was ~24 cm (0.8 ft) during the 20th century with about half the rise attributed to subsidence (Hicks et al 1983, Kana et al 1984).

The IPCC (2007) consensus is that SLR will be at least double the 20th century rate during the 21st century.

[Note: 1 ft = 0.3048 m]

Recent Sediment Sources

While sea level establishes the shoreline position, local influxes or losses of sediment modify it. At millennial scales, the principal coastal plain rivers of South Carolina have controlled where sediment is discharged. The two river systems of importance to the geologic history of Sullivan's Island are the Cooper River and the Santee River. At various times, the Santee River system has been dominant and has carried most of the freshwater flow from the Piedmont of South Carolina (Hayes 1994). However, channel avulsions have also diverted the discharge to the Cooper River (Fig 2.7).

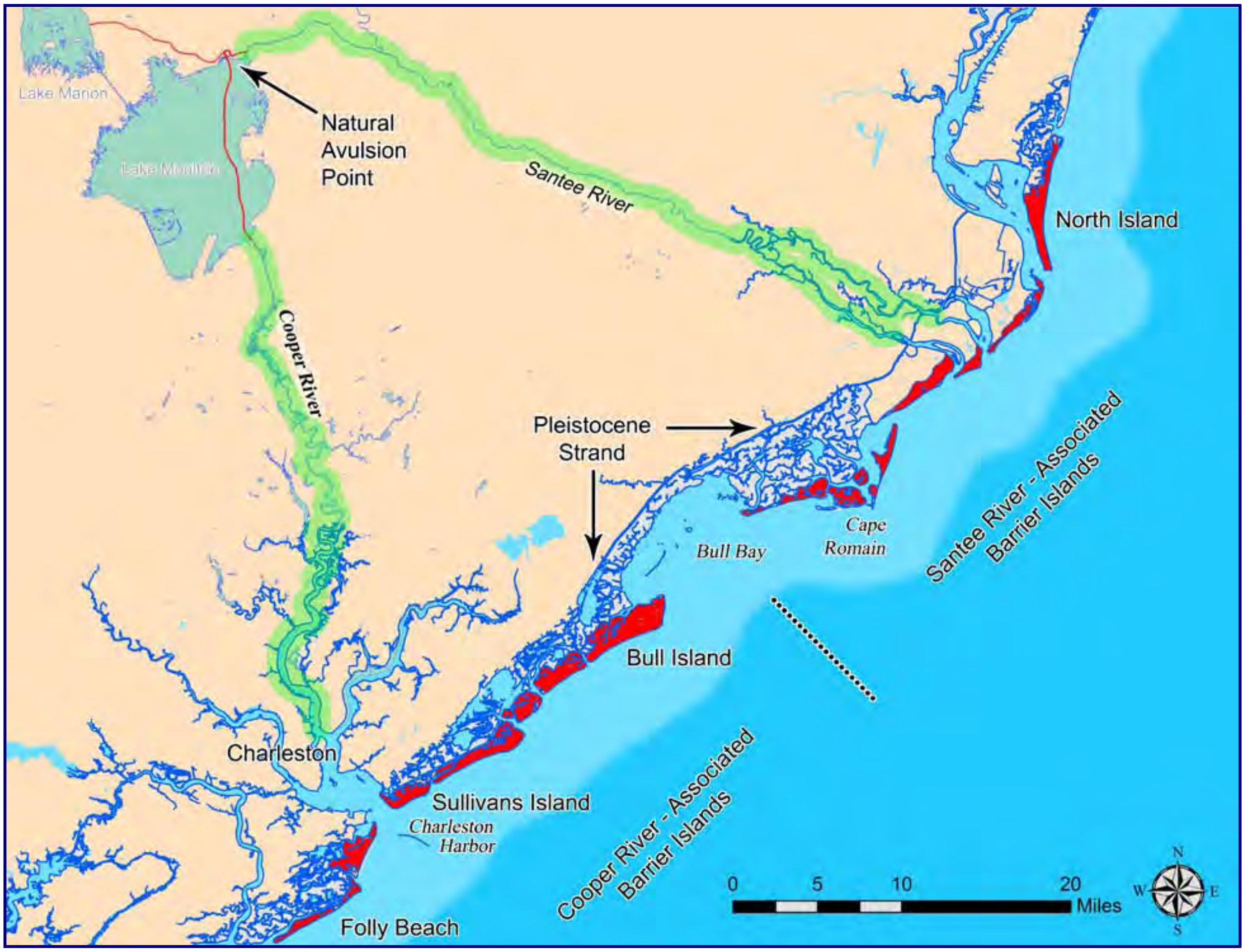


FIGURE 2.7. The central South Carolina coast showing groups of barrier islands associated with the Santee River and Cooper River drainage basins. Channel avulsions (the sudden shift of a river's course from one channel to another) affect the supply of sediment to the coast. The Santee was diverted into the Cooper River in the 1930s to provide hydroelectric power. This led to increased shoaling in Charleston Harbor. Most of the flow was rediverted back to the Santee via a man-made diversion canal in 1982. Barrier islands associated with the Santee River were highly erosional during much of the 20th century (Stephen et al 1975, Brown 1977).

The barrier islands north of Bull Bay are associated with sediments that accumulated around the Santee Delta when discharge was by way of that system. It is speculated the barriers flanking Charleston Harbor originated as part of a delta system of Cooper River and its associated distributary channels when that system was active.

The timing of natural channel avulsions in the Santee-Cooper River system is unknown. However, the 20th century history is interesting because of man-made changes in the flows (Schubel 1971, Kjerfve 1976). During the 1930s, hydroelectric dams were built upstream, and the flow was diverted from the Santee River to the Cooper River. Prior to the 1930s, shoaling was a relatively minor problem in Charleston Harbor. However with diversion, the rate of sedimentation increased dramatically (USACE 1968a). Combined with the need for deeper navigation channels, dredging costs increased exponentially. This also led to debates regarding the origin of sediments infilling Charleston Harbor (cf – Neiheisel 1965, Van Nieuwenhuise et al 1978). Some attributed shoaling to increased river discharge due to the river diversion while others detected an increased landward transport of sediments from the inner shelf and adjacent beaches because of changed estuarine circulation processes (cf – Kjerfve 1976, Van Nieuwenhuise et al 1978). The latter would be of concern to Sullivan's Island because some of the sands infilling the harbor might be derived from the barrier beaches.

Before the debate about the source of shoaling was settled, the US Army Corps of Engineers developed a plan to redivert the Cooper River flows back to the Santee system (USACE 1976). A rediversion canal was completed in 1982 and since that time only about 3,500 cubic feet per second (cfs) flow into the Cooper River. This average volume is necessary to maintain freshwater conditions for certain upstream industries along the Cooper River. Lower flows would allow seawater intrusion further upstream.

One might think that the rise of sea level or the rediversion of the Santee-Cooper River discharge would have led to erosion of Sullivan's Island because of a reduction in sediment supply or inundation of the coast. Indeed, both factors may account for some of the observed change in the shoreline position. However, at decade to century time scales, there is a much more important source of sand to Sullivan's Island — littoral sand shifting from Isle of Palms across Breach Inlet. The scale of this source overwhelms and masks the incremental effects of SLR and Charleston Harbor shoaling with important implications for the ALMP.

Sand Transport Along the Coast

Sand moves along the coast under the influence of waves and tides. Away from inlets, waves are the controlling force; the height and angle, with respect to the shoreline, control the magnitude and net direction of sand transport (Komar 1998). Waves approach Sullivan's Island from the northeast to the southwest. Strongest winds and waves are generally from the northeast, while prevailing winds and waves are from the south-southwest (Hayes 1976). Thus, sand moves in either direction along South Carolina beaches. But when averaged over the year, the net direction of sediment transport is from northeast to southwest (and into Charleston Harbor along the west shoreline of Sullivan's Island) (FitzGerald 1982, Nelligan 1982). Early estimates indicated there is an average net transport of 200,000 cubic yards per year (cy/yr) passing the Charleston entrance jetty near the middle of the island (FitzGerald 1984). This sand comes from Isle of Palms.

Wherever barrier islands are separated by tidal inlets, longshore transport is interrupted by the ebb and flood discharge through the channel. In many settings, the inlets are flood-dominant and tend to draw off sand from adjacent ocean beaches into the lagoon. But central South Carolina has inlets that tend to be ebb-dominant (FitzGerald et al 1976, Nummedal and Humphries 1978). This means sand transported to the inlet channel will tend to be flushed offshore and remain in the littoral zone, where it is deposited in a delta — referred to as an ebb-tidal delta because it accumulates sand at the seaward (ebb) end of the channel (Hayes 1980).

Sand in the ebb-tidal delta becomes subject to wave energy directed toward shore as well as tidal currents moving in and out of the inlet (Fig 2.8). When sand shifts from the ebb-tidal delta to the downcoast shoreline, we say it has "bypassed" the inlet (Bruun and Gerritsen 1959). The rate of bypassing is of importance because this process controls the stability of the adjacent beaches.

Inlets can withhold sand in their deltas for long periods or release large quantities to adjacent beaches during episodic events. **Sullivan's Island has accreted over the past century because the rate of sand bypassing from Isle of Palms has exceeded the rate of loss to Charleston Harbor** (FitzGerald 1982, Nelligan1982). If Isle of Palms stopped providing sand, Sullivan's Island would erode. Before describing the process of inlet sediment bypassing in detail, it is useful to see how Sullivan's Island relates to other barrier island forms.

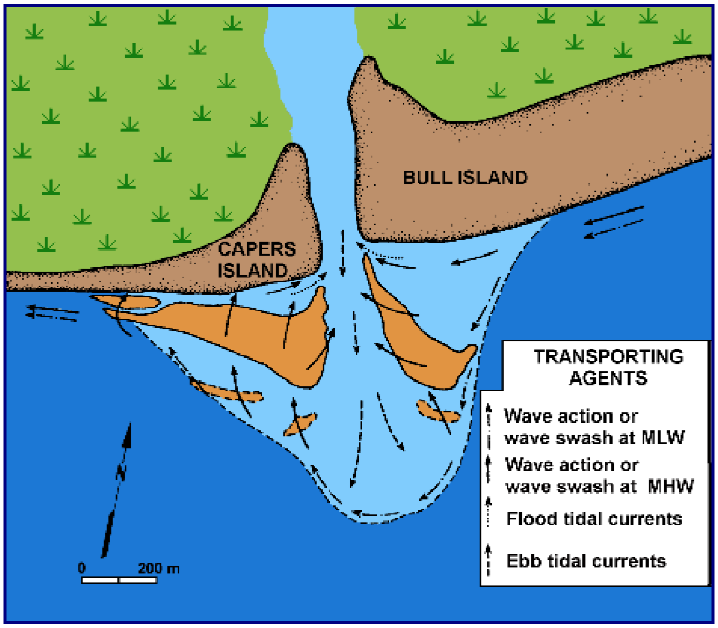


FIGURE 2.8.

Sand circulation patterns for a stable, natural inlet system backed by a marsh-filled lagoon, such as Price Inlet, showing how sand shifts from the "updrift" beach (Bull Island – source) to the "downdrift" beach (Capers Island – sink). Ebb currents are stronger than flood currents and flush sand offshore. Waves shape the off-shore shoals into bars and tend to push them landward. The complex of channels and shoals on the ocean side of the inlet is referred to as an ebb-tidal delta. These features are exceedingly important along the South Carolina coast, because they impact wave energy and sand transport along the adjacent beaches. Ebb-tidal deltas can withhold or release sand episodically, thus affecting the stability of barrier islands.

[After FitzGerald et al 1976]

Barrier Island Morphology

The relative energy of waves and tides along the central South Carolina coast are more balanced than along the North Carolina Outer Banks, where waves tend to be more dominant. Average wave height decreases from North Carolina to Georgia whereas tide range increases (Hayes 1976, Brown 1977). Around Sullivan's Island, mean wave heights are ~2.0 ft (Kana 1977); mean tide range is 5.0 ft; and spring tide range is 5.8 ft (NOAA 1994). Tides generally only move sandy sediment where they can generate currents through confined channels. However, they control the water levels at which waves expend their energy (Hayes 1976, 1994). Wave-breaking and dissipation are the primary forces moving sand along the open coast. Tidal currents in channels are the primary forces moving sand in inlets.

South Carolina has more inlets than North Carolina because of its greater tide range (Hayes 1976). Hayes (1979) described two primary barrier island morphologies based on the relative importance of tides and waves. "Microtidal" barrier islands, in settings with low tide range such as the Texas coast, tend to be long and narrow with widely spaced inlets, small ebb-tidal deltas, and open-water lagoons (Fig 2.9, left). "Mesotidal" barrier islands, in settings with moderately high tide ranges and ample sediment supply such as Charleston, tend to be short and stubby with large ebb-tidal deltas and marsh-filled lagoons (Fig 2.9, right). Mesotidal barrier islands have more variable morphology because of the sheltering effect of ebb-tidal deltas.

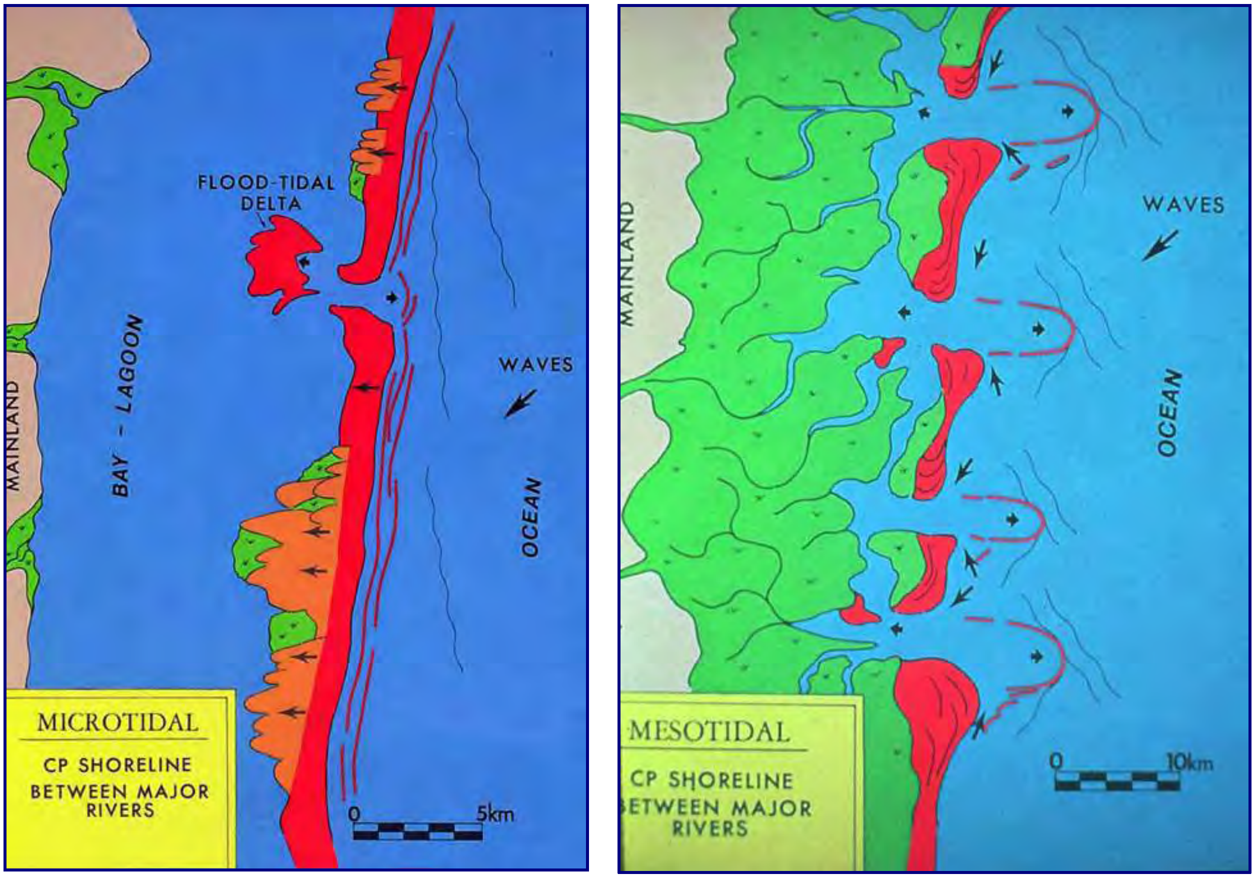


FIGURE 2.9. General models of coastal plain (CP) barrier island morphology as a function of tide range. Sullivan's Island is a "mesotidal" barrier island because it exists in a setting where tides are ~6 ft, inlets are closely spaced, and marsh-filled lagoons predominate. [Source: Hayes 1976, 1979]

Hayes (1979) coined the term "drumstick" barrier island based on the shapes found along the South Carolina coast. Note the similarity of Isle of Palms to a chicken drumstick (Fig 2.10). The upcoast (east) end tends to be bulbous, whereas the downcoast (west) end tends to be elongate. The overall shape of the island reflects net sand transport moving from the bulbous end to the elongated end (Hayes 1979).

Barrier islands are further classified as "beach ridge barriers" or "transgressive" barriers (Hayes 1976, 1994). Healthy barrier islands, such as Sullivan's Island and Isle of Palms, consist of a series of dune lines (beach ridges), more or less parallel to the coast, that represent prior shorelines. With each episode of accretion, new dune lines form, marking the shape of the beach at that time. The oldest ridges are generally along the landward margin of the barrier island, and the youngest is represented by the present foredune. Thus, a walk across Sullivan's Island from the Ben Sawyer Bridge to the beach takes one from the oldest to youngest part of the island.

FIGURE 2.10. Isle of Palms, a classic "drumstick"-shaped mesotidal barrier island, and Sullivan's Island, another "beach-ridge" barrier island, which match the Hayes (1976, 1979) classification illustrated in Figure 2.9. [Source: SCDNR 2006 and Research Planning Inc]

"Transgressive" barrier islands are characterized by erosion, low elevation, and washovers. They lack sufficient inputs of sand and lose sand to the adjacent inlets or lagoon. Because of their low elevations, the ocean frequently overtops the beach and "transgresses" the land. Waves "wash over" the barrier island and sweep sand into the marsh or lagoon on the back side. Examples of transgressive barrier islands in South Carolina are Racoon Key near Cape Romain and Edingsville Beach off Edisto Island (Fig 2.11).

Clearly, Sullivan's Island is not a transgressive barrier island; otherwise, it would be wholly unsuitable for development. If it is a "regressive" barrier island, it must be receiving more sand than it is losing, averaged over decades. As previously mentioned, the primary source of sand is littoral transport moving from Isle of Palms across Breach Inlet. The next section describes this process in detail.

FIGURE 2.11. Edingsville Beach off Edisto Island, an example of a "transgressive" washover barrier island, unsuitable for development. Dark patches on the beach are marsh deposits re-exposed as the barrier washes over the marsh during storm events. [Photo by TW Kana, 31 May 2008]

Inlet Sediment Bypassing

FitzGerald et al (1978) described three types of inlet sediment bypassing applicable along the South Carolina coast (Fig 2.12). "Model 1" applies to small, shallow inlets that migrate in the direction of net littoral drift. A spit builds on the updrift side of the inlet, forcing the channel downcoast. Spit growth combined with channel cutting erodes the downcoast island (or beach), shortening it in the process. If the newly formed spit remains low and unstable, a storm or high tide event may breach it and allow a new channel to form. Successive tides may favor the new channel because it offers a shorter exit point. The net result of spit breaching is eventual closure of the prior inlet and attachment of the remnant spit to the downcoast shoreline (Fig 2.8, Model 1, lower sketch). Pawleys Inlet, at the south end of Pawleys Island, is an excellent example of this model.

"Model 2" (Fig 2.12) (FitzGerald et al 1978) illustrates how sand bypasses stable natural inlets. In this case, the channel remains in the same position, and sand accumulates in a fairly symmetrical ebb-tidal delta. Shoals form offshore and become subject to waves which re-shape them into bars and push them shoreward. Inlet sediment bypassing occurs when a bar migrates onshore and merges with the beach. Sand in the ebb-tidal delta is pushed and pulled by tides and waves. If there is a prolonged period of fair-weather conditions with low waves, the tides exert more influence, and with the ebb tide being stronger, sand will move further offshore. But if a series of storms occurs in quick succession, waves become stronger relative to tidal currents; this tends to build up bars and move them closer to shore (Fig 2.13).

Examples of stable natural inlets include nearby Price Inlet, Capers Inlet, and Dewees Inlet. All are believed to be situated in paleo distributaries of the Cooper River drainage system. They tend to be anchored in Pleistocene sediments, such as the dense Cooper Marl, which underlie the mobile Holocene sands that form South Carolina's modern barrier islands (Hayes 1994). The Cooper Marl can be found 15–25 ft below sea level, so South Carolina's stable inlets tend to be ones having channels greater than ~20 ft deep in the constricted areas between adjacent barrier islands (Hayes and Sexton 1989).

The third model of FitzGerald et al (1978) (Fig 2.12) is most applicable to Breach Inlet and Sullivan's Island. Referred to as the ebb-tidal delta breaching model, it describes the method by which the inlet channel shifts position upon reaching the ocean due to growth and movement of offshore bars. No longer confined between adjacent barrier islands, the channel shoals and meanders around the sand bars that are accumulating offshore. The updrift side of the ebb-tidal delta often builds (through additions of longshore drift), forcing the channel to turn downcoast. This over-extension eventually becomes inefficient for tidal flows. A break in the updrift shoal will draw off some of the discharge and eventually become the dominant channel. As this happens, the downcoast portion of the shoal is free to move ashore by waves.

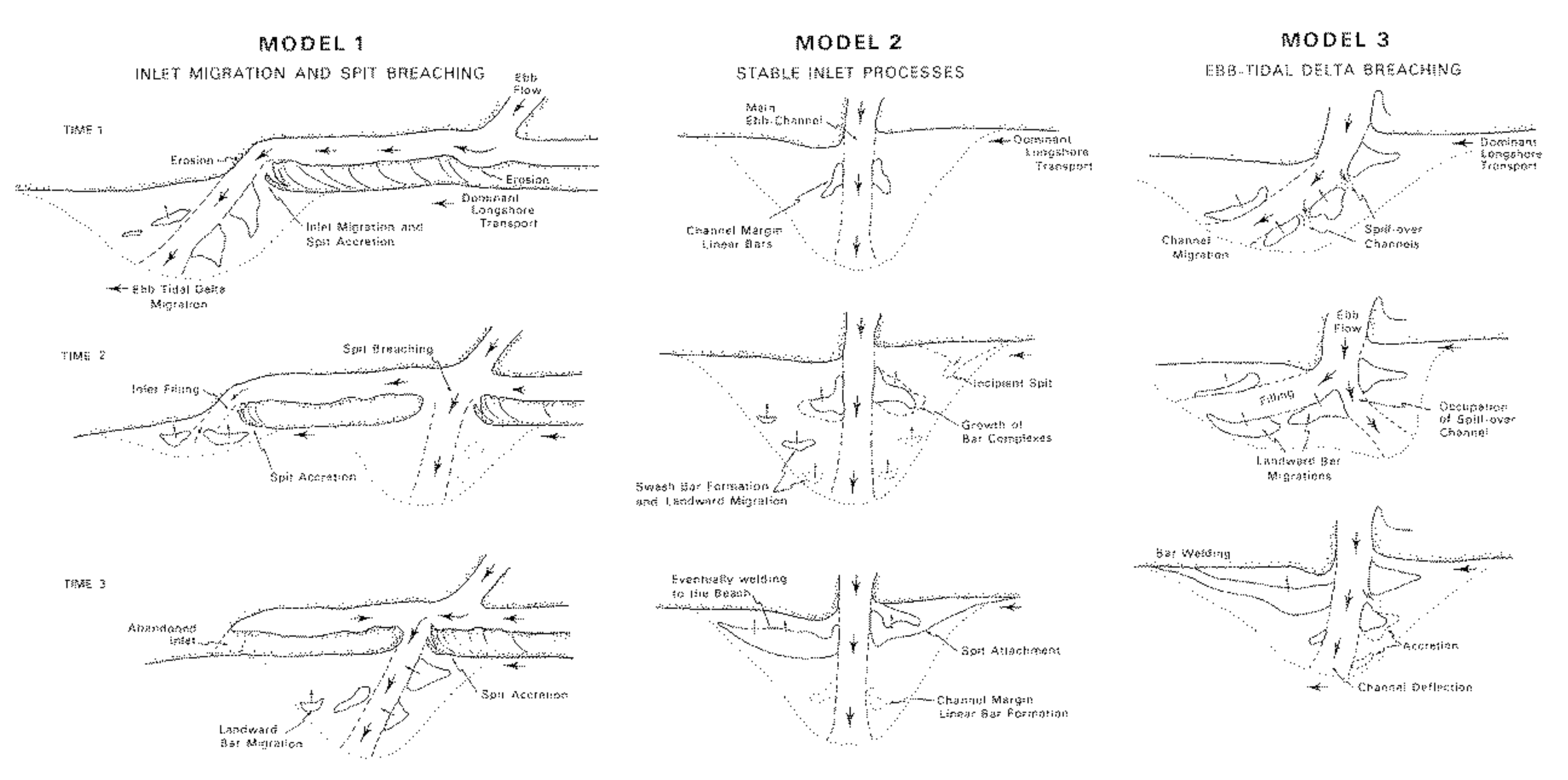


FIGURE 2.12. General models of inlet sediment bypassing for the South Carolina coast. Breach Inlet most closely matches Model 3. Its channel is anchored by shore-protection structures around the bridge to Isle of Palms. The outer portion of the channel is deflected west by sand moving into the inlet from Isle of Palms. Periodically, the outer bars breach through “spillover” channels, freeing sand to migrate onto Sullivan’s Island. [From FitzGerald et al 1978]

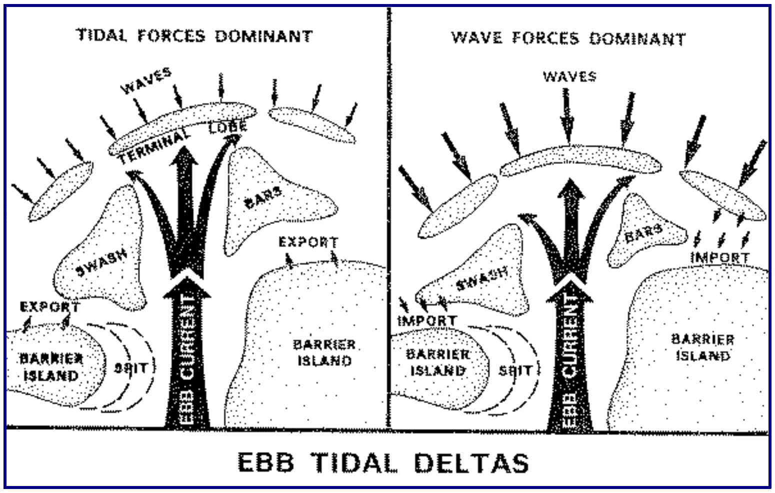


FIGURE 2.13.

Yearly or seasonal variations in wave energy can modify the ebb-tidal delta, favoring contraction and import of sediment to adjacent beaches (when wave energy is higher than normal) and expansion of the delta (when waves are lower than normal). [From Kana et al 1999]

Bypassing occurs, therefore, as a result of a breach in the ebb-tidal delta. The prime South Carolina example of this model is Breach Inlet. The channel, in this case, remains positionally stable between Isle of Palms and Sullivan's Island because of shore-protection structures (bridge abutments, revetments, and groins). If the channel were not armored, it would tend to migrate west, cutting off the end of Sullivan's Island. Figure 2.14 shows how well Breach Inlet fits the third model of FitzGerald et al (1978). Note the deflection of the inlet by the shoal extending from Isle of Palms. Prior to this photo, the channel was forced even further downcoast along the oceanfront of Sullivan's Island. Then a breach through the bar (center of photo) offered a shortcut to the ocean. Note the breaking waves offshore, marking accumulation of a new delta of sand. As the channel takes the new course, the sandbar to the west (left side) is being pushed shoreward by waves. Eventually, it will merge with the beach, adding a new supply of sand to Sullivan's Island. **This is the underlying process responsible for Sullivan's Island's accreting oceanfront.**

Sexton and Hayes (1982) and Kana et al (1985) described the final stages of inlet bypassing, based on numerous examples from South Carolina inlets (Fig 2.15). Referring to the process as "shoal bypassing" because the cycle is initiated when an offshore shoal coalesces into a distinct sand bar and begins to migrate onshore, Kana et al (1985) identified three stages as follows:

FIGURE 2.14. Oblique aerial photograph at low tide showing the deflection of Breach Inlet around shoals extending from Isle of Palms (right side of photo). Breaks in the shoals allow the channel to shift, freeing sand further west (left side of photo) to move onshore and accrete along Sullivan's Island. [Photo circa 2005 by TW Kana]

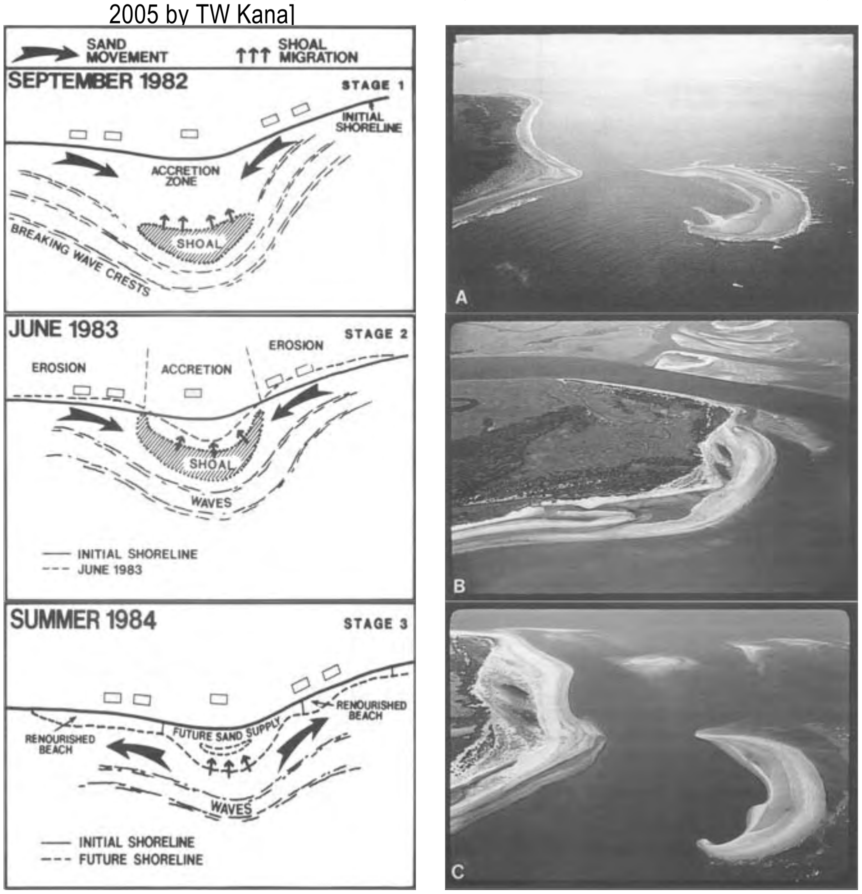


FIGURE 2.15.

The three stages of shoal attachment based on a case study at Dewees Inlet/Isle of Palms (South Carolina).

The photos show a large-scale shoal-bypass event involving over one million cubic yards at Stono Inlet/Kiawah Island (SC) between 1977 (A) and 1983 (B).

A successive event began around 1986, culminating in attachment around 1990. Views are looking north at low tide.

[After Kana et al 1999]

Stage 1 – Offshore shoal coalesces into a distinct sand bar and detaches from the ebb-tidal delta because of a realignment of the channel, particularly a shift to a more upcoast position. During Stage 1, the shoal is becoming emergent as it moves into shallow water. This results in greater wave breaking and energy dissipation, and modifies the wave direction around the shoal. Sheltering by the shoal allows sand to accumulate along the beach in its lee. At the same time, altered wave angles cause focused erosion adjacent to the accretion zone.

Stage 2 – The shoal merges with the beach usually at one end leaving a small lagoon between the bar and the beach. (See Figure 2.14 – area in the left half of the photo.) This is generally the time of maximum erosion along the beaches flanking the shoal because of the severe protrusion of the shoreline by the accreting bar. The examples in Figure 2.15 are from the east ends of Kiawah Island and Isle of Palms. A 1983 event at Isle of Palms caused property damage and forced some owners to build seawalls. A similar event in 2007 made headlines until the community nourished the eroding areas in June 2008 (CSE 2007).

Stage 3 – Upon attachment, the shoal can no longer migrate landward. Instead, the outer portion of the bar is attacked by waves, and sand is redistributed along the beach. During Stage 3, the adjacent beaches are renourished naturally. This process continues until the bulge associated with the shoal bypass event evens out with the adjacent shoreline.

Gaudiano (1998) studied shoal-bypassing events for nine inlets in South Carolina, including Breach Inlet, and determined that the size and frequency of shoal bypassing is related to the size of the inlet. Small inlets, such as Pawleys, exhibit frequent small-scale events, whereas large inlets tend to release much larger shoals at longer time intervals. For Sullivan's Island, Gaudiano (1998) found that the frequency of shoal-bypassing events averaged one every five years. New events were observed in 1954, 1959, 1963, 1977, 1982, 1988, 1989, 1993, and 1994. The average volume of sand added to Sullivan's Island was ~50,000 cy per event. This volume is conservative because the study methodology did not account for the entire underwater volume (Gaudiano and Kana 2001).

Charleston Harbor Changes

Situated as it is at the entrance to Charleston Harbor, Sullivan's Island has been on the "healthy" side of the harbor. Sand moving downcoast from Isle of Palms and Sullivan's Island had helped to build the south spit and shoals across the harbor entrance (Fig 2.16). A 1779 chart shows deflection of the harbor channel to the south. Several breaks occurred over the bar extending from present-day Sullivan's Island, with markings for a "Five feet Channel" and an "Eight feet Channel." The main ship channel was off the southern tip of Morris Island at that time with an indicated depth of 3 fathoms (18 ft). Note the similarity between Figure 2.16 and Model 3 of FitzGerald et al (1978) shown in Figure 2.12. Breach Inlet, on which Model 3 was based, is a small-scale version of the Charleston Harbor entrance in the 1700s.

As shipping expanded in the 1800s, there was a need for a deeper, safer entrance to Charleston Harbor. Rock jetties were constructed by the federal government between 1878 and 1898. Both jetties incorporated a weir section between the shoreline and outer portion of the structure to provide access for small craft. The jetties also flared at the shoreline so that sand passing across the weir could be dredged periodically under protected conditions. This hourglass configuration brought the north jetty ashore near the center of Sullivan's Island (~Station 20).

Figure 2.17 shows the changes around Charleston Harbor between 1867 and 1964. One consequence of jetty construction was a cutoff of sand bypassing the entrance channel via shoal movement. The result for Morris Island was rapid erosion as illustrated in the comparative shorelines in Figure 2.17.

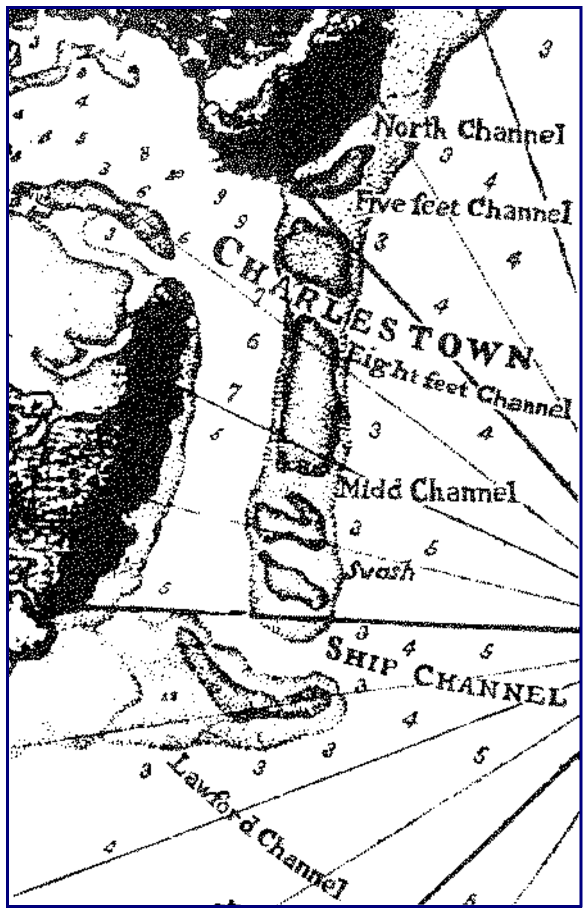


FIGURE 2.16. A 1779 map of Charleston Harbor prior to jetty construction, showing the over-extension of ebb-tidal delta shoals from present-day Sullivan's Island. [Map source unknown; as published by FitzGerald 1988, Fig 12]

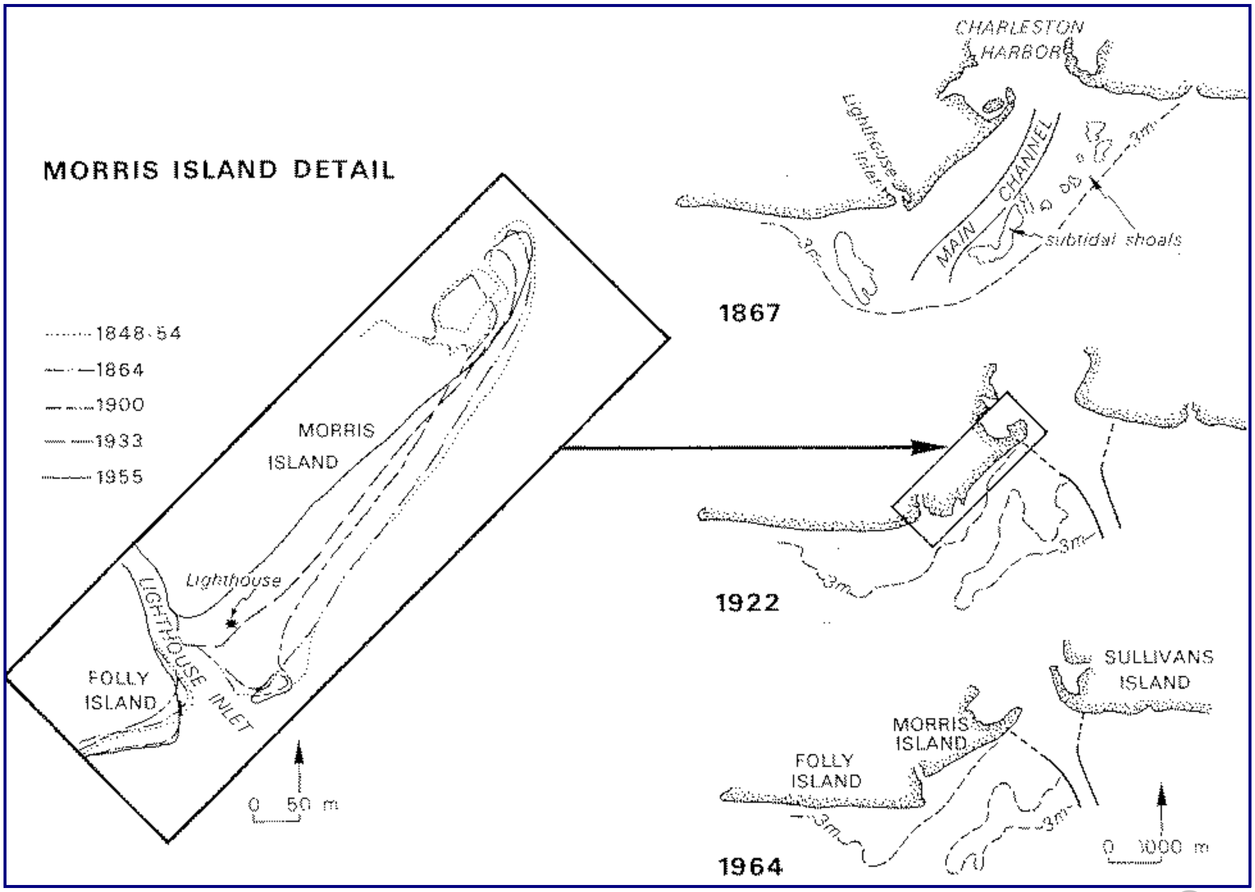


FIGURE 2.17. Generalized changes in the Charleston Harbor entrance and Morris Island between 1867 and 1964. The jetties were completed in 1898. Construction of the jetties and harbor deepening virtually eliminated natural sediment bypassing across the harbor. The result was erosion along Morris Island. [From FitzGerald 1988, Fig 13]

Sullivan's Island, by comparison, accumulated sand moving downcoast. There are no surveys available covering the initial ~25 years after jetty construction. However, based on observations in similar settings, it is believed the landward end of the north jetty was quickly buried by littoral drift. Once buried, excess sand moved past the weir section to the west end of the island. Sand-retaining structures, such as jetties or groins, are no longer functional if they cannot be seen. The onshore part of the jetty, today, is partially exposed at points across the beach (Fig 2.18) but, in general, remains nonfunctional as a sand trap by virtue of its burial. Sand trapping by the north jetty may have accounted for Sullivan's Island's accretion a century ago, but shoal bypassing from Breach Inlet accounts for the buildup in recent decades.

07/15/2010

FIGURE 2.18. Oblique aerial photo of Sullivan's Island looking north at low tide on 17 February 2007. The landward end of the north jetty for Charleston Harbor (arrow) is generally buried and nonfunctional. Sullivan's Island is accretional because of excess sand bypassing Breach Inlet and accumulating along the beach on both sides of the jetty — not because of sand trapping by the jetty. Its effect on sand trapping diminished soon after construction. Note the sand bars merging with the beach in the center of the photo (Stations 23–29). [Photo by TW Kana]

DRAFT

2.4 Barrier Island Ecology – General Overview

The barrier islands along the coast of South Carolina, including Sullivan's Island, create a nearly continuous protective buffer for estuaries, bays, and the mainland from the powerful erosive force of the ocean (USDOI 1988). Barrier islands absorb wave energy and are environmentally important ecosystems that contain unique and ecologically significant biological communities (Schwartz 1973). Being adjacent to the open ocean, barrier islands are subjected to a unique set of extreme physical, environmental, and chemical conditions – such as strong winds, salt spray, poor soil development, unstable substrate conditions, tides, and currents. These factors contribute to their specific biota (Bellis 1995, Wilson and Sykes 2001). The physical and biological components of barrier islands function together as a "network," providing the specific habitat characteristics which allow for distinctive ecosystems to occur (USDOI 1988).

Zonation

Early botanists, when surveying barrier islands in the 19th and 20th centuries, noted the unusually high degree of zonation of vegetative communities within a small area occurring on barrier islands (Bellis 1995). Also, compared to mainland vegetation communities, a large degree of intraspecific variation occurs on barrier islands (Hardin et al 2001). In other words, relative to a comparable sized portion of the mainland, barrier islands support a more diverse set of vegetation communities. Floristic zonation refers to the arrangement of plants into specific "biogeographic" areas. On barrier islands, floristic zonation is driven by the particular set of environmental conditions that occur there.

Environmental Extremes

Salt spray plays an important role in the vegetative structure and composition of barrier islands (Young et al 1994). Some plant species have evolved varying levels of toleration to the desiccating effects of regular contact with salt. Many dominant woody plants found on barrier islands – such as wax myrtle (*Morella cerifera*), yaupon holly (*Ilex vomitoria*) and live oak (*Quercus virginiana*) – are more tolerant of oceanic salt spray than other common mainland species (Wells and Shunk 1938). Species such as these tolerate more salt and have a competitive edge over faster growing yet less salt-tolerant species (Wells 1939). Therefore, vegetation community composition on barrier islands is, in part, driven by the frequency of salt intrusion, which is generally a function of proximity to the ocean.

The pruning effect of salt spray also impacts the morphology of vegetation. Salt spray tends to prune shrub vegetation into a streamlined form aligned with prevailing winds. During periods of strong onshore winds, salt spray from breaking waves becomes airborne and is carried onshore. The majority of salt spray is intercepted at the seaward boundary of maritime vegetation. Young unhardened developing branches and terminal buds are most vulnerable to desiccation by salt. When terminal buds are destroyed, the plant's response is to develop lateral buds, which results in horizontal rather than vertical growth. By this process, vegetation is kept low nearer the ocean. As distance from the ocean increases, the effects diminish and vegetation grows higher, resulting in a windswept, streamlined appearance (Boyce 1954, Bellis 1995).

There is some debate in the scientific community regarding the driving environmental force behind barrier-island floristic zonation. While some argue that salt spray is the primary environmental factor (eg – Wilson and Sykes 2001), others argue that the effects of wind are the driving force (eg – Maun and Perumal 1999). The process by which wind affects plant distribution is sand movement. Plant species may be eliminated when sand burial exceeds their limit of tolerance, thus creating zones of different plant species driven by exposure to windblown sand (Maun and Perumal 2001). The grasses that thrive in this environment, such as sea oats (*Uniola paniculata*), have extensive root and rhizome systems which allow them to produce new growth after burial from windblown sand (Duncan and Duncan 1987).

Ecosystems

As described by the U.S. Department of Interior (USDOI 1988)–Coastal Barriers Study Group, Atlantic Coast barrier islands generally have five distinct ecosystems: (1) coastal marine, (2) maritime, (3) estuarine, (4) freshwater (riverine, lacustrine, palustrine) and (5) upland on mainland. Distinct geological, biological and botanical features characterize each ecosystem type. Figure 2.19 is a cross-section of a typical, barrier-island ecosystem. Note the five distinct vegetation communities and their proximity to the ocean. Factors such as wind, salt, tides, currents and soil nutrients control their geographic position across the island. Those sections within proximity to the AL study area are discussed below.

<u>Coastal marine ecosystem</u>: The coastal marine ecosystem extends from the seaward side of the primary dune to 3 miles offshore and is seaward of the AL at Sullivan's Island. Due to the physical factors characterizing this harsh environment (winds, currents, salt, tides, etc), this area supports few terrestrial plants. Suspended photosynthetic algae, which receives nutrients from both estuarine and riverine outputs, provides the majority of the primary production in this environment (USDOI 1988).

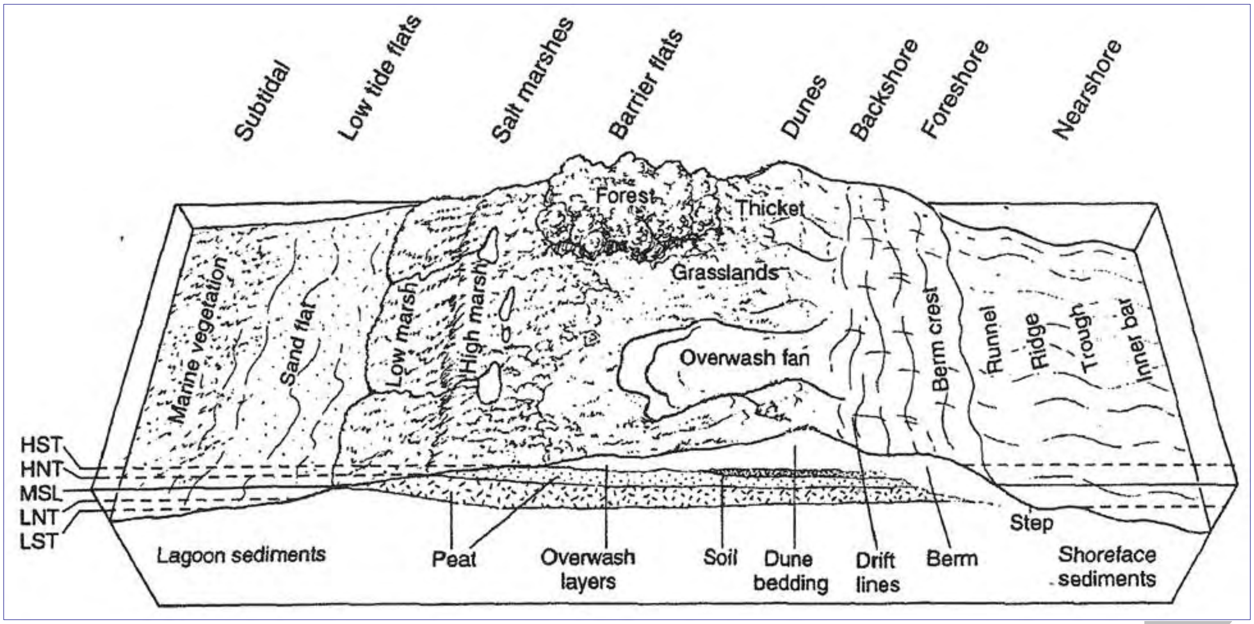


FIGURE 2.19. The basic physiographic and ecological zones of a typical barrier island. [The diagram indicates the zonation on typical barrier beaches and does not imply that every barrier resembles the drawing.] (From Bellis 1995)

Although this habitat provides a harsh environment for terrestrial vegetation, many faunal species are known to inhabit the area. Species of anadromous fish can be found using this ecosystem as transitional areas between life stages while catadromous fish may inhabit these areas for their entire life cycle. Sea turtles use this area for mating, nesting and, feeding. In addition, many shorebirds (such as terns, ducks, pelicans, gulls, and skimmers) exploit the area's food resources.

<u>Maritime ecosystem</u>: The AL area of Sullivan's Island occurs within this ecosystem, which is bound by the primary dune on the seaward side and extends to the mean high-tide mark on the bay side of the island. This ecosystem includes many habitat types and is characterized by floristic zonation due to salt spray and wind interaction. Thus, the more salt-tolerant species are found closer to the ocean in the dune and transition shrub habitat types, while the less salt-tolerant species tend to be found in the interior of the island in the maritime forest. This ecosystem type is generally divided into three distinct sections – dune community, transitional shrub zone, and maritime forest – with each section containing a range of vegetation communities (USDOI 1988).

- The **dune community** is found from the primary dune to the transitional shrub zone. This area typically contains a variety of salt and wind tolerant species such as dune grasses and forbs, which account for the majority of primary productivity in this area. Avian species are the main fauna found here. Due to the harsh physical conditions a limited number of herpetofauna and mammalian species use these areas. However, where high levels of succulent forage and dense cover occur, species such as mice, moles, rats and rabbits can be found (US DOI 1988). Specific vegetation communities, documented by the study team at Sullivan's Island, occurring within the dune community are maritime dune grassland, maritime interdune wetland, and backdune grassland (described in Section 3.3).

- The **transitional shrub zone** occurs between the dune community and the maritime forest. This zone is a distinct transitional zone, characterized by a relatively low flora species richness and extremely dense vegetation structure. Due to the vegetation structure in this community, a high number of avian, mammalian and herpetofauna species can be found. Specific vegetation communities documented at Sullivan's Island within the transitional shrub zone are **maritime shrubland** and **manipulated maritime shrubland** (described in Section 3.3).

- The **maritime forest** occurs inland of the transitional shrub zone and extends across the barrier island to the transitional shrub zone which fronts the marsh. This zone's exact location is difficult to define, because its composition is largely dependent on the effects of salt spray both on the seaward side and marsh side (Warner 1976). This habitat is composed of larger, less salt-tolerant hardwood and coniferous species, and provides favored habitat for most terrestrial fauna. Specific vegetation communities documented at Sullivan's Island within the maritime forest are **early successional maritime forest** and **hardwood depression** (described in Section 3.3).

<u>Estuarine ecosystem</u>: This ecosystem occurs between the upper reaches of saltwater influence on the bay side of the barrier island and the upper reaches of saltwater influence on the mainland. This estuarine ecosystem does not occur within the Sullivan's Island AL study area. Estuarine areas are highly productive and include habitats such as oyster beds, tidal marshes, and mud flats. Prolific marsh vegetation – such as cordgrass (*Spartina spp.*) and black needle rush (*Juncus romerianus*) – and nutrient input from rivers provide a base for the detrital food web within this ecosystem. An abundance of nutrients and protection from the ocean by barrier islands make this ecosystem one of the most productive systems on the planet (Warner 1976). The estuarine ecosystem hosts a large number of fish species, aquatic invertebrate species, and avian and aquatic mammal species.

Flora

The flora of barrier islands have adapted physiologically to thrive under the harsh conditions. For example, salt-tolerant plants possess small, waxy, flexible leaves to resist the damaging effects of salt spray and wind conditions. In addition, many grass species have the ability to produce asexually by means of rhizomes or root runners. Rhizomes also provide stability in the mobile, sandy soil environment (Harper 1985). Vegetation serves to stabilize and trap sand in oceanfront dunes, particularly where dunes are fronted by a dry sand beach. Open-coast vegetation takes the general forms – dune builders, burial-tolerant stabilizers, and burial-intolerant stabilizers (Hosier 1973, Woodhouse 1982, Ehrenfeld 1990). Dune builders grow vertically, rather than laterally, near the margins of vegetation. This growth form produces steep dune slopes. Burial-tolerant stabilizers grow in response to burial with growth occurring horizontally through an extensive network of rhizomes which stabilizes substrate (Harper 1985, Fahrig et al 1994). Burial-intolerant stabilizers are found farther inland, often colonizing dune swales. Being intolerant to burial, these compact growth forms effectively bind substrate (Stallin 2002).

On stable barrier islands (those that are neither accreting nor eroding), the foredune can grow very large because of a steady supply of windblown sand accumulating in one place. However, on rapidly accreting barrier islands such as Sullivan's Island, new foredunes will form before prior dunes can grow to high elevations. The interior dunes become sheltered by seaward dunes and stabilize by vegetation which inhabits further vertical growth.

Soil fertility on barrier islands is low. To deal with this, some plants have developed symbiotic relationships with fungi and bacteria that manufacture necessary soil nutrients and assist plants with uptake of scarce nutrients (Godfrey 1976, Koske and Polson 1984). Maritime plants often have shallow root systems that allow the plant to efficiently capture scarce nutrients which enter the soil as leaf litter decays (Hillestad et al 1975).

Succession

Succession is the process by which an ecological community changes over time. On barrier islands, succession is an integral ecological process by which early successional plant communities (such as dune systems) develop into a climax community (such as mature maritime forest). A climax community is one that has reached a steady state and is best adapted for the average conditions of the area. What makes barrier islands unique is their dynamic, unstable environments. Mainland environments are fixed spatially and have relatively stable conditions, which allow these ecosystems to grow and mature at rates that are easily identified and are fairly consistent. In contrast, coastlines are dynamic. Each stage of succession progressively stabilizes the soil, which prepares for the next successional stage (Fig 2.20, Bellis 1995). However, environmental extremes, such as those discussed herein slow or even stop vegetation community succession on barrier islands.

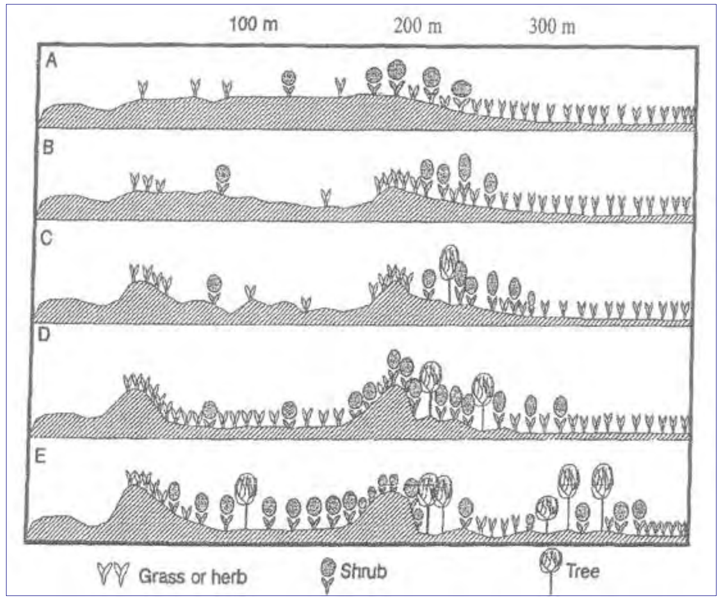


FIGURE 2.20. Hypothetical cross-section of vegetative succession on an accreting barrier island. The ocean is at the left, the mainland is to the right. [From Bellis 1995]

Fauna

Barrier island ecology, with its diverse arrangement of vegetation cover, provides excellent habitat for numerous fauna. Both invertebrate and vertebrate species utilize Sullivan Island's abundance of diverse cover stands, which are arranged within the complex of wetland and upland habitats.

However, because of the limited size of most barrier islands and the natural barriers that impede immigration (marsh, open water, etc), terrestrial fauna are usually limited in population size. In addition, finite food and freshwater resources limit recruitment compared to mainland populations, which contributes to low population sizes.

Comprehensive inventories and studies of fauna occurring on barrier islands have not been compiled. Based on the habitat requirements of endemic fauna species and the environmental parameters present on barrier islands, the Team prepared lists of mammalian species and herpetofauna likely to found in the AL study area (Appendices 6 and 7). This compilation of occurrences is partly based upon observance of species in the field and partly based on a literature review of species known to occur within the vegetation communities found on barrier islands. The Team conducted a series of bird surveys within the AL study area, the results of which are discussed in Section 3.4. Nuisance fauna, such as rats, were also evaluated and are discussed in Section 3.5.

2.5 Summary of Setting and History

Sullivan's Island is an ~4-mile-long barrier island adjacent to Charleston Harbor with a permanent population of nearly 2,000 people. It is geologically young, having formed within the past ~5,000 years. Despite sea-level rise of nearly 1 ft during the past century, Sullivan's Island has accumulated sand and grown seaward along most of its shoreline. The underlying process responsible for Sullivan's Island's accretion is sediment bypassing from Isle of Palms across Breach Inlet. More sand reaches Sullivan's Island along its east end than leaves at the west end. Accretion leads to formation of new dune ridges before prior dunes can gain significant elevation. Vegetation adapted to poor soils, salt spray, and occasional flooding follows a succession related to the age and stability of the land with pioneering species (eg – grasses) ultimately giving way to maritime forest. A diverse set of grass, shrub, and forest communities coexist within the accreted land and interior areas of Sullivan's Island, providing ecological niches attractive to a wide range of animal species.

The basic formation processes detailed in Section 2 have important implications for the ALMP and limit the range of alternatives that are practical or feasible. These, in turn, impact costs of implementation of the ALMP. Following is a summary of implications of the various geographic, physical processes and ecological controls on the evolution of the accreted land.

Factor	General Implications for the ALMP
Geography	Proximity to Charleston and easy access mean higher-than-normal public usage.
	Historical monuments have great socioeconomic importance and may offer opportunities for external grants in support of the ALMP.
	AL area represents ~20 percent of high ground area of Sullivan's Island, which is protected by existing conservation easements.
	Strategic position and size of AL area between existing development and the beach introduce access and security issues that are generally not present along most barrier beaches.
	Proximity to Charleston Harbor has led to construction of a jetty, which anchors the shoreline and likely contributes to the long-term accretion trend at Sullivan's Island.
Population	High percentage of full-time residents and large visitor population make Sullivan's Island an "urban beach" with potentially higher incidence of crime.
Factor	**General Implications for the ALMP**
Geology and Coastal Processes	Land is geologically young and evolving rapidly, a general process which is likely to continue into the future.
	Sand is primarily derived from littoral transport and "bypassing" from Isle of Palms. If stopped, the AL area would begin to erode.
	Sea level has risen about 1 ft over the past century and is expected to rise on the order of 2-3 ft during the 21st century with implications on the rate of accretion and the frequency and magnitude of damaging storm surges over the AL area.
Vegetation Zone	Barrier islands support diverse biological communities within relatively small areas in relation to exposure to beach processes, salt spray, and condition of soil. Natural zonation and the degree to which certain plants tolerate extreme conditions will limit the range of alternatives for vegetation manipulation within the AL area.
Vegetation Succession	This ecological process is integral to the evolution of barrier-island habitats. Upon formation of land, pioneering species of grasses and salt-tolerant shrubs necessarily precede growth of maritime forest (applicable to beach-ridge barrier islands in the temperate southeastern U.S.). The ALMP must consider the natural succession of vegetation in this setting, particularly if the land remains stable or continues to accrete.

3.0 SULLIVAN'S ISLAND CONDITION SURVEYS – 2008

As part of the ALMP study and according to the scope of services (Town of Sullivan's Island 2007), the project team completed a detailed condition survey of the Sullivan's Island shoreline and accreted land (AL). This chapter presents the following results:

- Base map showing existing conditions, including development, roads, access paths, and a datum-based mean highwater.
- Topographic map based on a combination of LIDAR* data, ground-truth transects via RTK-GPS and interpretation of aerial orthophotos.
- Resource inventory in the form of a vegetation community-type map based on a ground-truth survey and interpretation of aerial orthophotos.
- Representative ground photos of vegetation communities within the study area.

[*LIDAR – Light Detection and Ranging is an airborne system of lasers which uses light reflection off the earth's surface to estimate elevation of the land.]

CSE and Sabine & Waters initiated surveys in summer 2008 using Trimble's R8 GNSS RTK-GPS surveying equipment. Vegetation was mapped in the field and verified with the aid of rectified aerial orthophotos. Vegetation was correlated with topography as a further check on the delineations of plant community types.

3.1 Project Survey Control Line and Reference Transects

Figure 3.1 is a base map of Sullivan's Island showing key landmarks, roads, building footprints, present shoreline, OCRM beach survey monuments, and the AL study area. The survey control line follows Middle Street using engineering nomenclature for transect origins. Survey transects approximately perpendicular to the beach are numbered sequentially from west to east. The AL study area encompasses ~13,000 ft of oceanfront. Widths between platted lots and the seaward vegetation line range from 200 ft to 1,300 ft. As Figure 3.1 shows, the study area has two wide zones separated by a narrow area centered between transect 80+00 and transect 100+00. The most recent false-color infrared orthophotograph of the island shows the limit of vegetation in the study area (Fig 3.2). Bright red is shrub or tree vegetation, deep red to purple is generally wetland area, and light grayish red is grassy area.

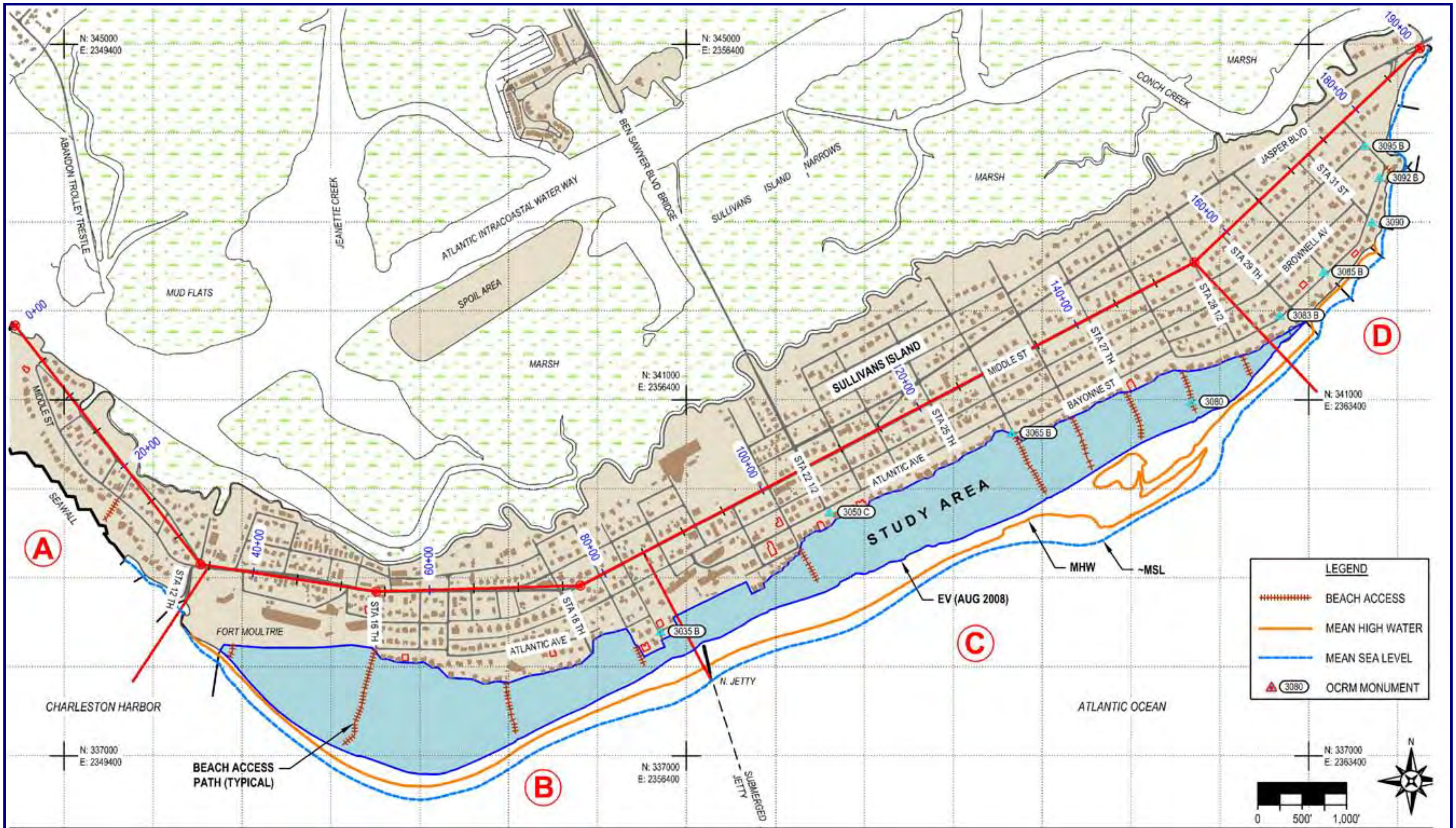


FIGURE 3.1. Study base map showing the AL study area, key landmarks, the survey control line along Middle Street and reference transect numbers, building footprints, the 2008 seaward vegetation line (EV), OCRM beach monitoring monuments, and primary beach accesses (dashed red lines). MHW = mean high water. MSL = mean sea level.

FIGURE 3.2. Infrared aerial orthophoto (2006) of Sullivan's Island showing the 2006 and 2008 seaward edge of vegetation and study reaches. [Source: SCDNR]

Using the aerial orthophotograph and ground-truth survey, the team identified four areas ("reaches") for evaluation:

A West shoreline along Charleston Harbor (transects 0+00 to 35+00). This is outside the AL study area.

B Western half of the AL study area (transects 35+00 to 85+00).

C Eastern half of the AL study area (transects 85+00 to 155+00).

D Breach Inlet shoreline (transects 155+00 to 190+00).

[NOTE: Because the survey control line is offset landward of the coast and Sullivan's Island curves into Charleston Harbor, distances along the survey control line do not match lengths along the high-tide line.]

3.2 Topographic Map Via Digital Terrain Model (DTM)

The Team's ground-truth survey involved collection of thousands of elevation points via RTK-GPS within the study area (Fig 3.3). LIDAR data were also obtained to fill gaps in the coverage and serve as a check on both surveys. Data were entered into the computer and a "model" (referred to as a DTM – digital terrain model) topographic surface was constructed using AutoCAD™ Civil 3-D software. The model provides a best-fit contour map of the area of interest by interpolating among the survey points. Figure 3.4 shows the resulting topographic map of the study area using 2-ft contours.

Figure 3.5 is a color version of the DTM for the study area. This illustrates the relatively low relief of most of the AL study area. The majority of elevations are between 6 ft and 8 ft NAVD.***** Low areas which accumulate water can be seen between ridges around Station 16 (about transects 45+00 to 60+00) and Station 25 (about transects 110+00 to 130+00). There are other swales at somewhat higher elevations which also collect standing water. Note in the color-coded DTM the relatively small differences in elevation between the dune ridges and swales. Typical relief is less than 5 ft. The highest dune ridge with elevations of >12 ft fronts Fort Moultrie. No continuous dune ridges exceed 12 ft above sea level over the remaining study area.

[*NAVD – North American Vertical Datum of 1988 which is approximately equal to present mean sea level.]

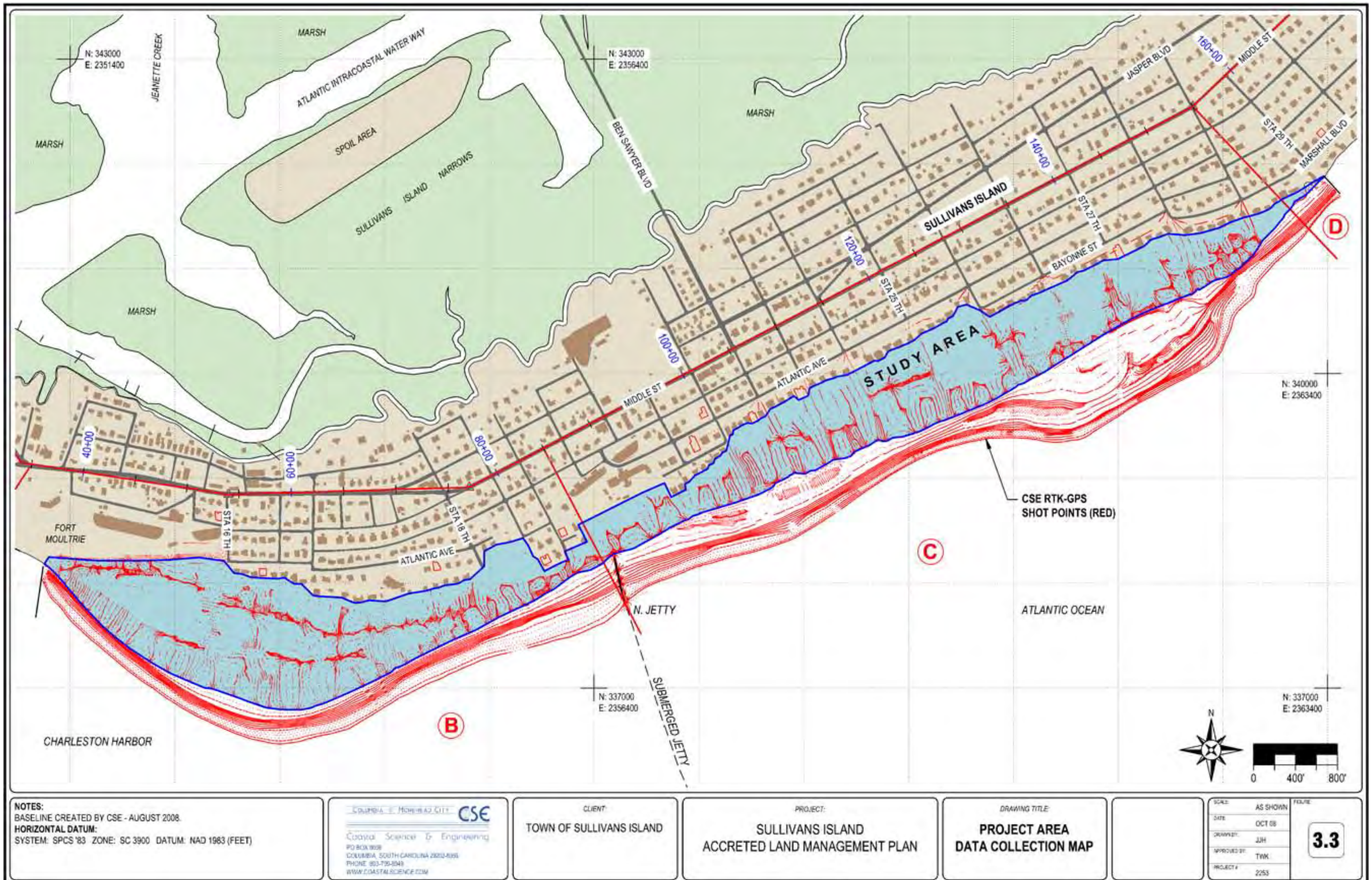


FIGURE 3.3. Individual shot points via RTK-GPS in the ALMP study area obtained in summer 2008 (multiple field deployments to acquire all the data). Some interior areas could not be surveyed due to extensive tree cover. These data were supplemented by LIDAR data and were used to prepare a contour map of the area. Individual points merge as lines where the data density was high, such as along the open beach.

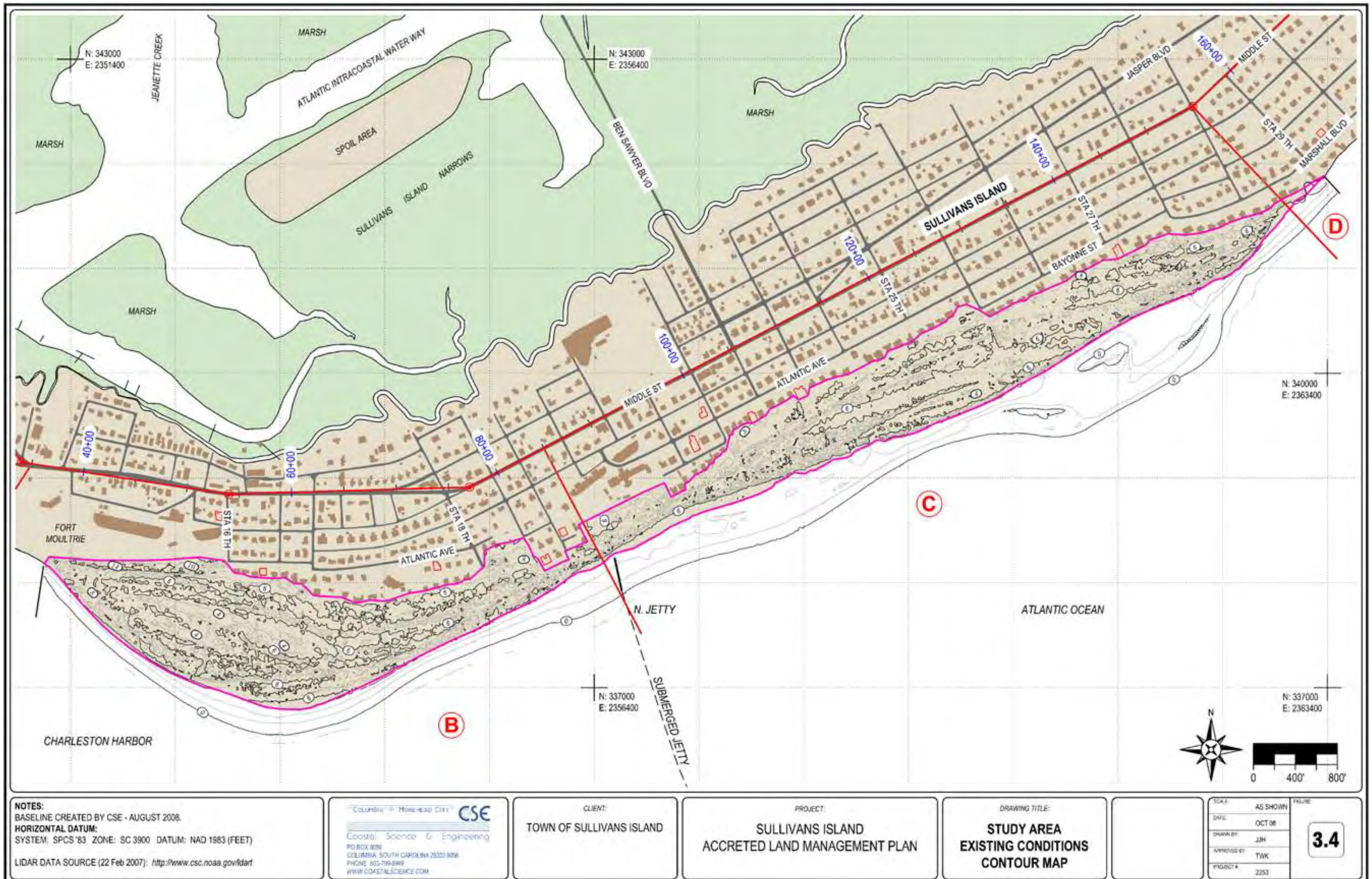


FIGURE 3.4. Contour map based on a "digital terrain model" (DTM) of the survey points (via RTK-GPS and/or LIDAR) for the ALMP study area. Data obtained in summer 2008.

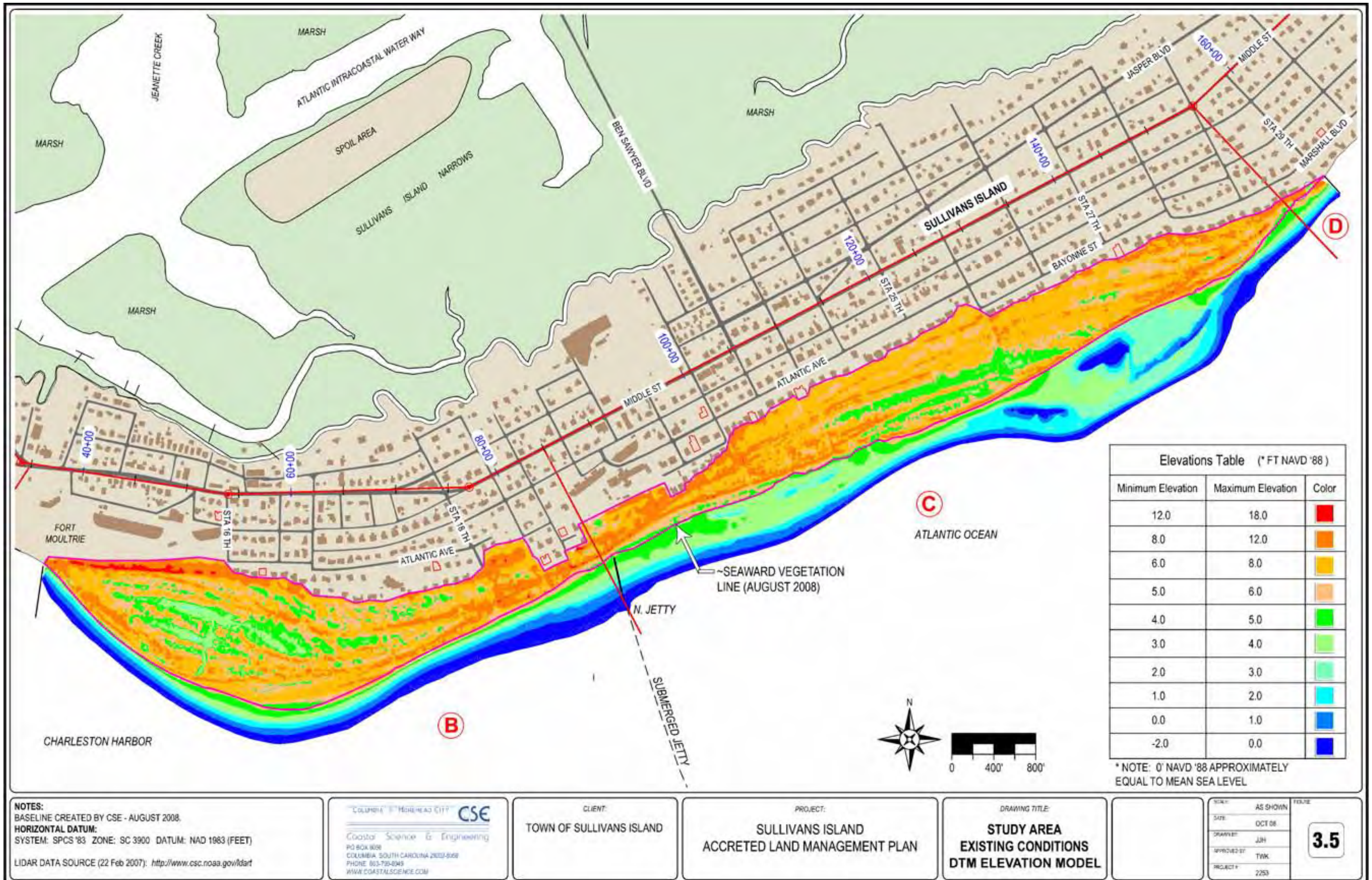


FIGURE 3.5. Color-coded DTM (digital terrain model) contour map of the ALMP study area and active beach showing the relatively small variations in elevation between the dune ridges (typically @ 6–12 ft) and the swales (typically @ 4–6 ft. Map developed from a combination of LIDAR and RTK-GPS data obtained between February 2007 (LIDAR) and August 2008 (RTK-GPS).

The active beach typically begins at the +5 ft to +6 ft contour because this elevation represents the normal limit of spring high tide (~3.5 ft NAVD) plus the effect of wave runup as ocean waves dissipate across the beach. Any land in the AL study area that is below ~5 ft is subject to inundation during minor storm events. Also, these low elevations are close to the water table and, therefore, are more likely to remain wet after prolonged rainfall. Wet areas, such as the green elevations on Figure 3.5, allow propagation of wetland plants, but also impede access to the beach for extended periods.

The approximate seaward vegetation line is indicated on Figure 3.5. Note the extent of beach seaward of the vegetation line, particularly in the area from transect 85+00 to transect 150+00. Normally, a South Carolina beach in the Charleston area is about 300 ft wide between the vegetation line and mean low water. Along Sullivan's Island, some sections of active beach are over 1,000 ft wide. This reflects recent attachment of sand bars that migrated onshore from Breach Inlet. The low areas across the active beach (some of which remain underwater) are remnant channels that were abandoned after the inlet shifted east. Using the shoal-bypassing model previously shown in Figure 2.15, Sullivan's Island is presently in "Stage 3," where the bars have attached and are in the process of spreading laterally along the beach. This is an indicator of ongoing accretion in the AL study area.

Representative Cross-Sections

The DTM (Fig 3.5) was used to prepare cross-sections every 1,000 ft along the study area. Figure 3.6 shows the profiles from the landward margin of the AL area to the low-tide beach. The profiles are greatly exaggerated in the vertical. Distances are measured from the study's survey control line along Middle Street (0 ft distance on each cross-section). Following are some important characteristics of the profiles:

1) Few dunes exceed 10 ft mean sea level in elevation.
2) Relief of the dunes is typically only a few feet.
3) The active beach (right side of each profile) includes broad areas where excess sand is moving onshore (cf – profiles 90+00, 100+00, 130+00, and 140+00).
4) The average elevation across the study area (landward of the active beach) is ~8 ft NAVD'88.

The next section presents the vegetation patterns over the study area and relates them to the topography.

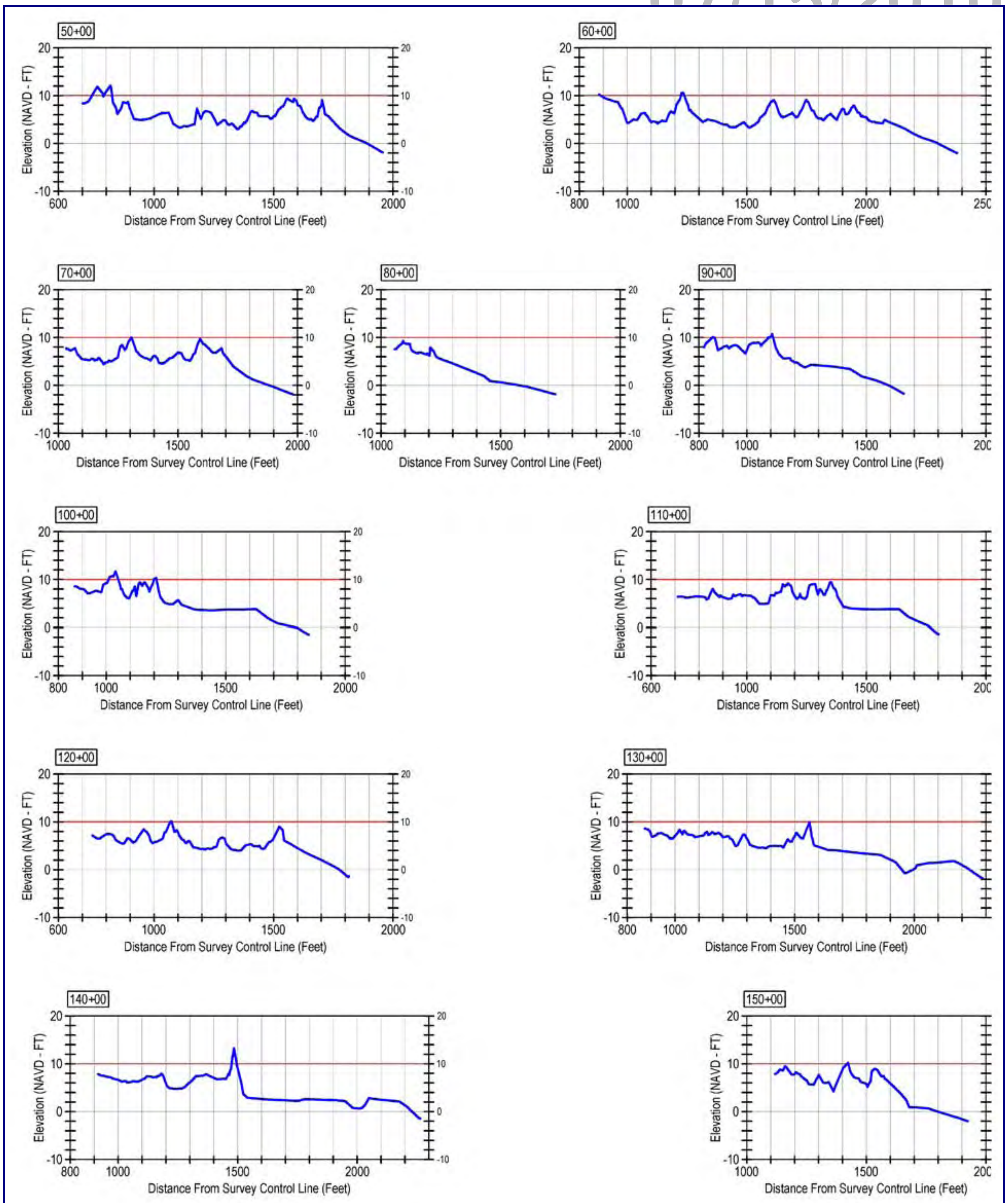


FIGURE 3.6. Representative cross-sections along the study area between oceanfront development and the low-tide beach. Note few elevations that exceed 10 ft and the typical elevation of the land at ~8 ft above NAVD'88 (approximate mean sea level datum). The right side of each cross-section is the active beach. Vertical exaggeration is ~30 to 1. Survey control line created by CSE (August 2008). Vertical datum: NAVD'88. Upland LIDAR data source (27 February 2007): www.csc.noaa.gov/ldart.

3.3 Vegetation Survey

Methodology

Sabine & Waters Inc (S&W) conducted the vegetation inventory and ecological community classification of the AL study area as per requirements of the study. The team began by mapping broad vegetation communities using color-infrared and true-color photography and ArcView software (GIS by ESRI™). Within each of these community types, three 10-meter (m) by 10-m quadrats were randomly placed. Field vegetation surveys were conducted within each of these quadrats between April and September 2008. Within the 10-m by 10-m quadrat, stem diameters (DBH), stem heights, stem counts, and percent cover of all overstory species (woody vegetation >5 m in height) were recorded. Nested within the overstory quadrat was a 4-m by 4-m sub-quadrat, in which basal stem diameters, stem heights, stem counts, and percent cover for all existing shrub species (woody vegetation <5 m in height) were measured. Nested within the shrub sub-quadrat was a 1-m by 1-m herbaceous sub-quadrat, in which stem heights, stem counts, and percent cover for all nonwoody vegetation were recorded. During field vegetation sampling, vegetation community boundaries were ground-truthed using Garmin GPSMap 60CX units, and any occurrences of rare or threatened plant species as well as any other features of interest were marked.

The Team compiled vegetation data into a database appropriate for use in storm-surge modeling (Section 5). Vegetation parameters included in this database were stem diameter, stem height, and stem density by species. Vegetation data (composition and structure) were used along with soil condition, hydrology, and geophysical characteristics to classify ecological communities in the AL study area based on NatureServe's International Classification of Ecological Communities (ICEC) (Grossman et al 1998). NatureServe (http://www.natureserve.org) is a nonprofit conservation organization established by The Nature Conservancy to provide scientific information and tools for conservation planning through a network of natural heritage programs and conservation data centers located in the United States, Latin America, and the Caribbean. NatureServe and its network of natural heritage programs are considered the leading source for information about rare and endangered species and threatened ecosystems and are used by South Carolina DNR as well as other organizations.

Vegetation Communities

The Team identified 13 vegetation communities with similar vegetation structure. The use of these data for model simulations of storm surges and waves over the AL study area are discussed in detail in Section 5. The vegetation of the AL study area was classified into nine ecological communities:

1) Maritime foredune grassland	4) Pathways and lawns	7) Manipulated maritime shrubland
2) Maritime backdune grassland	5) Maritime interdunal wetland	8) Early successional maritime forest
3) Manipulated maritime backdune grassland	6) Maritime shrubland	9) Maritime hardwood depression

These communities are discussed individually in detail herein and are illustrated on Figure 3.7. A complete list of plant species identified in each community can be found in Appendix 8.

Included below each ecological community description is the ICEC type that best fits the conditions observed within the AL study area. Due to the unique nature of the AL study area, the ecological communities identified did not all fit neatly into the ICEC. This was expected given the history of land use and habitat manipulation and the young/early successional nature of the AL study area. The following classifications were the team's best efforts to classify the communities. For this reason, an "ICEC Fit" rating is included for each community type to give residents an idea of how similar the communities within the AL area are to the International Ecological Community listed.

Even though some of the communities in the AL area do not fit well into the classification system, the classification system and the NatureServe website were incorporated to encourage investigation and critical thinking about the current state and future use of the AL area. We hope to engage the town of Sullivan's Island in an informed discussion, not in the specifics of one ecological community classification versus another, but in the future of the area given its current state. We encourage readers to investigate the NatureServe website and the data provided herein, then draw their own conclusions about the state of this area and its future use.

FIGURE 3.7. The nine ecological communities in the AL study area identified by Sabine & Waters in summer 2008.

Maritime Foredune Grassland

This coastal dune community occurs on and just inland of the foredune ridge, immediately adjacent to the beach (cf – Fig 3.7). The extreme environment (including harsh sun, deep xeric sand, salt spray, and high winds) limits vegetation to hardy grasses and broad-leaved herbs (forbs) (Nelson 1986, Schafale & Weakley 1990, Martin 1991). The grasses, such as sea oats, that thrive in this environment have extensive root and rhizome systems which allow them to produce new growth after burial by windblown sand (Duncan & Duncan 1987). This vegetation traps windblown sand which accumulates to form low dunes.

Herbaceous vegetation such as sea oats, seaside pennywort (*Hydrocotyle bonariensis*), saltgrass (*Distichlis spicata*), beach morning glory (*Ipomoea imperati*), and seabeach evening primrose (*Oenothera humifusa*) were common throughout this community. Trailing vines such as fiddle-leaf morning-glory (*Ipomoea stolonifera*) occurred on the foredune ridge, often in dense colonies, with trailing runners reaching seaward toward the beach. While none were seen during the survey, island glass lizards (*Ophisaurus ventralis*), a rare legless lizard, have been found in this habitat (pers comm, Stephen Bentley). Sea turtles use this area as nesting sites, and painted buntings (*Passerina ciris*) were found foraging on seeds in this community.

ICEC Type: South Atlantic Loamy Coastal Dunegrass
NatureServe Identifier: CEGL004039
ICEC Fit: Excellent
Synonyms: Dune grassland, interdunal swales, dune meadow, maritime grassland (Nelson 1986), sand dune (Gehlhausen and Harper 1998)

Maritime Backdune Grassland

This community occurs on back dune ridges, often bisecting maritime forest or inland of maritime foredune grassland communities. Back-dune scrub communities support no overstory and only scattered shrub species [such as prickly pear (*Opuntia* spp)] and low thickets of dune and sawtooth greenbriar (*Smilax auriculata* and *Smilax bonanox*). These sandy ridges may have remained open due to extremely dry, sandy soils that limit colonization by shrub species. The herbaceous community is diverse and includes spider-wort (*Tradescantia ohiensis*), seaside pennywort, prickly pear, seabeach evening primrose, gulf croton (*Croton punctatus*), sea oats, camphorweed (*Heterotheca subaxillaris*), and others. These sandy ridges appear to be regularly traveled by pedestrians, evidenced by the distinct trail seen in the above photograph. Wildlife signs, including tracks and scat, are common on these pathways. Mammals such as raccoons (*Procyon lotor*) and swamp rabbits (*Sylvilagus aquaticus*) frequently use these pathways. A gray fox (*Urocyon cinereoargenteus*) was spotted early one morning walking along one of these trails.

ICEC Type:	Seaside Greenbrier / Camphorweed – Trailing Wild Bean – (Sea oats) Herbaceous Vegetation
NatureServe Identifier:	CEGL004234
ICEC Fit:	Execellent

Manipulated Maritime Backdune Grassland

This community contains similar vegetation as the maritime backdune grassland. However, regular pruning has resulted in dense thickets of dune greenbriar and sawtooth greenbriar, which appear to be displacing other vegetation. The ICEC classification with the best fit for this community is provided; however, due to heavy manipulation in the form of regular pruning, this community lacks the plant species diversity described for the ICEC classification.

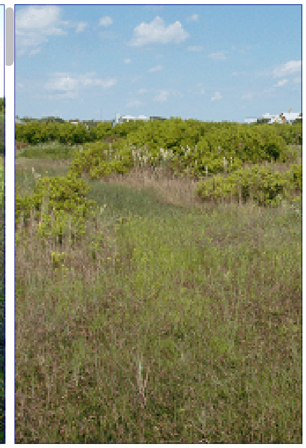
Compare photographs of maritime backdune grassland and manipulated maritime backdune grassland.

ICEC Type:	Seaside Greenbrier / Camphor Goldenaster – Trailing Wild Bean – (Sea oats) Herbaceous Vegetation
NatureServe Identifier:	CEGL004234
ICEC Fit:	Fair

Pathways and Lawns

The vegetation found along pedestrian pathways and lawns is a mix of typical, barrier-island dune inhabitants as well as those commonly found in rural areas. No overstory or shrubs are present. Herbaceous vegetation includes various typical lawn grasses [eg – bahia grass (*Paspalum notatum*) and crabgrass (*Digitaria* sp)], frog fruits *(Phyla nodiflora*), English plantain (*Plantago lanceolata*), buttonweed (*Diodia virginiana*), prickly pear, and others.

Maritime Interdunal Wetland



This community occurs in the flats and interdunal swales behind the foredune ridge. Protected from most tidal flooding, these areas are kept in a state of early succession by strong winds, salt spray, and occasional flooding during storm events and spring tides. Freshwater from inland runoff and rain mix with occasional saltwater, creating pools with varying degrees of salinity (Duncan & Duncan 1987). Vegetation within this community varies by elevation, salinity, and hydroperiod, but generally supports grasses, sedges, rushes, forbs, and pioneer woody vegetation. Common among the vegetation present is the ability to withstand the harsh conditions present and constant burial by windblown sand (Stalter and Odum 1993). The vegetation composition within this community type varied widely due to environmental conditions listed herein. Describing each wetland community type was beyond the scope and needs of this report. For this reason, the ICEC classification listed includes many vegetation community types, some of which occur within the AL area. For more information regarding the vegetation community types within this classification, visit www.NatureServe.org.

Shrub species are limited to scattered seashore elder (*Iva imbricata*), wax myrtle, and groundsel tree (*Baccharis halimifolia*). The herbaceous community is most prolific. In low-lying mesic flats, dominant herbaceous species include pennywort, fern flatsedge (*Cyperus filicinus*), Carolina fimbry (*Fimbristylis caroliniana*), frog-fruits, and fingergrass (*Eustachys petraea*). In the wettest portions of this community, which were flooded at the time of the survey, herbaceous vegetation included narrowleaf cattail (*Typha angustifolia*), bushy bluestem (*Andropogon glomeratus*), pennywort, saltmarsh morning glory (*Ipomoea sagittata*), bulrush (*Scirpus* sp), common rush (*Juncus effusus*), and many others. Common shrubs are groundsel tree and wax myrtle. American alligators (*Alligator mississippiensis*) potentially occur in the wettest portions of this community (Nelson 1986).

ICEC Type: Southeastern Coastal Plain Interdunal Wetland
NatureServe Identifier: CES203.258
ICEC Fit: Good
Synonyms: Marsh pond (Wharton 1977), interdune pond (Nelson 1986), overwash (Gehlhausen and Harper 1998).

Maritime Shrubland

This shrub-dominated community occurs inland of open grassland communities and is an intermediate successional stage between maritime grassland and maritime forest (Duncan & Duncan 1987). It is closely related to the maritime interdunal wetland; however, the maritime shrubland is rarely flooded (Nelson 1986). This habitat type forms an impenetrable thicket that protects inland vegetation from salt spray and strong winds, allowing trees to colonize, forming the Early Successional Maritime Forest described later (Stalter & Odum 1993).

Characterized by very dense vegetation ~2–3 m tall, the maritime shrubland community has little or no overstory present, except for a few scattered sugarberry *(Celtis laevigata*) and large wax myrtle. The shrub layer is very dense and is composed of pioneer shrub species such as wax myrtle, groundsel tree and vine thickets of blackberry (*Rubus* sp), Virginia creeper (*Parthenocissus quinquefolia*), peppervine (*Ampelopsis arborea*), poison ivy (*Toxicodendron radicans*), and maypop (*Passiflora incarnata*). For the most part, herbaceous vegetation is absent; where it does occur, smartweeds (*Polygonum* sp) are prevalent. Chinese tallow, an invasive exotic, was encountered in this vegetation community. These wax myrtle thickets are suitable nesting habitat for painted buntings.

ICEC Type: Wax Myrtle Saturated Shrubland Alliance
NatureServe Identifier: A.1906
ICEC Fit: Excellent
Synonyms: Wax myrtle thicket (Sharitz 1975), maritime shrub thicket (Nelson 1986), maritime shrub (Gehlhausen & Harper 1998).

Manipulated Maritime Shrubland

This community receives regular pruning and has resulted in a hedge-like condition ~7–8 ft high. No overstory exists in this habitat type, but shrub and vine species form a nearly continuous dense thicket. The photograph was taken on a beach access path cut through the AL area. Wax myrtle, rattlebush (*Daubentonia punicea*), groundsel tree, and Chinese tallow are the most common shrubs in the thickets. Occasional openings in the thickets allow an herbaceous community to develop. Common herbaceous species are maypop, Virginia creeper, blackberry, poison ivy, prickly pear, dog fennel (*Eupatorium capillifolium*), camphorweed, and others. The ICEC classification with the best fit for this community is listed; however, due to heavy manipulation in the form of regular pruning, this community lacks the plant species diversity described for the ICEC classification.

ICEC Type: Wax Myrtle Saturated Shrubland Alliance
NatureServe Identifier: A.1906
ICEC Fit: Fair
Synonyms: Wax myrtle thicket (Sharitz 1975), maritime shrub thicket (Nelson 1986), maritime shrub (Gehlhausen & Harper 1998).

Early Successional Maritime Forest

At maturity, the maritime forest is the climax vegetation community of coastal dune systems (Stalter & Odum 1993). While this community in the AL area is too young to be considered a mature maritime forest, it is the oldest habitat found in the AL study area. Historical photography reveals that much of this area was vegetated as early as 1963.

Residing on stabilized dune ridges and swales and protected from salt spray, strongest winds, and tidal overwash, this habitat type generally occurs farther inland than other community types and supports the greatest quantity of trees in the area. Though somewhat protected, vegetation in the maritime forest is well adapted to salt spray, harsh sunlight, wind shear, low water availability, and nutrient-poor soils (Stalter & Odum 1993). Due to the early successional nature of this community, it does not fit well with the ICEC classification listed. The classification listed is a climax forest that is most likely to develop in this area over time. Many of the species present in the AL area today will be replaced by those described in the ICEC classification as it matures and approaches a climax community. This process may take as many as several hundred years.

The overstory consists of sparse to densely spaced early successional tree species, such as sugarberry, laurel cherry (*Prunus caroliniana*), pecan (*Carya illinoensis*), eastern red cedar (*Juniperus virginiana*), and in low dune swales, black willow (*Salix nigra*). The midstory density is also quite variable and consists of wax myrtle, yaupon, and many younger versions of the overstory species. In some areas, vines such as Virginia creeper, poison ivy, blackberry, and peppervine form dense thickets. Ground cover in the maritime forest is generally sparse, probably due to very little light reaching the forest floor. Typically, herbaceous plant species include seaside pennywort, spider-wort, fireweed (*Erechtites hieracifolia*), and dog fennel. Vines, such as those forming dense thickets, are also found creeping low along the forest floor. A yellow rat snake (*Elaphe obsoleta*) was observed in this area as well as numerous swamp rabbit scat (fecal matter). Invasive exotic species encountered in the vegetation community include wisteria, Chinese privet, and Chinese tallow.

ICEC Type: Atlantic Coast Maritime Evergreen Forest
NatureServe Identifier: CEGL007027
ICEC Fit: Fair
Synonyms: Salt spray climax (Wells 1939), mature live oak hammock (Laessle & Monk 1961), maritime closed dunes (Rayner & Batson 1976), maritime strand forest, upland maritime strand forest (Wharton 1997), maritime forest (Nelson 1986), evergreen maritime forest (Gehlhausen & Harper 1998).

Maritime Hardwood Depression

Occupying dune swales of the inland portions of the AL area, these low-area habitats are characterized by a moderately dense overstory of sugarberry, black willow, Chinese tallow, pecan and mulberry (*Morus rubra*). The shrub layer is moderately dense to dense and contains laurel cherry, yaupon, groundsel tree, eastern red cedar, beautyberry (*Calicarpa americana*), and many of the same species found in the overstory. Due to the density of the shrub and overstory layers, very little sunlight reaches the forest floor, resulting in a sparse understory. Species include common vines, goldenrod (*Solidago* spp), dog fennel, spiderwort, common tree saplings, and others.

This community did not fit well into the ICEC classification. The classification listed describes a maritime community found primarily in North Carolina. A similar classification (Southern Atlantic Coastal Plain Carolina Willow Dune Swale) describes a community found in Georgia and Florida. There may be a lack of data for the South Carolina analog of these nearby communities.

ICEC Type: Middle Atlantic Coastal Plain Carolina Willow Dune Scale
NatureServe Identifier: CEGL004222
ICEC Fit: Poor
Synonyms: Maritime swamp forest, maritime shrub swamp, swamp forest (Bellis 1995).

Vegetation Community Values

Each of the nine vegetation communities described has value as habitat for numerous birds, mammals, reptiles, plants, and other forms of life. The presence of vegetation helps stabilize the soil and reduce losses to erosion. Because each habitat has a unique set of qualitative values, it is not feasible to rank communities by importance. Following is a brief summary of some of the values of each community identified by the Team.

The **maritime foredune grassland** is the seawardmost line of vegetation. Due to constant exposure to winds and salt spray, extreme heat during the summer, often very dry conditions, and occasional saltwater overwash, only the most hardy of species exist here. Vegetation that is able to survive plays an important role in dune stabilization and dune growth. This vegetation also provides forage for a number of songbirds, and nesting and escape cover for shorebirds, such as Wilson's plovers, as well as small mammals and reptiles, such as the rare legless lizard. Sea turtles often make their nests immediately seaward of this habitat. Perhaps more than any other habitat, the foredune grassland is the quintessential vista between coastal development and the beach.

Much like the maritime foredune grassland, the **maritime backdune grassland** community includes many pioneer species that are adapted to the extreme conditions adjacent to the beach. Maritime backdune grassland, often found just behind maritime foredune grassland, or on very dry dune ridges in the maritime forest, is an open habitat with no overstory. The grasses and forbs found in this community provide forage for wildlife. Where this community is found within the maritime forest, the openings provide convenient pathways for wildlife, such as the gray fox, one of which the Team observed in the area early one morning. The maritime backdune grassland community also plays an important role in stabilizing the soil from the erosive effects of wind, water, or pedestrian traffic.

Vegetation **communities manipulated by pruning** and modified from their natural states offer different benefits than their unaltered counterparts. When the vegetation is altered, the wildlife suitability of the area is affected as well. Manipulated communities make attractive habitat for rats as well as nesting habitat for songbirds. The rare painted bunting was found in a manipulated community during the Team's bird surveys. These communities also perform the important function of soil stabilization, while offering some incremental level of storm-surge reduction (discussed in Section 5.5). A primary benefit of the manipulation of these communities is the that views of the ocean are retained for the homes that border the AL.

Pathways and lawns are artificial creations requiring maintenance. The plant species are typically dominated by exotic sod grasses with a mix of a few native species. This community has little benefit to native wildlife, other than as a minor food source and travel. These areas are necessary for beach access. As such, these communities could be improved by removing the exotic grasses and constructing boardwalks. There are several boardwalks already in place in the AL. These boardwalks improve access to the beach (especially during rainy periods), reduce erosion, and improve views by giving the pedestrian a higher view point. Railings along boardwalks, especially adjacent to open areas, are a useful means of keeping pedestrians away from sensitive habitats or enhancing security along paths.

Maritime wetlands, such as the maritime interdunal wetlands and maritime hardwood depressions found within the AL, are extremely important to wildlife on barrier islands. These areas serve as the primary source of fresh water on the island. They also contribute significantly to wildlife diversity. Without these wetlands, major groups of animals (such as frogs, salamanders, water snakes, turtles, aquatic birds, and aquatic mammals) are largely excluded (Bellis 1996). These areas further contribute to wildlife populations by providing a more varied and dependable food source for nonaquatic wildlife (Bellis 1996). Trees associated with these wetlands also contribute to reducing the effects of storm surge, and the water basins serve to catch and store storm water during heavy rains, reducing the erosive effects of runoff.

The **maritime shrubland** community within the AL acts as a buffer for the adjacent maritime forest. Found just inland of the foredune and backdune grasslands, the dense thickets of shrub vegetation that compose this community block winds and catch much of the salt spray that comes from the sea, allowing less hardy vegetation to grow and develop into the maritime forest. These thickets also make great escape cover and nesting habitat for songbirds (such as the painted bunting and common ground dove) and small mammals. As with all other communities, the shrubland community stabilizes the soil. The larger, woody vegetation of this community provides incremental storm-surge protection (Section 5.5).

The **early successional maritime forest** community within the AL contains most of the trees in the area. Unlike the grassland communities which provide wildlife habitat in only two dimensions, the maritime forest (because of the presence of trees) provides habitat in three dimensions. The wildlife community that occupies the ground and low areas in the forest differs from the community found in the treetops, which allows for a greater diversity of life in a smaller area. Trees in the maritime forest also contribute incrementally to storm-surge protection, help stabilize soils, and retain moisture. Tree canopy provides shade for wildlife and people, and reduces the extreme heat which occurs during the summer on barrier islands in the Southeast.

Each of the vegetation communities within the AL has something to offer the natural community as well as the human community. The diversity of habitats in the AL is, perhaps, the primary benefit and one that sets it apart from typical grassland habitats that front most of the developed coast.

3.4 Bird Surveys

The Team, with assistance from Audubon South Carolina's Director of Bird Conservation, Mr. Jeff Mollenhauer, conducted bird surveys of the Sullivan's Island AL area on 20 May, 27 May, 10–11 June, 19 August, 23 September, and 21 October 2008. Due to limited time available, the majority of bird surveys were conducted within Reach B, though limited surveys were also completed within Reach C and Reach D. The Team chose Reach B as the primary survey area because it contained a representation of all vegetation community types in the AL area. Birds were identified by sight and call during pedestrian surveys conducted in May and June to capture winter residents and spring migrants. June through August surveys were conducted to identify spring migrants as well as summer residents. The Team conducted September and October surveys to capture summer residents and fall migrants.

Methods

Between 20 May and 21 October 2008, six surveys were conducted for breeding and migrating birds within the AL study area. Surveys consisted of counting all birds heard/seen within five linear transects within the AL area. Each transect was ~800 ft (~250 m) long by ~325 ft (100 m) wide. The duration of each transect surveyed was ~10 minutes. Transects 1 and 3 were sited in early successional maritime forest and maritime shrub communities (Fig 3.8). Transects 4 and 5 were located in manipulated communities, which had been pruned by property owners. Transect 2 was located in the maritime dune grassland community bordering the beach. A survey of the beach was conducted as well, counting birds encountered on the beach, in nearshore waters, and along the primary dune line.

FIGURE 3.8. Bird survey transects in the AL study area identified by Sabine & Waters in summer 2008.

Results

In total, the team documented 76 species of birds that utilize the AL study area. Several high-priority species were found during both the breeding season and migration periods within the AL area including:

Wilson's Plover[1]	Semi-palmated Sandpiper[1]
Piping Plover[1, 2]	Least Tern[1]
Red Knot[1]	Prairie Warbler[1]
Sanderling[1]	Painted Bunting[1]

[1]Audubon Watch List [2]Federally endangered/threatened

Of these species, Wilson's plover, piping plover, red knot, semi-palmated sandpiper, and least tern are found primarily on the beach or in nearshore waters. Common ground dove, prairie warbler, and painted bunting are found within the shrubland and maritime forest habitats. It is thought that Wilson's plover, common ground dove, and painted bunting are breeding within the property boundaries, although no nests were located during the surveys.

During the Team's August, September, and October 2008 surveys, a high abundance of migrating neotropical migratory songbirds was found. Prairie warbler, palm warbler, common yellowthroat, red-eyed vireo, and gray catbird were especially abundant, but smaller numbers of American redstart, northern waterthrush, northern parula, indigo bunting, and bobolink were also encountered. The bobolink and palm warblers were found along the grassy dunes, while the other migrants were found within the shrubland and maritime forest. Appendix 9 is a complete list of birds identified during surveys within general vegetation communities.

Within the wooded transects (1, 3, 4, and 5), species diversity and abundance were highest along transects 1 and 3, the early successional maritime forest and shrubland. Thirty-seven species were identified in these communities (Table 3.1, Appendix 9). The team identified 25, 22, and 17 species in manipulated, beach, and grassland communities (respectively). The beach contained 14 species that were found nowhere else in the AL area. Early successional maritime forest contained 6 species found in no other community. Maritime grasslands and manipulated areas both contained 3 species that were found in no other community.

TABLE 3.1. Number of bird species and individuals found on five transects in the AL study area.

Transect	Migrant Species	Migrant Individuals	Total Species	Total Individuals
1	8	20	16	39
2	4	5	11	36
3	6	9	16	48
4	2	7	9	27
5	2	5	13	28

Discussion

Based on the bird survey results, all community types within the AL area contained species unique to those communities, illustrating the importance of community diversity to faunal diversity. The beach, maritime forest, and maritime shrubland of the AL area contained the greatest number of species not found in other communities. Forested areas contained the greatest species diversity, attracting migrating and breeding songbirds (painted bunting, prairie warbler, common ground dove, etc). The adjacent beach provides attractive habitat for shorebirds and seabirds (Wilson's plover, piping plover, least tern, etc) found in no other community. This is not surprising since most of shorebirds and seabirds typically remain on the beach or seaward. Manipulated areas contained more diversity than grasslands and beach, but few unique species were found there. While grassland and beach communities contained the lowest species diversity, all high-priority species found during the surveys were identified in these communities.

Sullivan's Island, located north of Charleston Harbor, may serve as an important resting site for migrating birds flying south in the fall. Before crossing large bodies of water, such as Charleston Harbor, migrating birds look for areas to stop and "catch their breath" before continuing south. The presence and scale of the AL area adjacent to Charleston Harbor makes it an attractive and important resting site for migrating songbirds in the fall. This is evidenced by the large number of species observed utilizing the area during surveys and attests to the ecological value of the AL study area.

3.5 Nuisance Fauna – Rats

Several landowners with property adjacent to the AL have observed an increase in the rat population in recent years. The Town Council recognizes this as a problem and so the issue is addressed in this report. No rats were observed during the Team's investigations in the AL study area. This is not surprising, however, due to the reclusive nature and nocturnal habits of rats. Species that are mostly likely to occur in the AL area are marsh rice rat (*Oryzomys* *palustris*), hispid cotton rat (*Sigmodon hispidus*), eastern woodrat (*Neotoma floridana*), Norway rat (*Rattus norvegicus*), and black rat (*Rattus rattus*). Given the history of land-use practices in the AL, most likely, residents have seen an increase in the population of black rats and/or Norway rats.

Black rats (also known as roof rats or ship rats) are native to Southeast Asia, having been transported all over the world aboard ships. The species probably arrived in North America in the mid-1500s aboard ships of early European explorers (Walker 1964). Despite the name, not all black rats are black; they are often grayish or brown. Black rats are better adapted to tropical climates, but probably thrive on the subtropical climate of Sullivan's Island. Black rats are excellent climbers, so are found nesting in the upper stories of buildings, in tangled vines, and in trees. Nests are roughly spherical, constructed of twigs and dry leaves. Black rats feed primarily on grains and fruits, but will opportunistically feed on insects, slugs, snails, and bird eggs and nestlings. Black rats reach sexual maturity in 13–16 weeks and may have up to six litters per year with as many as ten offspring per litter. Common predators of black rats include snakes, raptors, dogs, and cats (Whitaker 1996).

Despite the name, Norway rats (also known as common rat, brown rat, water rat, or sewer rat) are not native to Norway, rather to Japan and central Asia. They were transported throughout the world aboard ships and arrived in North America around 1776 in boxes of grain brought by Hessian troops hired by the British troops to fight the American colonists (Whitaker 1996). Norway rats are distinguished from black rats by the length of their tails. Norway rats have a proportionally longer tail, more than half the total body length, while black rat tails are less than half the total body length. Norway rats are quite aggressive and adaptable, often displacing native rats, including black rats. Norway rats are not as agile as black rats so prefer to burrow in the ground beneath protective cover, rather than climb. Being omnivorous, Norway rats feed on almost anything, including meat, insects, wild plants, seeds, and stored grain (Linzey 1998). When food is abundant, females may have 12 litters with up to 22 young per litter. When local populations become severely overcrowded, mass migrations may occur. This occurred in 1727 in Russia, where millions of rats were observed crossing the Volga River. These same migrations were the origins of the children's tale of the Pied Piper. Common predators of the Norway rat include snakes, raptors, skunks, weasels, minks, and dogs.

Given the habitat preferences of the black and Norway rats briefly described herein, the AL area at Sullivan's Island provides an abundance of suitable habitat. The dense thickets, produced by periodic pruning of shrub vegetation on the eastern end, provide acres of nesting habitat for both species as well as protective cover from predators. The most effective means of reducing the rat population would be to reduce habitat availability by discontinuing the practice of shrub pruning. By simply allowing the vegetation to grow, the thicket would naturally open, reducing nesting habitat and allowing predators improved access. Alternatively, replacing much of the maritime shrub with maritime grassland would have similar results. If the Town wishes to continue with the practice of shrub pruning, a waterproof poisoned bait could be used to control rat populations around homes. These baits, however, may have negative impacts on pets and native wildlife.

4.0 HISTORICAL CHANGES

This section presents historical data on the shoreline, storm impacts, vegetation, and related topics in the accreted land (AL) study area. The discussion of the evolution of the AL draws on the data and habitat classifications described in Section 3 as well as basic information on barrier-island formation and coastal processes in Section 2. It follows the earlier sections to help the reader understand and interpret the changes within the AL study area. Because this section necessarily relies on historical aerial photographs, it focuses on changes during the past 60–70 years, coinciding with the availability of images.

4.1 Shoreline and Inlet Changes

The study team obtained historical vertical, aerial photos dating back to 1941 (Figs 4.1–4.5). Because of established infrastructure and buildings, it was possible to scale-adjust each image, superimpose the survey control line along Middle Street, and estimate the size of the accreted land over time. Accretion rates were determined by mapping the seaward vegetation line on each photo. The distance to the vegetation line was measured every ~1,000 ft along the control line; then the change in distance over time (by transect) was determined. Figures 4.1–4.5 encompass the following dates:

1941	1953	1967	1979	1999
1949	1963	1973	1983	2006

Two "shorelines" were interpreted on each image. First is the seawardmost vegetation line. This represents the highest, most-landward tide and wave runup limit around the time of a particular aerial photo. The second line is the "dry sand/wet sand" contact line along the active beach. Experience has shown this line to be in the vicinity of normal mean high water along the open coast (Kana and Gaudiano 2001).

A quick perusal of Figures 4.1–4.5 shows that the accreted land did not exist in 1941. Note in Figure 4.1 (upper) how the oceanfront buildings were situated close to the seaward vegetation line, particularly around transect 90+00 to transect 110+00. By 1949 (Fig 4.1, lower), the central section of Sullivan's Island had widened by 100 ft along the vegetation line. One interesting observation for the 1940s is the demolition (which reportedly occurred in 1947) of old Army quarantine barracks at the eastern end of the island. Breach Inlet fronted the eastern end and was oriented obliquely to the strandline of the coast. During this time, there were no groins along the inlet. A terminal groin is visible off the western end of Fort Moultrie ~1 mile from the north jetty for Charleston Harbor.

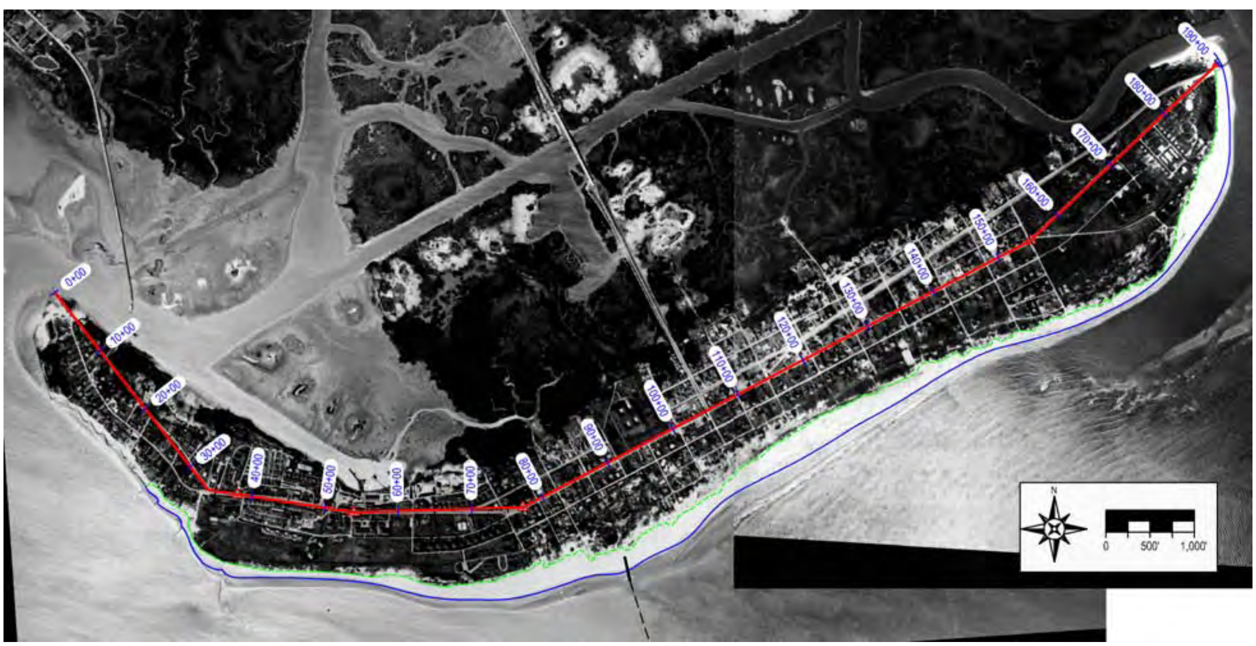


FIGURE 4.1. Scale-adjusted vertical aerial photographs of Sullivan's Island in **1941** (upper) and in **1949** (lower) by US Department of Agriculture with roads, seaward vegetation line, and the wet-sand/dry-sand contact line superimposed. [Scale-adjusted images courtesy of WPC Inc]

Another noteworthy feature in 1949 (Fig 4.1, lower) is the bar at the mouth of Breach Inlet. Wave-breaking over the bar is visible, and its sheltering effect probably accounts for the broad bulge in the shoreline at the mouth of the inlet. Between 1949 and 1963, Breach Inlet shifted position and allowed the shoal at the mouth of the inlet to migrate onshore (cf – Fig 4.2). Note the bulge around transect 150+00 in the 1963 image (Fig 4.2, lower).

The period 1949 to 1963 also saw development of a large sand spit around transect 55+00 (Fig 4.2, lower). Morphology of the spit indicates migration to the west. [Note the hook shape in Figure 4.2, lower.] The seaward vegetation line at the end of the spit was over 1,000 ft seaward of the nearest houses. Those same houses, if they had existed in 1941, would have been situated on the seaward vegetation line around that time (cf – Fig 4.1, upper). The 1963 image (Fig 4.2, lower) marks the first evidence of groins along Breach Inlet.

The 1967 image (Fig 4.3, upper) shows an irregular shoreline with many houses east of transect 125+00 situated close to the seaward vegetation line. At this time, a shoal-bypass event was in Stage 2 (partial attachment) at the mouth of the inlet. The western half of the oceanfront had a series of dune ridges seaward of development. Vegetation in the area from approximately transect 55+00 to transect 100+00 was becoming denser. Note the darker patches inland of the beach which correspond to trees such as wax myrtles.

By 1973 (Fig 4.3, lower), tree vegetation had expanded to Fort Moultrie, but the eastern half of the oceanfront remained fairly free of tree cover. The middle of the island was narrow while the eastern end exhibited a broad bulge in the lee of shoals associated with Breach Inlet. [Note the broad band of breaking waves at the right side of the image.]

Images from 1979 and 1983 are notable for the great expansion of tree-cover along the western half of the island (Fig 4.4). By 1979, there were several broad bands of dense forest from Fort Moultrie to the north jetty. The eastern half of the AL study area remained narrower with only a few small patches of forest vegetation. The overall morphology of the beach continued to reflect broad bulges at the mouth of Breach Inlet and the area around Station 16. The center of the island, meanwhile, retained an arcuate form, characteristic of stable beaches between "headlands." In Sullivan's Island's case, the headlands are the sand accumulation zones at the mouth of Breach Inlet and the area between the north jetty and Fort Moultrie.

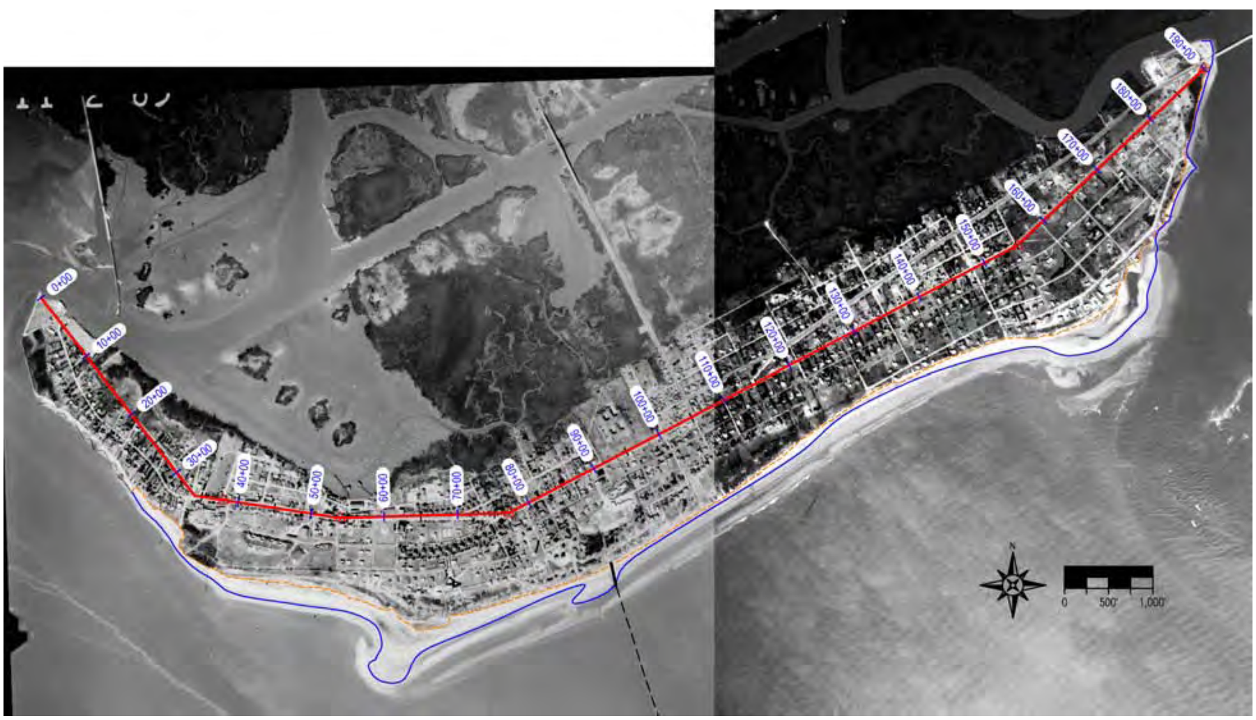


FIGURE 4.2. Scale-adjusted vertical aerial photographs of Sullivan's Island in **1953** (upper) and in **1963** (lower) by US Department of Agriculture with roads, seaward vegetation line, and the wet-sand/dry-sand contact line superimposed.

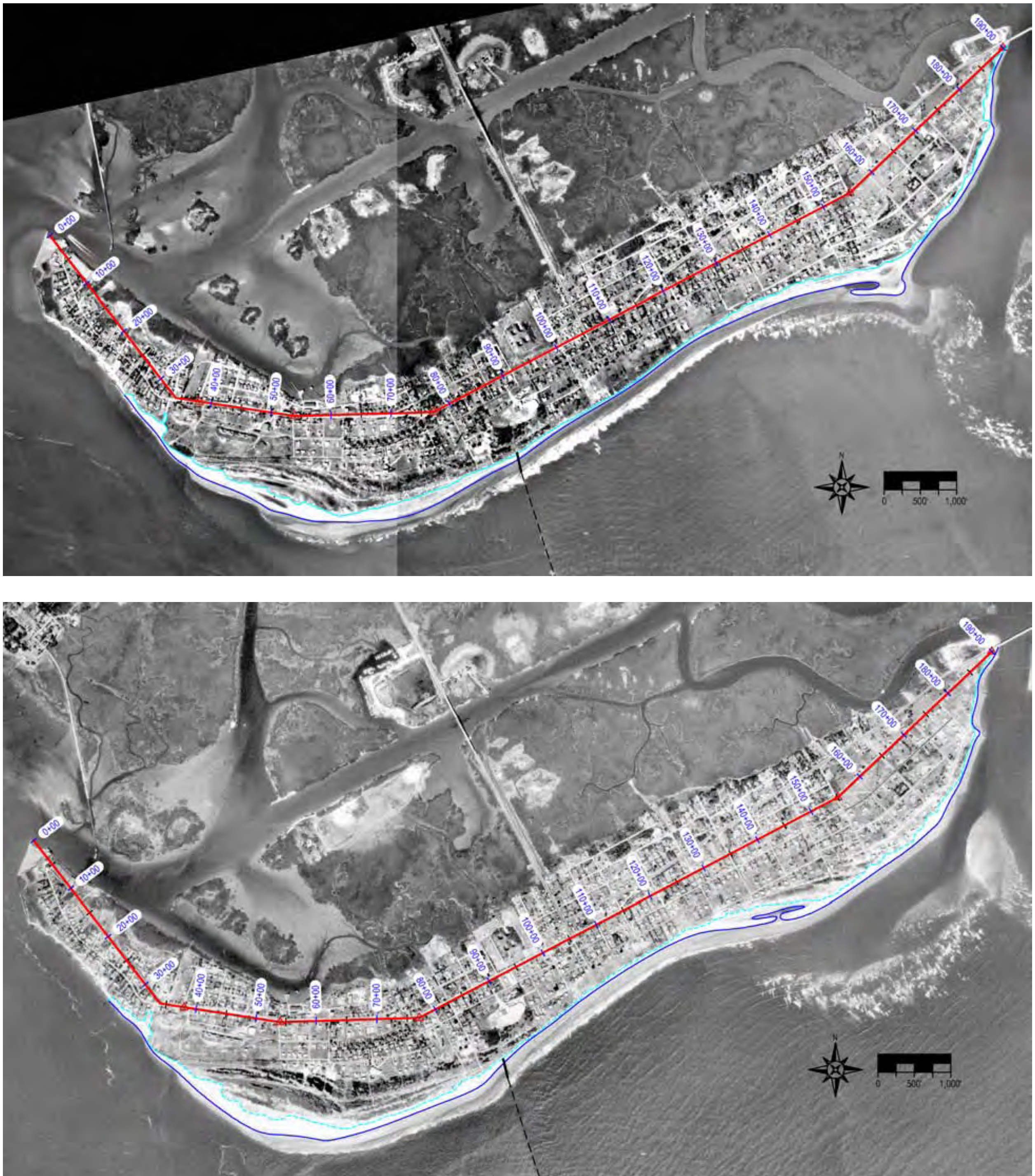


FIGURE 4.3. Scale-adjusted vertical aerial photographs of Sullivan's Island in **1967** (upper) and in **1973** (lower) by US Department of Agriculture with roads, seaward vegetation line, and the wet-sand/dry-sand contact line superimposed.

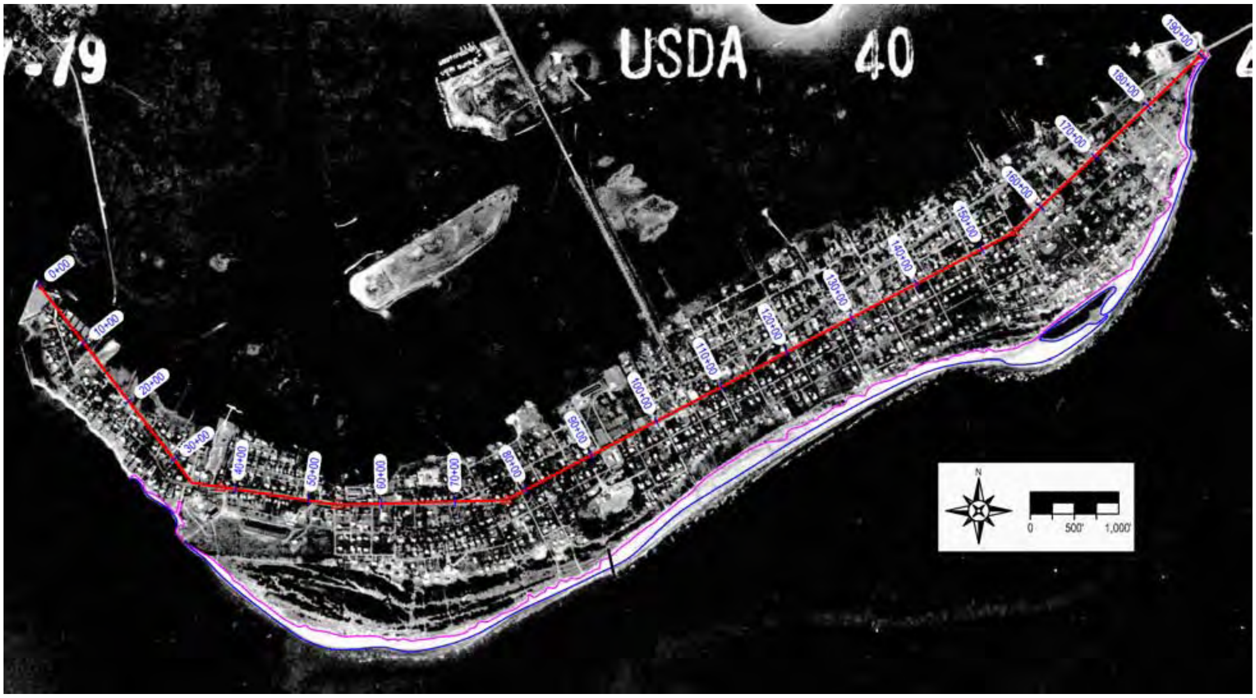


FIGURE 4.4. Scale-adjusted vertical aerial photographs of Sullivan's Island in **1979** (upper) and in **1983** (lower) by US Department of Agriculture with roads, seaward vegetation line, and the wet-sand/dry-sand contact line superimposed.

No vertical aerial photo from the early 1990s was available to the team in a format that could be included in this report. However, OCRM prepared orthophotos at “1 inch equals 100-ft” scale in 1993, which shows persistence of forest vegetation in the study area four years after Hurricane *Hugo* (September 1989). The 1999 image (Fig 4.5, upper) confirms the health of the AL area and expanded vegetation cover along the eastern half of the study area. In 1999, the center of Sullivan’s Island remained narrow with less than 100 ft between some houses and the seaward vegetation line. Interestingly, the narrowest band of vegetation in the study area was about 1000 ft updrift (east) of the north jetty. This provides additional evidence that the jetty has less impact on sand trapping than inlet sediment-bypassing processes at Breach Inlet.

Between 1999 and 2006, a shoal-bypass event resulted in attachment of a mile-long sand bar along the eastern half of the study area (Fig 4.5, lower). Note in the 2006 image the connection of the bar to the beach near the north jetty and the near-connection between transects 140+00 and 160+00. The section of the study area that was narrowest in 1999 has received a large influx of sand this decade.

Figure 4.6 presents comparative shorelines for the available photo dates superimposed on the 2006 orthophotograph. The trends in shoreline change provide the basis for establishing Reaches A–D. From Fort Moultrie west, the historical shorelines generally fall on top of each other because that reach has been stabilized by structures. Reach B (western half of the oceanfront) shows the major buildup of accreted land between 1953 and 1973; since 1973, that area has remained fairly constant.

The eastern half of the study area (Reach C) exhibited little change from 1941 to 1983. However, there was rapid accretion between 1983 and 1999 with continued growth through the present.

Reach D along Breach Inlet shows relatively small fluctuations in the vegetation line for the simple reason it is stabilized by groins and revetments.

FIGURE 4.5. Orthorectified, vertical aerial photographs of Sullivan's Island in **1999** (upper) and in **2006** (lower) by SCDNR with roads, seaward vegetation line, and the wet-sand/dry-sand contact line superimposed.

FIGURE 4.6. Historical shorelines for the period 1941 to 2008 superimposed on the 2006 orthophotograph based on the images in Figures 4.1 to 4.5.

A cursory glance at the photos confirms the following major trends:

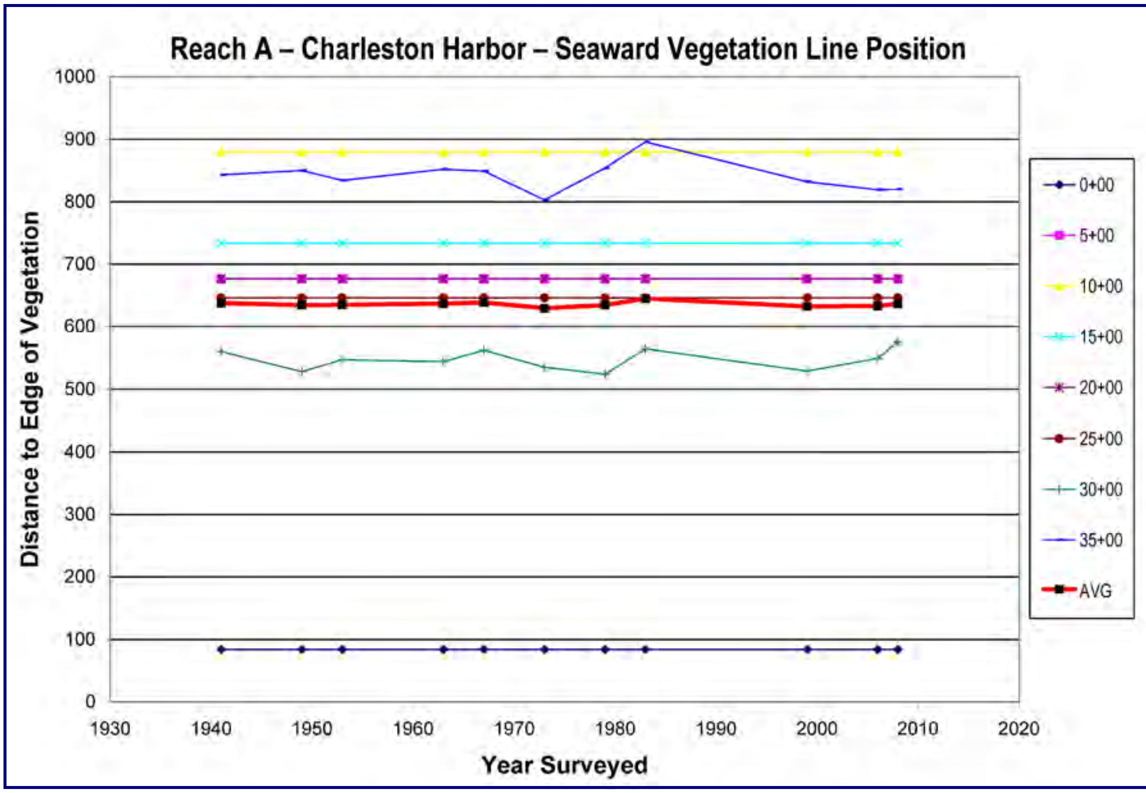
- Stable ends of the island (Reach A and Reach D).
- Western half of the AL area (Reach B) formed between 1953 and 1973 making most of the reach at least 35 years old.
- Eastern half of the AL area (Reach C) formed between 1983 and 1999, making most of the reach less than 20 years old.

Differences in the age of Reach B and Reach C are reflected in the degree and type of vegetation cover (discussed in detail in Section 4.4).

The Team analyzed shoreline changes systematically by measuring distances from the survey control line to the seaward vegetation line and the wet-dry sand line by transect and date. Appendix 10 contains detailed tables of distances by station and reach along with supporting graphs. Figures 4.7–4.8 show the data for the seaward vegetation line movement along with the average trend for the reach. Among the highlights to note on each graph:

1) Reach B and Reach C (main study area) have widened by an average of ~600 ft at the vegetation line.
2) Reach A and Reach D (ends of the island) have changed relatively little since 1941 because of shore-protection structures.
3) Reach B (western AL study area) rapidly accreted between 1953 and 1983. Since 1983, there has been relatively little change along this reach.
4) Reach C (eastern AL study area) gained about 150 ft between 1941 and 1963, then remained relatively stable for 20 years. Most of the accretion in this reach took place between 1983 and the present.

The above-listed trends are highlighted for each reach in Figure 4.9, which shows the average position of the seaward vegetation line over time.



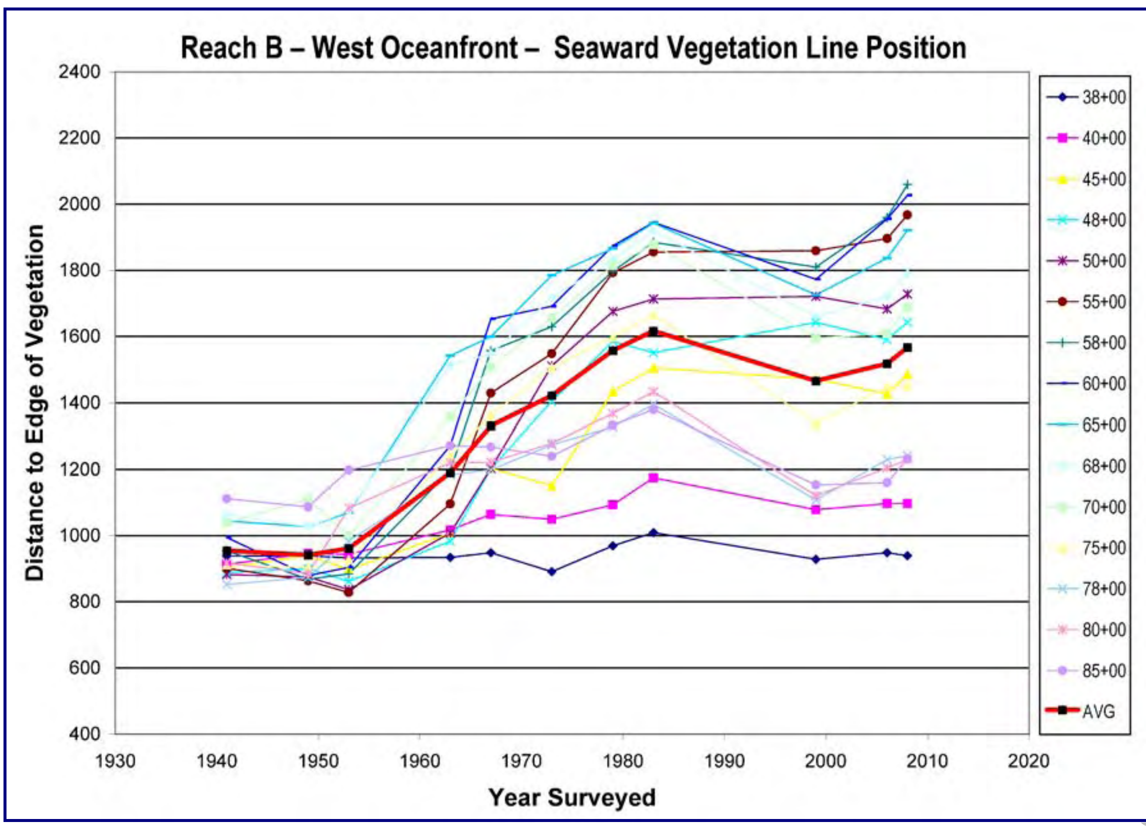


FIGURE 4.7. Trends in seaward vegetation line position by reach for 1941–2008 (based on the data in Appendix 10).

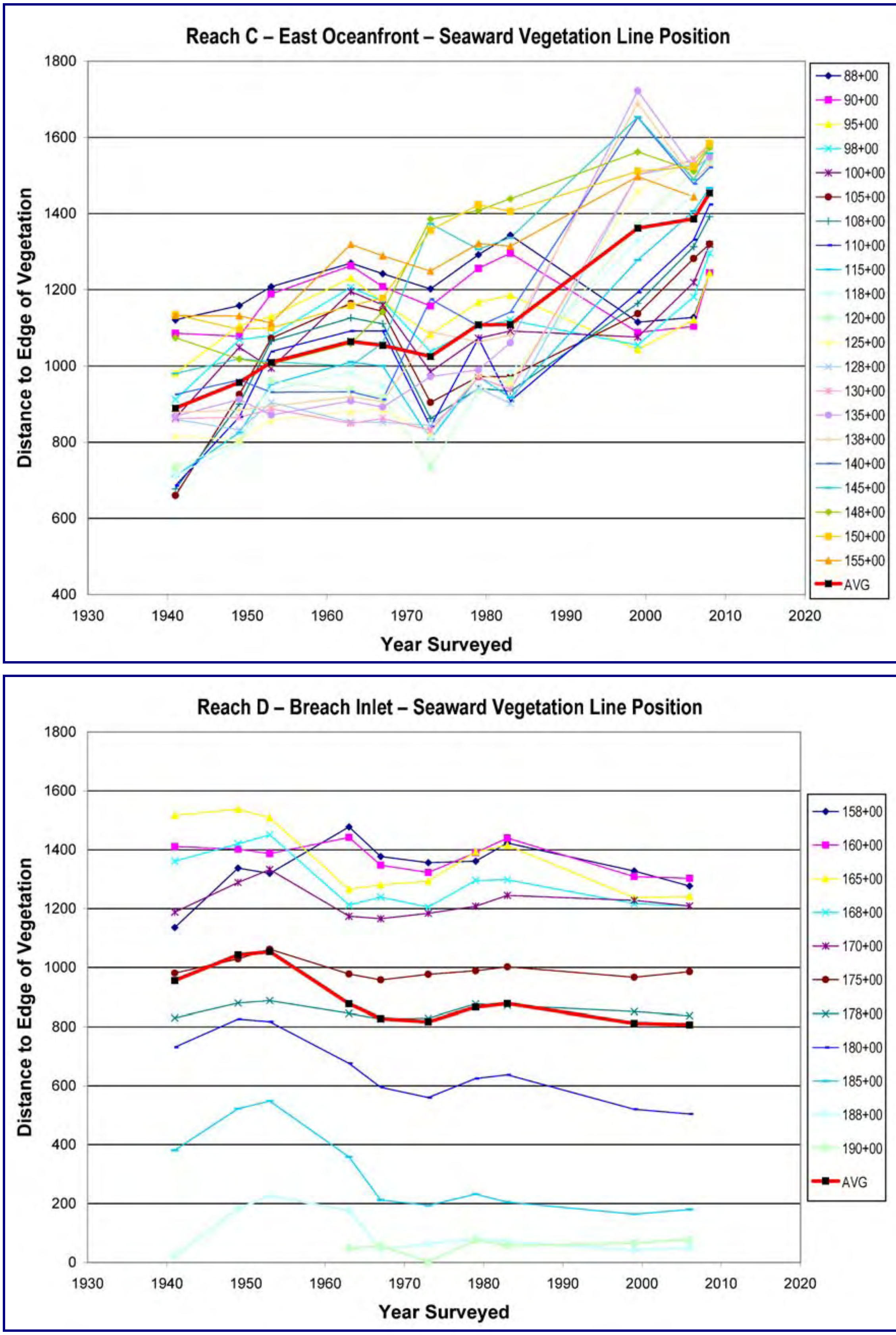


FIGURE 4.8. Trends in seaward vegetation line position by reach for 1941–2008 (based on the data in Appendix 10).

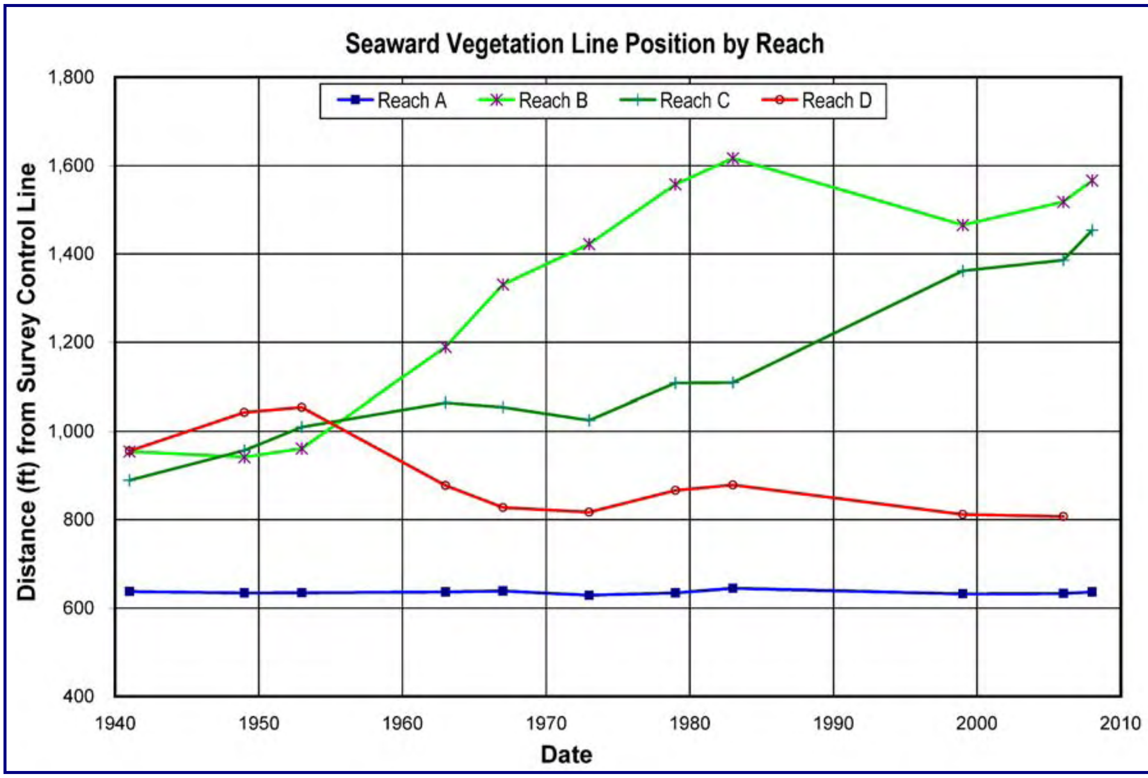


FIGURE 4.9. Average distance from Middle Street to the seaward vegetation line by reach between 1941 and 2008.

Figure 4.10 shows the average annual shoreline change rate by transect for the vegetation line and wet-sand/dry-sand line along Sullivan's Island based on the data in Appendix 10. What is apparent in the graph of Figure 4.10 is that the rate of change varies within the AL study area, reaching a maximum accretion near the middle of each reach and minimum values at the ends of the reaches. In Reach B, for example, the average annual change between 1941 and 2008 is over 15 feet per year (ft/yr) around transect 60+00 (~500 ft east of Station 16). Accretion decreases to about 2 ft/yr at the ends of the reach (near transects 40+00 and 85+00 – north jetty). In Reach C, the average annual change peaks at ~12 ft/yr near transect 120+00 (~Station 25). The net result of prolonged accretion has been development of two broad bulges in the shoreline along the oceanfront study area, separated by a narrow section of accreted land in the vicinity of the north jetty.

It can be shown that linear shoreline change is equivalent to a "unit volume" change across the active profile of the beach, based on the typical elevation of the backbeach areas and depth of measurable sand transport and profile change offshore. Kana and Gaudiano (2001) determined that 1 ft of recession (or accretion) is equal to ~0.6 cubic yard per foot (cy/ft) at Sullivan's Island.

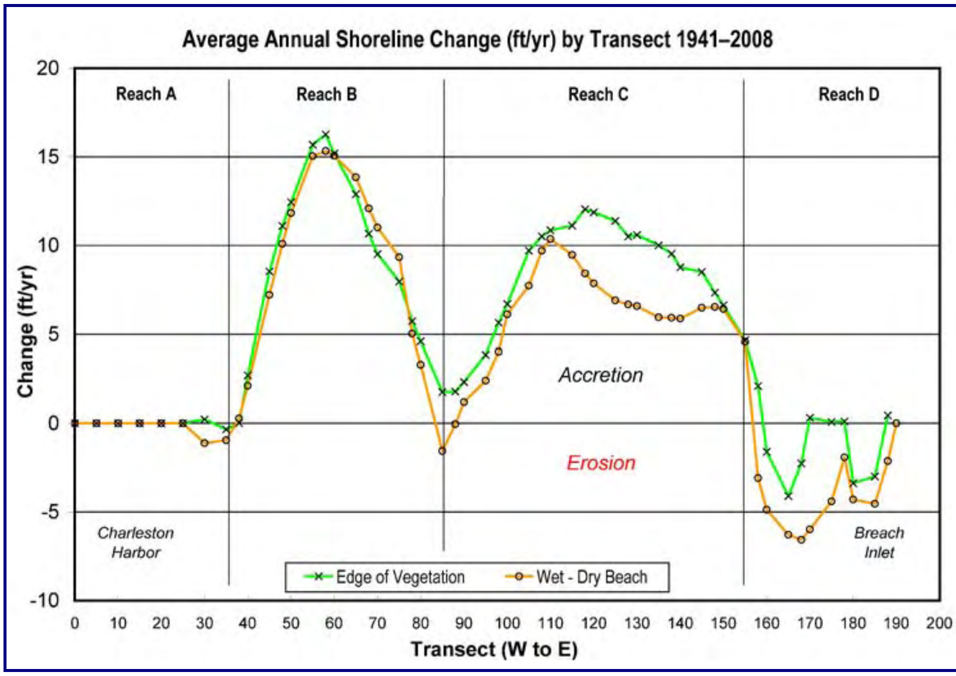


FIGURE 4.10. Average annual change in shoreline position by transect for the period 1941 to 2008.

Unit volumes (Fig 4.11) are a measure of the quantity of sand contained in a 1-ft length of beach between the foredune and outer limit of the littoral zone (referred to as the “depth of closure” where there is negligible change in the bottom elevation from one year or decade to the next). Table A10 (Appendix 10) converts the linear shoreline changes to an equivalent unit volume change. Then results are extrapolated from transect to transect using the “average-end-area method” to estimate the total volumes gained or lost from reach to reach.

Figure 4.12 summarizes the results by reach on an annualized basis for the periods 1941 to 1983, 1983 to 2008, and 1941 to 2008. Figure 4.12 shows the net change per year (upper) and the unit-width change per foot of shoreline per year (lower). The latter results normalize the data so they are not biased by different reach lengths. Rates of change for Reach B and Reach C show significant differences among the periods evaluated. From 1941 to 1983, for example, Reach B accreted at an average of over 19 cubic yards per foot per year (cy/ft/yr), while Reach C accreted one-third as fast (~5.9 cy/ft/yr). Then rates reversed from 1983 to 2008 with Reach B actually eroding (losses of ~2.6 cy/ft/yr), while Reach C accreted at over 15 cy/ft/yr. When averaged over 67 years (1941– 2008), the average annual change for both reaches was very similar at ~10–11 cy/ft/yr. Reach D (Breach Inlet), during the same period of time (1941–2008), lost ~375,000 cy (~2 cy/ft/yr). Average annual losses along Breach Inlet have been about 5,600 cy/yr in contrast to annual gains of ~125,000 cy/yr along the AL study area (Reach B and Reach C).

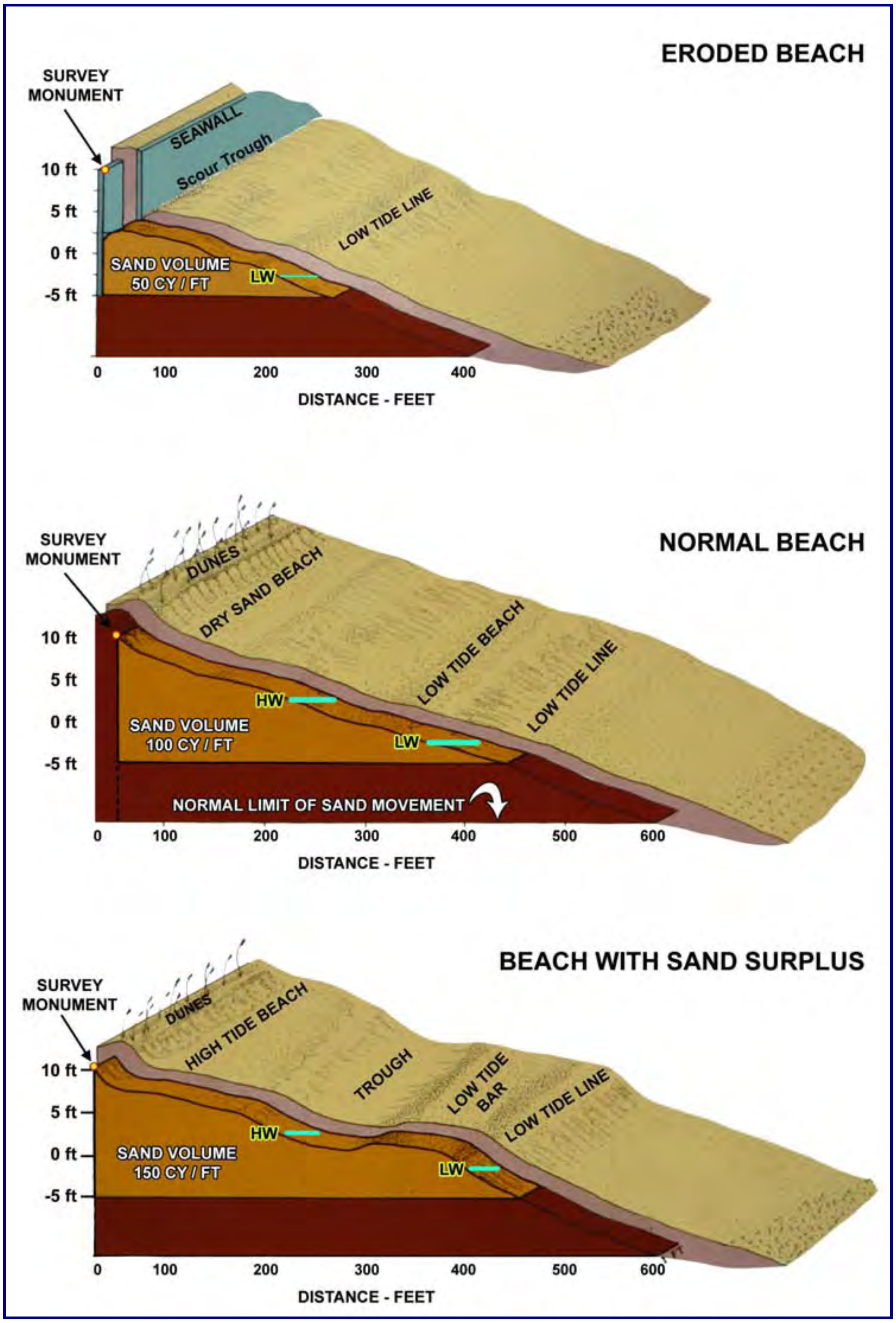
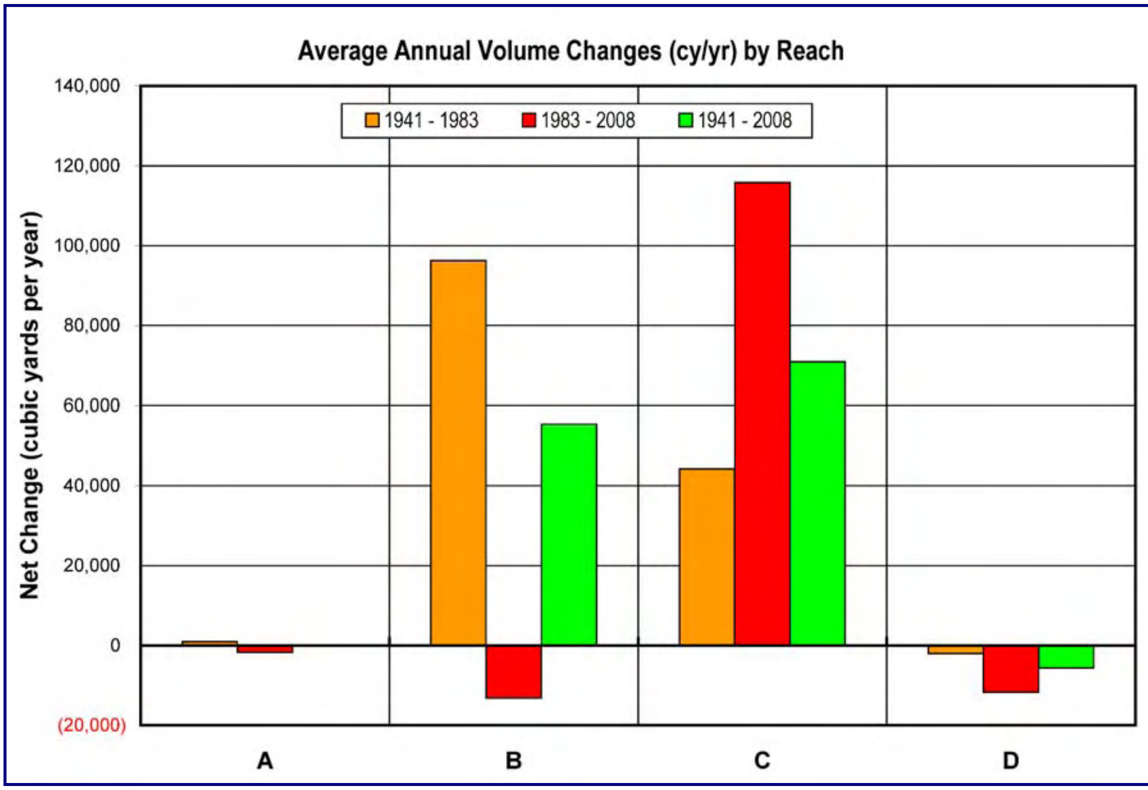


FIGURE 4.11. The concept of unit-width beach volumes, the quantity of sand contained within a 1-ft length of beach. [After Kana 1990]



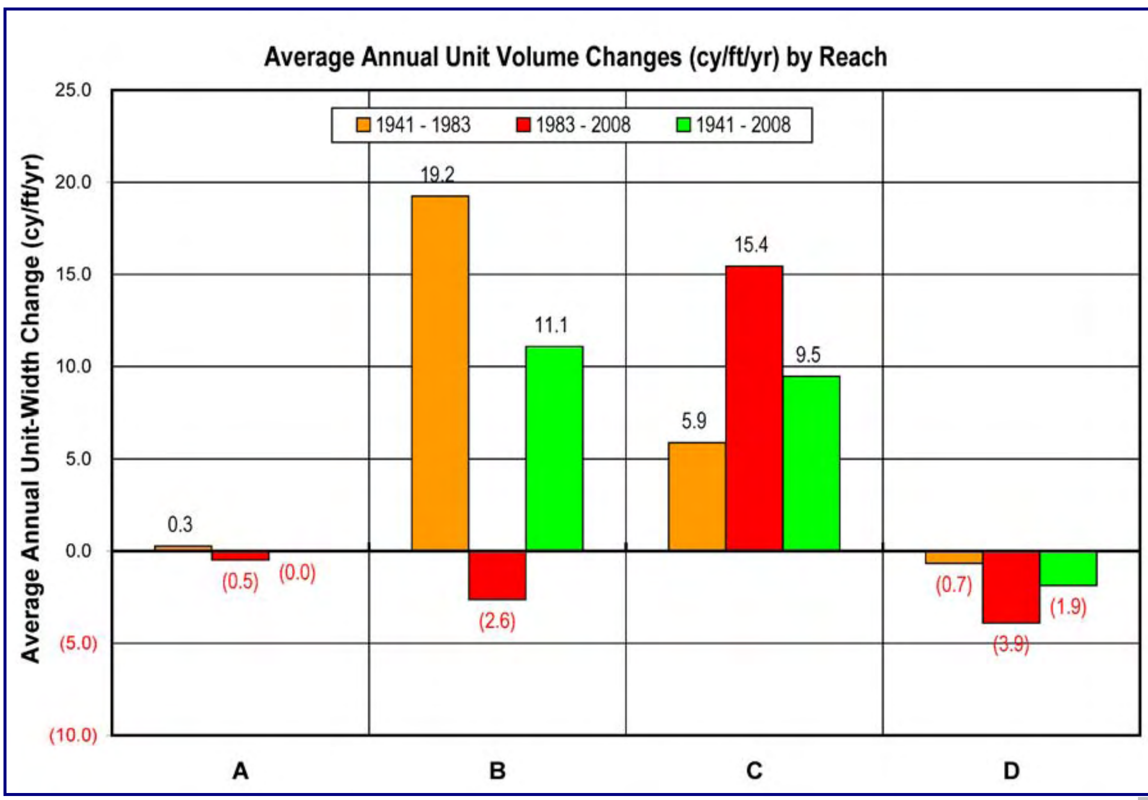


FIGURE 4.12. Average annual change in sand volume by reach for three periods 1941 to 2008.
[UPPER] Net change per year by reach. **[LOWER]** Average unit-width volume change per year by reach.

The sustained accretion along the Sullivan's Island oceanfront at over 10 cy/ft/yr makes the study area one of the healthiest, most rapidly accreting beaches along the US East Coast.

Table A10 (Appendix 10) also provides an estimate of the net volume of sand gained or lost along Sullivan's Island reach by reach. Since 1941, Reach B has gained upward of 3.7 million cubic yards, and Reach C has gained 4.7 million cubic yards. If these quantities were placed via hydraulic dredge in a traditional nourishment project, the cost to the community in today's dollars would be of the order $50-75 million.

4.2 Storm Histories, Storm Surge, and Flood Levels

Sullivan's Island is vulnerable to storm-surge flooding and wave damage because of its direct exposure to the open coast. Although severe hurricanes have not impacted the Charleston area for two decades, storm surge and waves still present the most probable natural hazard risk to the island. The severity of flooding and wave action on the majority of developed property is influenced by the morphology, vegetation, and sediments within the AL study area.

Storm surge is defined as the difference in elevation between an observed water level at the coast and what would have been the normal water level due to astronomic tides. Surges of most concern are associated with strong winds blowing toward shore and "piling" up the water against the coastline. Not surprisingly, the highest surges are associated with landfall hurricanes. The actual height of the surge depends on wind speed, storm duration, slope of the continental shelf, basin geometry, phasing with the tidal cycle, and a number of other factors. Surge levels are predictable by means of sophisticated statistical models and computer simulations of hypothetical storms (calibrated using actual storm-tide histories).

FEMA (the federal agency responsible for administering the flood insurance program) establishes flood elevations based on standard "return periods" of 10 years, 50 years, 100 years, and 500 years. These are statistical results of storm-tide probabilities within a given time period. The 100-year storm tide, for example, is considered to be the water level with a 1 percent chance of occurrence at any time during a 100-year period. The 10-year storm tide would be lower than the 100-year tide, but would have a 10 percent chance of occurrence in any given year. The 500-year tide would be the highest among the three water levels, but only have a 0.2 percent chance of occurrence in any given year. Hurricane *Hugo* (September 1989) produced what is considered to be an ~100-year tide along Isle of Palms. While predicted storm-surge levels are often assumed to apply uniformly along large portions of the coast, there is significant variability from place to place, particularly with distance form the ocean. Thus, "attenuation" of tidal surges and associates storm waves across the land is an important planning consideration for the ALMP.

A complete review of storm histories is beyond the scope of the present study. The most recent flood insurance study for Charleston County (FEMA 2004) summarizes predicted stillwater flood levels for various return period storms* (Table 4.1). For the shoreline from Charleston Harbor to Breach Inlet, the predicted storm tide levels (without wave run-up) are as follows (from FEMA 2004, Table 5).

TABLE 4.1. FEMA (2004) predicted, still-water storm-tide levels at Sullivan's Island for various return-period storms.

	Elevation (ft NGVD'29)	Elevation (ft NAVD'88)
10-year storm tide	8.9	7.9
50-year storm tide	11.2	10.2
100-year storm tide	12.0	11.0
500-year storm tide	13.6	12.6

***Return period (ie – 10-year, 50-year, etc) refers to the probability of occurrence of a particular maximum water level within the given period of time. The 50-year storm tide level has a 2 percent chance of occurring in any given year; the 100-year level has a 1 percent chance of occurring each year, etc. Water levels are given in the standard datum of 1929 and the more recent datum of 1988, on which the present report is based. NAVD'88 is the North American Vertical Datum of 1988 which approximately equals mean sea level during the 1970s and 1980s.

The predicted storm tides are based on computer model simulations of storms entering the coast in the vicinity of the site of interest. Such models are "calibrated" using historical storms and their associated high-water levels. The study Team used FEMA-predicted flood levels as a starting point for computer simulations of storm surge and wave impacts over the AL study area under several representative scenarios (Section 5 of this report).

Storm tide levels along Sullivan's Island are impacted by a number of factors:

- Frequency and magnitude of storms, particularly hurricanes.
- Storm approach direction with storms entering the coast at right angles producing higher surges.
- Landfall point with storms entering slightly south of Sullivan's Island generating highest surges along the island.
- Shallow depth of the continental shelf off Sullivan's Island which amplifies the surge compared with shorelines fronted by deeper waters.

FEMA (2004) summarized the major storms that have impacted Charleston County. There are anecdotal reports dating back to the 1600s, but records become more reliable in the early 1800s. Damaging storms were known to occur in 1686, 1713, 1728, 1752, 1783, and 1787. During the 19th century, there were six more damaging storms as detailed in Table 4.2 (excerpted from FEMA 2004, pgs 8–10). The 20th century also saw six damaging storms. The storms described in Table 4.2 do not include numerous extratropical storms ("northeasters") or hurricanes which passed close by without making landfall along Charleston County.

Fortunately for Sullivan's Island, few storms have been "direct hits" (Table 4.2). The majority have entered well south or north of the island. However, Hurricane *Hugo* (21 September 1989) is the storm of record with landfall over the island. This produced water levels of 12–13 ft NGVD'29 along the open coast and even higher levels along portions of Isle of Palms and Bull Bay to the north.

TABLE 4.2. Description of major storms impacting Charleston County in the 19th and 20th centuries. [Excerpted from FEMA (2004), pgs 8–10.]

7 September 1804 – This severe hurricane moved inland between Savannah (GA) and Charleston (SC), causing significant damage on the coasts of Georgia and South Carolina. This storm is said to have caused more than 500 drowning deaths in South Carolina. The hurricane also caused major damage to the South Carolina economy. Historical notes contain no data on the height of the storm tides or strength of the winds.

27 August 1813 – This storm passed near Charleston, causing a large loss of lives and property. It rates a position close to the top of Charleston's meteorological list for its combination of severe winds, heights of flood tide, and general destruction.

27 September 1822 – This small, destructive hurricane passed inland between the cities of Georgetown and Charleston. It caused unprecedented tides at Georgetown and several hundred deaths in Charleston, the Town of Sullivan's Island, Georgetown, and North Island.

7 August 1854 – This major hurricane approached the United States from the south-southeast, driving the waters of the Atlantic Ocean into the bays and inlets, over some of the low-lying islands along the South Carolina coast. The storm commenced on Thursday (7 August) and did not end until Saturday night, causing severe suffering in the Town of Port Royal in Beaufort County.

25 August 1855 – This hurricane made landfall north of Savannah on a northeasterly course and passed to the west of Wilmington (NC). The storm is said to have damaged 90 percent of the houses in Charleston and severely damaged all of the South Carolina coast. As a result of this destructive storm, it was proposed that a weather reporting network be set up in the West Indies and Mexico.

27 August 1893 – This severe hurricane made landfall around the Georgia and lower South Carolina coasts. An estimate of more than 1,000 people lost their lives on the coastal islands and in the lowlands between the City of Tybee Island (GA) and Charleston (SCDPA 1973). The highest tide in this storm was estimated to have ranged from 17.0 ft to 19.5 ft MSL at Savannah Beach (GA) (USACE 1968). At Charleston, the tide was 8.9 ft MSL. Extensive property damage was caused along the Georgia and South Carolina coasts.

23–30 August 1911 – The center of this hurricane crossed the coast between Savannah (GA) and Charleston (SC) on 28 August. This storm is considered in the same category as the storm of 1940 (described below). At Charleston, the barometer fell to 992 millibars (mb) (29.30 inches). The wind at the weather bureau office reached 81 mph from the southeast (USDOC 1949). Seventeen lives were lost, and damage totaled about $1 million. The storm passed into the Piedmont section of South Carolina and then recurved to the northeast (USDOC 1971). At Charleston, the tide reached 7.5 ft MSL, the third highest of Charleston County records.

11 August 1940 – This hurricane entered the coast from the southeast, between Savannah County (GA) and Beaufort County (SC) at about 4 p.m. on 11 August. Near Beaufort County, the tide is estimated to have reached 14.2 ft MSL. Near the southern tip of Edisto Island, a high watermark indicated a tide of 13.6 ft MSL on the open coast. About 175 cottages were destroyed on Edisto Island. On Folly Island, the maximum tide determined from a National Ocean Survey benchmark was 8.3 ft MSL. The entire beachfront eroded an average of 75 ft. At Charleston, most of the damage was to buildings, wharves, and boats along the waterfront. Large areas of the low waterfront perimeter in the city were inundated, and many automobiles were damaged by the storm tide, which reached an elevation of 8 ft MSL. Estimated damage to the city was $1 million. Sullivan's Island, the City of Isle of Palms, and Pawleys Island suffered minor damage. Overall, this hurricane was responsible for 34 deaths and caused damage estimated at $6.6 million (USACE 1957).

TABLE 4.2. (continued) Description of major storms impacting Charleston County in the 19th and 20th centuries. [Excerpted from FEMA (2004), pgs 8–10.]

15 October 1954 – Hurricane *Hazel* crossed the coast just north of the City of Myrtle Beach (SC). This hurricane was one of the most destructive to strike the Carolinas in terms of property damage. Hurricane winds hit the Atlantic coast between Georgetown (SC) and Cape Lookout (NC). Storm tides devastated the immediate oceanfront along this stretch of coast. High tides of 16.6 ft MSL were observed at Holden Beach Bridge and the Town of Calabash (NC). The lowest recorded barometric pressure of 938 mb (27.71 inches) was reported at Little River Inlet on the South Carolina-North Carolina border. Folly Island, Sullivan's Island, and Isle of Palms suffered light property damage and slight beach erosion. The City of Charleston experienced no serious damage. Total property damage was estimated at $34 million in North Carolina and at $27 million in South Carolina.

29 September 1959 – Hurricane *Gracie* moved inland on September 29. The center passed over the South Carolina coast at St. Helena about 10 miles east of the Beaufort. Damage of disaster proportions occurred in the coastal region from Beaufort to Charleston, and considerable additional damage occurred in the area of Walterboro. A barometric pressure of 950 mb (28.06 inches) was reported at Beaufort. The total damage inflicted by the storm was estimated at $14 million. High-watermarks, which were reported near the Town of Edisto Beach (SC), ranged from 7.3 ft to 11.9 ft MSL.

25 August – 7 September 1979 – Hurricane *David* was the most intense storm of the century to affect the islands of the eastern Caribbean. However, the storm was not a major hurricane when it struck the United States just north of Palm Beach (FL) on 3 September and made a second landfall about 24 hours later near Savannah Beach (GA). In the United States, *David* was responsible for five deaths and about $300 million in damages.

12–25 September 1989 – Hurricane *Hugo* struck the Charleston (SC) area about midnight on 22 September, near high tide. As of 1990, *Hugo* was the most destructive hurricane (in dollar losses) to ever strike the continental U.S. coastline. High-water elevations (including wave setup and wave crest contributions) were 12–13 ft NGVD'29 at the open coast from the City of Folly Beach northward to the City of Myrtle Beach, with elevations up to 19 ft NGVD'29 in bay areas in the vicinity of the maximum winds. Downtown Charleston experienced high-water elevations of ~10 ft NGVD'29.

4.3 Historical Vegetation Succession

The study Team interpreted changes in historical vegetation succession using aerial photography dating back to 1941 (see Figs 4.1–4.5). Historical vegetation communities were identified from photographic signatures based on comparison of vegetation signatures on 2008 aerial photography to vegetation communities identified in the field (Section 3.3). The Team based assumptions of species occurrence from historical photographs on species composition of present-day vegetation communities. [Portions of Figures 4.1–4.5 are repeated here to aid the reader.]

In 1941, the coastline consisted of a mix of residential development and early successional maritime dune grassland (see Fig 4.1). Dune grassland vegetation, probably dominated by sea oats as it is today, was most extensive in Reach B, the eastern half of Reach C, and Reach D. These areas contained little or no development and appeared to be in a natural state. Dune ridges appear almost white on the photograph and probably support only scattered vegetation. Dune swales, somewhat protected from salt spray and strong winds, support denser vegetation and appear darker. Little change in vegetation occurred between 1941 and 1949, with the exception of an expansion at the mouth of Breach Inlet (160+00) and perhaps some development of the existing maritime foredune grassland community.

By 1963, accretion along Reach B can be seen (Fig 4.2 and Fig 4.13). Maritime foredune grassland has expanded ~1,000 ft from the seaward row of houses. Some maritime shrub growth on the inland edge of the AL area has developed and appears as dark blotches on the aerial photograph. The shoreline bulge at Breach Inlet has also continued to grow, as has residential development following that growth. The seaward row of residential homes was established in both areas by 1963. Seaward of the homes, ~250 ft of dune grassland appear to have been established at the Breach Inlet bulge (Reach C).

Between 1963 and 1967, the accretion area along Reach B continued to expand, and interior vegetation began to develop into a maritime shrubland community, with wax myrtles dominating the shrub community (see Fig 4.3). Interdunal flats and low elevation swales are visible on the western half of Reach B, which will later be seen to develop into the wetland communities that exist today. Lighter patches representing dune ridges bisect the flats and swales, the latter of which will grow into the early successional maritime forests found today. Trees begin to colonize the area around 90+00, likely a mix of live oak and loblolly pine, which is present in this area today. The bulge at Breach Inlet has eroded slightly, reducing the extent of maritime grassland, though a narrow band of maritime shrubland vegetation appears to have colonized the inland portion.

By 1973, sand can be seen accumulating between 130+00 and 150+00, the eastern half of Reach C, with maritime foredune grassland developing (Fig 4.3 and Fig 4.14). Reach B appears to continue to accrete as well, widening the seaward band of maritime backdune grassland as well as the inland band of maritime shrubland. The white bands of dune ridges appear darker, indicating further development of the dune grassland occupying the area. Interdunal flats and dune swales appear to be developing denser vegetation as well.

FIGURE 4.13. Sullivan's Island AL study area in **1963** (Reach B – upper, Reach C – lower). Note seaward buildup along with expanding patches of shrub vegetation (dark zones seaward of buildings).

The 1979 photo reveals that the vegetation line along Reach B is about 1,000 ft seaward of buildings, which is close to the present-day extent of vegetation (see Fig. 4.4). Maritime shrub vegetation on the interior portion of the area has matured to early successional maritime forest, and inland dune swales are developing into hardwood depressions. The interior area of Reach C around 90+00 continues to develop into maritime forest, and accretion adds new land between 140+00 and 160+00. With that accretion, there was further development of the interior maritime shrub habitat and an expansion seaward of dune grassland habitat in Reach C.

Between 1979 and 1983, the island experienced moderate erosion along most of its coastline. Erosion continued through 1999 for most of the eastern half of Reach B and the western half of Reach C. Much of the maritime grassland community and some of the seaward portion of maritime shrub community present in this area were eroded, leaving a very narrow transition from intertidal beach to maritime shrub. The eastern half of Reach C saw rapid accretion and development of dune grassland and interdune flats and wetlands. Interior portions of Reach B continued to mature into early successional maritime forest and depressional wetland. Figure 4.15 shows the extent of shrub and forest vegetation in 1983. The eastern half of Reach B and all of Reach C accreted through 2006 and developed an outer band of maritime foredune grassland community (see Fig 4.5). Though some accretion continued through 2008, the 2006 vegetation community appears very similar to what it is today.

Figures 4.16 and 4.17 show portions of the 1983, 1999, and 2006 aerial photos for Reach B and Reach C (respectively). These images show how the Reach B shrub and forest community matured over two decades while the Reach C shrub and forest community was in a much earlier stage of succession.

FIGURE 4.14. Sullivan's Island AL study area in **1973**. Note greatly expanded areas of shrub vegetation in Reach B (upper panel) compared with 1963 conditions (Fig 4.13).

FIGURE 4.15. Sullivan's Island AL study area in **1983**. Note greatly expanded areas of shrub vegetation in Reach B (upper panel) compared with 1963 conditions (Fig 4.13).

FIGURE 4.16. Reach B in 1983, 1999, and 2006 (top to bottom) showing the increased density of shrub and forest vegetation.

FIGURE 4.17. Reach C in 1983, 1999, and 2006 (top to bottom) showing incipient shrub and forest vegetation (1983) expanding greatly by 2006.

4.4 Implications of Historical Changes on the ALMP

The Team's research on historical changes within the AL has important implications on the ALMP. First, the AL is only about 30–60 years old, depending on the reach. Little of the present high-ground area existed prior to 1941 (date of the first available vertical aerial photograph). Thus, every habitat observed today within the AL has evolved in just a few decades. This demonstrates the speed at which vegetation and natural succession of species can occur over lands subject to harsh environmental conditions.

Secondly, the relatively low elevations and relief of the AL reflect the high rate of shoreline movement (averaging over 10 ft/yr) and the lack of time for individual dune ridges to grow in height before a more seaward dune begins to form. This has left low areas where standing water promotes growth of wetland species.

Thirdly, the >1,000-ft width of the AL allows more diverse zonation of plant habitats than normally found seaward of "oceanfront" buildings on barrier islands. While the more seaward areas experience the harshest conditions of windblown sand, salt spray, and poor soils, landward areas are sheltered, less exposed to salt water, and able to support a wide range of freshwater species. Not surprisingly, the Team identified nine relatively distinct vegetation habitats within the AL.

The natural vegetation succession within the AL can be seen by walking across the land from sea to shore and by comparing vegetation densities within the western half (Reach B) and eastern half (Reach C). The age of the land increases from the shoreline to developed property. The western half of the AL is 20–30 years older than the eastern half. The seaward portions of the AL are dominated by dune grasses, whereas the oldest interior sections are dominated by maritime forest. As Section 3.3 describes in detail, even the maritime forest zones are not fully mature. Therefore, as a general statement it can be said that virtually all of the AL is in a state of vegetative transition. Many areas are considered to be in an early successional stage (grasses and shrubs), whereas some areas are much closer to the "climax maritime forest" stage.

While no area within the AL is considered to have reached an ultimate vegetative succession typical of low-country maritime forest habitat, the western portion of the AL is closest to that condition. An important difference between climax maritime forest and the present condition of the western half of the AL is the degree of lower story vegetation that remains within the tree canopy. With time, trees form an expanding canopy which blocks light and inhibits growth of lower story shrubs and vines. The net result is an increasingly open understory. This has implications for the ALMP in the following ways:

- The transition forest with denser understory is more susceptible to fire.
- Dense understory attracts some nuisance species such as rats.
- Lack of open areas creates more of a security issue along beach access paths.

Another implication of the historical evolution and way the land has accreted is the formation of wetland habitat within the AL. While not in the form of open-water ponds, the year-round wetland areas (as well as some sporadically wet areas) introduce and attract more diverse species and wildlife. Small pockets of standing water also produce nuisance insects, such as mosquitos. Wetlands within the Al are both a constraint and an opportunity. They are subject to federal and state jurisdiction and protection (see Section 1.4), but these areas could also be expanded and deepened in some sections (via limited excavation) to create open-water ponds. With proper design, the latter could be linked to present areas of standing water and promote drainage into ponds for a reduction in mosquito-breeding habitat. Open-water ponds, obviously, would impact vistas and introduce another amenity for the community.

Present efforts to control vegetation under the Town's 1991 ordinance confirm that it is possible to retard the natural succession from shrub to forest habitat. Pruning waxed myrtle and other authorized vegetation has the effect of maintaining and expanding the understory, particularly that of the pruned species. Vistas over the vegetation can be maintained and would require an ongoing effort. Because pruning has not been universal across the AL, the results of pruned corridors adjacent to unpruned corridors (eg – Reach C) demonstrate how the tree canopy can be varied throughout and produce a greater variety of vistas in comparison to that of a climax maritime forest – the ultimate succession stage for the entire area.

The history and relatively rapid creation of habitats within the AL indicate the following (with implications to the ALMP):

- The habitats are not static and will continue to evolve toward higher stands of mature forest species.
- The AL is likely to remain stable over the next ~50 years even under the threat of accelerated sea-level rise [present, most-likely scenarios of the IPCC (2007)].

- Erosion along the seaward edge of the AL may occur under sea-level rise scenarios but this will not prevent the maritime forest from growing along landward portions of the AL.

The historical evolution, present conditions, and existing management practices within the AL point to four broad alternatives for the area:

1) Do nothing and allow the AL to evolve naturally.

2) Continue present practices of limited pruning and path maintenance.

3) Implement more extensive management of vegetation to maintain a broader variety of habitats and vistas into the future.

4) Modify the topography and implement extensive management of vegetation to improve storm protection and maintain a broad diversity of habitats including creation of open-water ponds.

Among the key findings of the Team's study is that the AL is in transition from incipient dunes (grasses predominant) to mature maritime forest. Present vegetation conditions are transient in most areas and can only be maintained as-is by extensive management and manipulation into the future. Without any management activities, the existing grass and shrub habitats will transform naturally into forest habitat with an increasingly high canopy and diminishment of ocean vistas.

The next section of the report evaluates anticipated future changes in the shoreline and vegetation within the AL study area. Historical shoreline changes and the variety of existing habitats point to likely changes in the future. To evaluate potential impacts of pruning and manipulation of topography, the Team developed computer model simulations of storm tides and waves under several future scenarios. These simulations provide a means of quantifying and comparing the effects of particular-intensity storms on Sullivan's Island property if vegetation or the land is modified in some way.

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5.0 FUTURE CHANGES – LAND EVOLUTION

This section draws on the findings of the first four chapters of the report to outline future changes in the accreted land (AL) study area. Historical shoreline change provides a means of extrapolating changes into the future. For purposes of the ALMP, the rate of change is less important than the question of whether or not the existing land will remain stable. Any degree of accretion into the future means the AL is likely to support the continued growth of vegetation. The types of vegetation succession to expect can be similarly determined by extrapolating historical changes. Factors that could modify the rates of accretion or vegetation succession in the future include:

- Reductions in sand supply from Isle of Palms.
- Accelerated sea-level rise (SLR).
- Changes in the frequency and extent of pruning.
- Changes in the frequency and magnitude of damaging storms.

Section 5 outlines the likely evolution of the AL and its vegetation based on empirical projections of historical changes. The Team also evaluated potential impacts of damaging storm surges using computer models which simulate extreme conditions. These latter analyses allow alternate management scenarios to be tested and compared. For example, denser forest vegetation may attenuate storm surges more effectively than grasslands. Modification of topography may also alter the attenuation of storm surges. An important aspect of the ALMP is an evaluation of the likely changes that will occur as the land evolves under a range of alternatives. This provides a basis for selecting alternatives that best suit the needs of the community.

In this section, the Team considers three scenario conditions in the AL and evaluates their effect on storm surge attenuation, reduction of wave heights, and potential damages to existing property. The scenarios represent the following:

- Existing conditions with negligible change in vegetation cover.
- Modified conditions due to reductions in vegetation cover.
- Modified conditions due to minor topographic changes such as the addition of a beneficial dune of limited dimensions.

The scenarios evaluated are considered incremental and not a major sculpting of the land or wholesale clearing of vegetation. They are intended to illustrate the relative impacts of management activities that may be considered for the site. This section is intended to help the community interpret and understand the impact of future changes (artificial or natural) on the AL.

5.1 Evolution of Dunes and General Response to Storms

It should be clear from the natural history of Sullivan's Island that the oceanfront does not simply wax and wane between storms as many other beaches do. Rather, it has been on a trajectory of seaward growth superimposed on the natural beach cycle (Fig 5.1). What may not be evident is that rapid accretion inhibits growth of dunes along the oceanfront. Dunes grow by accumulation of windblown sand off the dry beach. South Carolina beaches tend to have lower dunes than their North Carolina counterparts, because the dry beach is typically narrower (less dry sand available) and winds are somewhat gentler (less energy to move sand). If the shoreline is relatively stable, a single dune line can be fed gradually by windblown sand. A stable shoreline, like Litchfield Beach, will often have a well-developed foredune reaching elevations of ~20 ft above mean sea level. However, shorelines that accrete

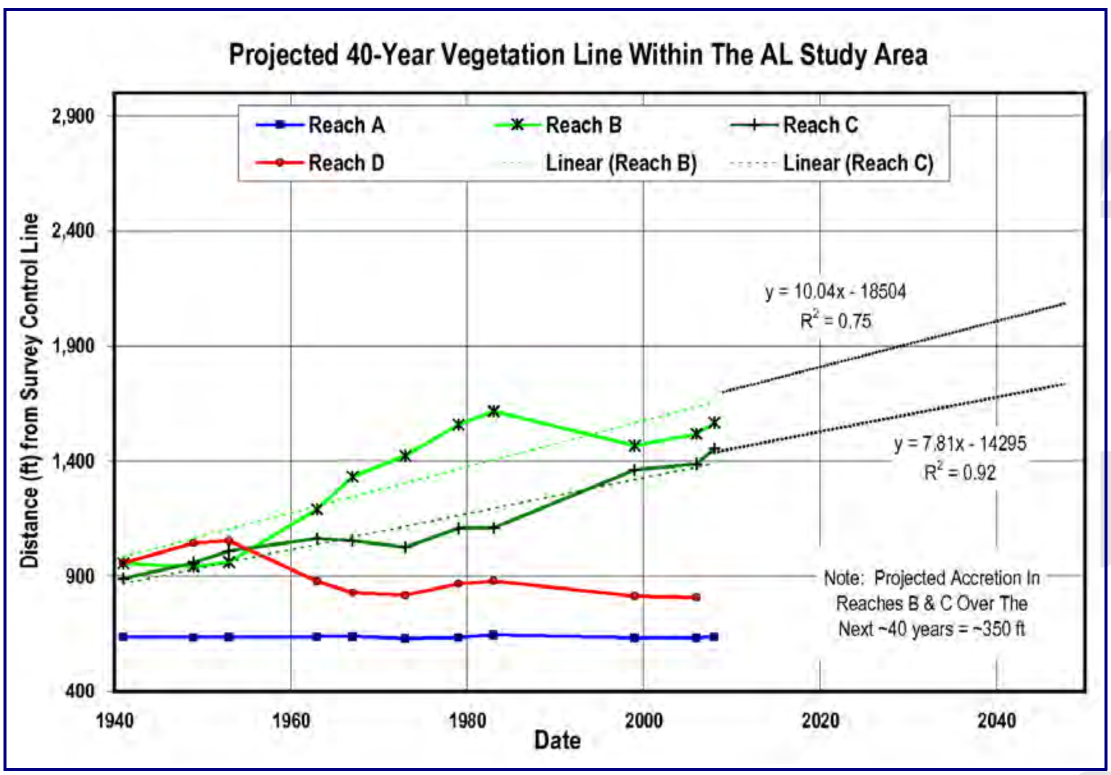


FIGURE 5.1. Projected future shoreline positions along Reach B and Reach C within the AL study area based on trends over the past 60 years. The projections have relatively high correlation coefficients based on historical trends. Average accretion rates are expected to be of the order 7–10 ft/yr if the rate of SLR remains similar to the 20th century trend. Under the IPCC (2007) SLR scenario of an approximate doubling or tripling of the 20th century rate, the Sullivan's Island shoreline would accrete at a lower rate (Kana et al 1984).

rapidly, particularly via episodic inlet sand-bypassing, will see the shoreline “jump” seaward before a well-developed dune can form.

When the shoreline jumps hundreds of feet, the prior foredune and swale become sheltered and vegetated. This “freezes” the topography and inhibits vertical growth of the land. Low relief and low elevations across the AL area at Sullivan’s Island attest to this process. As the representative cross-section in the previous section showed (see Fig 3.6), the typical elevation of the study area is ~8 ft above mean sea level. With only a few isolated exceptions, dune elevations generally do not exceed 12-ft mean sea level. As a result, nearly the entire AL study area is subject to flooding by a 50- or 100-year storm tide.

The response of accreting or eroding shorelines with high or low dunes became apparent during Hurricane *Hugo*. Kana et al (1990) and Kana (2005) identified four (4) beach types and described their responses to *Hugo*'s surge (Fig 5.2).

Type (1) Beaches – *Stable shorelines with a single, high foredune* (eg – Litchfield Beach). Dunes exceeding a width of ~80 ft at the base withstood the surge and waves of the hurricane with negligible damage to property. Dunes less than 80 ft wide at the base were more likely to breach and overwash. Emergency dunes pushed up after the storm tended to perform well. (Fig 5.2, upper)

Type (2) Beaches – *Eroding shorelines with a low dune* (eg – Pawleys Island). Damage was extensive because of the volume deficit on the beach. Emergency dunes performed poorly because of exposure to normal tides. (Fig 5.2, middle)

Type (3) Beaches – *Accreting shorelines with multiple, low dunes* (eg – Sullivan’s Island, Isle of Palms). Rapid accretion along some South Carolina beaches precludes formation of high dunes. Backshore areas become stabilized with vegetation before gaining height as more seaward dunes form and trap windblown sand. *Hugo*’s surge overtopped such areas and produced extensive damages to older properties not meeting today’s building and elevation standards. Emergency dune construction was successful and long-lasting. (Fig 5.2, lower)

Type (4) Beaches – *Eroding, armored shorelines with no dry beach* (eg – Folly Beach). Typical shore-protection structures were too low and inadequate to absorb the surge. Many seawalls and bulkheads collapsed along with habitable structures, producing damages similar to Type (2) beaches. (Not shown)

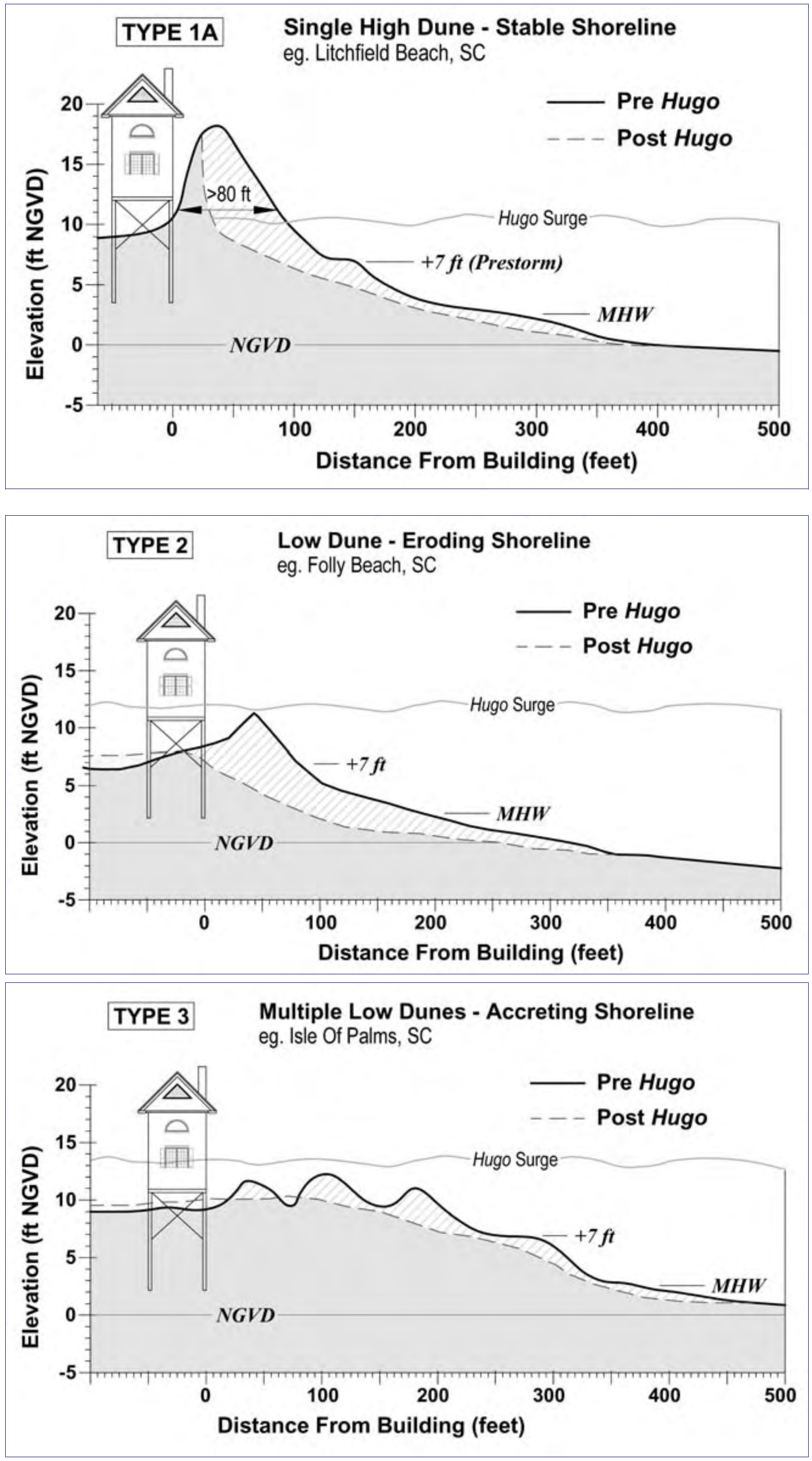


FIGURE 5.2. Beach profiles in response to Hurricane *Hugo*. **[UPPER]** Type (1) — typical of stable shorelines with a single, high foredune. **[MIDDLE]** Type (2) — typical of eroding shorelines with low foredunes, including reaches between groins. **[LOWER]** Type (3) — typical of accreting shorelines with multiple, low foredunes. *Hugo*'s surge overtopped the dunes and caused extensive damage to older buildings built below the 100-year flood level. [After Kana 2005]

Lessons learned from *Hugo*, which are applicable for Sullivan's Island and other sedimentary coasts exposed to major storms (Kana 1977b, 2005):

- Prestorm beach condition strongly influences erosion losses.
- Average, healthy beaches with a single, high dune tend to offer more protection (reduced property damages) than wide, accreting beaches with low dunes as well as narrow, eroding beaches.
- Properties along armored beaches in South Carolina sustained damage because seawalls were generally too low for the surge and not properly sized to withstand wave impacts.
- Maintenance by nourishment (or otherwise) of average, healthy beaches with at least one large dune ridge offers good (but not guaranteed) protection to oceanfront property during major storms.

5.2 FEMA Dune Volume Criteria

FEMA has long recommended a particular minimum volume of sand in the dune system for protection of coastal development. For ~100-year storm protection, FEMA (2003) recommends there be the equivalent of 20 cy/ft of sand volume above the local 100-year flood elevation. This is equivalent to a cross-sectional area of 540 square feet (ft^2) above the ~11 ft NAVD'88 contour. Some example profiles that satisfy this criteria are shown in Figure 5.3. While a majority of South Carolina beaches do not meet FEMA's storm protection criteria, Sullivan's Island fares worse than many because of its low elevations across the accreting land. To achieve FEMA's recommended "dune reservoir" volume, portions of the land would have to be raised by several feet to the 100-year flood elevation and then topped by a dune above that level. As Figure 5.3 illustrates, the shape and height of the dune could vary as long as the total cross-sectional area above the storm tide level exceeds 540 ft^2.

While high, substantial dunes clearly offer better protection in storms to oceanfront property, they inhibit views and alter the character of the oceanfront in some areas. The study team recognizes that high dunes introduce some of the same management controversies as tall vegetation for the simple reason that views tend to be blocked in each case. Based on the history of rapid accretion along the AL study area and its likely continuance, high dunes are not likely to form in the future unless they are artificially enhanced. While dune elevations are not expected to grow significantly, vegetation succession will result in higher canopies of trees and shrubs.

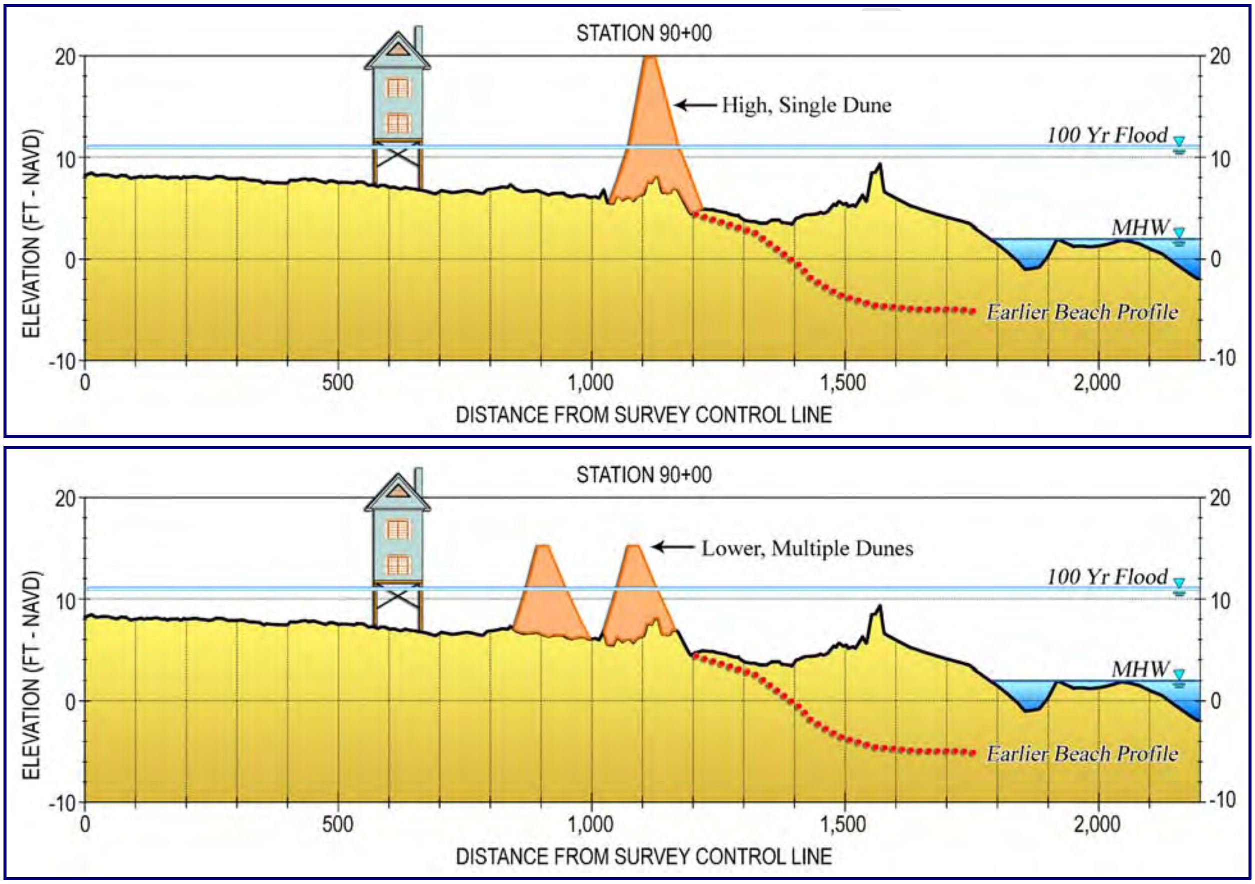


FIGURE 5.3. Typical profile across the AL study area of Sullivan's Island showing FEMA's (2005) recommended protective dune volume above the 100-year flood elevation. Alternate scenarios are given. Communities having sand volumes of this magnitude above the 100-year flood tend to sustain major storms with much less damage. Few oceanfront developments in South Carolina have this level of protection. (Note: Vertical exaggeration is ~30 times. House is not to scale.)

5.3 Shoreline Response to Accelerated Sea-Level Rise (SLR)

The Environmental Protection Agency (USEPA) (eg – Titus et al 1984, USEPA 2009) has evaluated potential impacts of accelerated SLR along the US coast under various future scenarios. The consensus is that SLR will accelerate during the 21st century with the most probable rates of rise presently estimated to be of the order 2–3 ft per century (IPCC 2007). Higher scenarios, as well as lower scenarios, remain a possibility. However, lacking clear predictions, communities must determine what scenarios are appropriate for their own planning. It is apparent that the rate of SLR can be measured over time and confirmed, but the future rates of rise cannot be predicted with precision. A question for Sullivan's Island is what will be the response of the shoreline under a range of SLR scenarios?

In an early case study of the potential impacts of SLR, which remains relevant today, Kana et al (1984) developed methodology and a pilot study of projected changes around Charleston, including portions of Sullivan's Island. This EPA-sponsored study demonstrated that the response along beaches differs from the response along sheltered shorelines because of the nature of sediments. Sandy material in the surf zone is noncohesive and can be easily pushed landward and upward by waves according to a simple concept proposed by Bruun (1962). In simple terms, Bruun showed that beaches tend to maintain their shape and profile while adjusting to changing sea levels (Fig 5.4). This has important implications for the AL study area and the ALMP, because it means there is a likelihood that land elevations along the seaward portion of Sullivan's Island will rise to keep pace with higher sea levels under certain scenarios. Clearly, a sudden SLR of the order 10 ft would flood high ground and produce a major displacement of shorelines and damage to many structures on the island. By comparison, SLR of the order 2-3 ft over one century (ie – the scenarios considered most likely by the IPCC 2007) represents a gradual change that may be accommodated by natural processes.

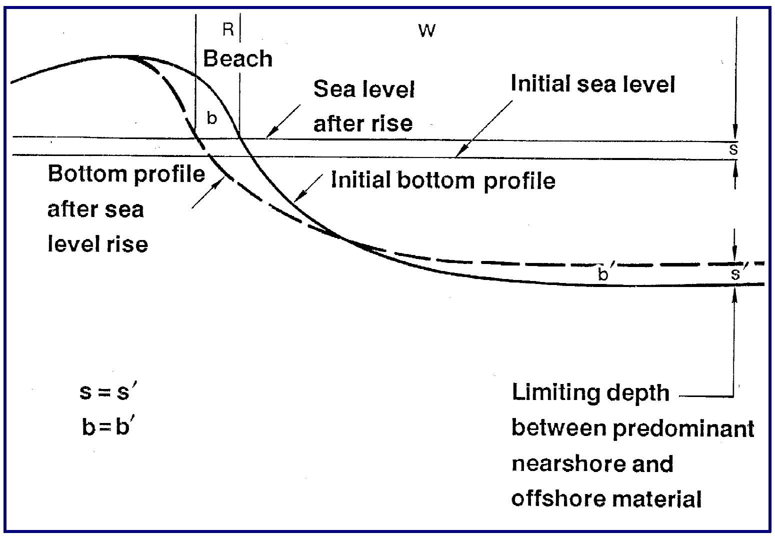


FIGURE 5.4.

The Bruun rule concept: a rise in sea level causes a recession of the beach with erosion along the upper beach balanced by accretion underwater. [Sources: Bruun 1962, Hands 1981, NRC 1987]

Kana et al (1984), using a modification of "Bruun's Rule," calculated the likely displacement of the ocean shoreline along Sullivan's Island for several SLR scenarios. Interestingly, the results showed that accreting areas will continue to accrete, but at a lower rate under the lowest scenarios (ie – SLR of the order ~1-1.5 ft). An SLR of the order 2 ft would reduce the accretion rate to zero, meaning no additional widening of the AL. Under an SLR of ~2.5-3 ft per century, the AL would recede, with the shoreline in 2075 projected to be about 250 ft landward of the 1980 shoreline. Successively higher SLR scenarios were shown to produce greater shoreline recession, but the results along the AL were counterbalanced partially by the natural accretion trend.

Despite the uncertainty in SLR during the next century, there is a range that may be accommodated within the AL before erosion encroaches on high ground. It appears this range is of the order 2-3 ft based on the Charleston case study (Kana et al 1984). The obvious implication for the ALMP is that SLR in the next 50 years or so is not expected to eliminate the AL. Instead, much of the existing terrain will remain viable high ground that continues to support a range of vegetation. Existing habitats within the AL could be adversely impacted by higher frequencies of storm-surge flooding, but landward areas are expected to remain protected and able to support maritime forest habitats. Thus, the present issues of land management in the AL will likely apply over the next several decades.

5.4 Future Vegetation Succession

The ultimate, climax vegetation community in an area is driven largely by the specific conditions and history of the area in which it occurs. Disturbance events such as hurricanes, human intervention, or introduction of invasive species can drastically alter the species composition of a vegetation community at any stage of succession. The AL area at Sullivan's Island has a history of such disturbances. Hurricane *Hugo* in 1989, pruning of vegetation to maintain views of the ocean, and the presence of Chinese tallow, wisteria (etc) are all examples of disturbance specific to the AL study area. Predicting the composition of the climax vegetation community when so many factors come into play is extremely difficult. The following is an attempt to paint a picture of changes that are expected to take place within the AL area in the coming years. These predictions are based on the findings of the vegetation surveys and other accounts of climax maritime vegetation communities in South Carolina and neighboring states (Nelson 1986, Bellis 1995).

Maritime Foredune Grassland – Though this vegetation community is considered early successional, continuous salt spray and overwash from storm events will likely keep this area as such. If the AL area continues to grow seaward, expect that a maritime foredune grassland will continue to develop outward at the edge of the expansion, and existing grassland will develop into maritime shrubland. This vegetation community composition is not likely to change significantly without some form of disturbance.

Maritime Backdune Grassland – These communities are probably being held in a state of early succession by poorly developed soils and scarcity of water. Over time, soils will improve, allowing shrub vegetation and, eventually, maritime forest to colonize the area. Backdune grassland in close proximity to the ocean may succeed only to maritime shrubland because of the influence of strong winds and salt spray.

Manipulated Maritime Backdune Grassland – This community, though currently under the influence of regular pruning, may develop into manipulated maritime shrub community as soils improve. If pruning continues, this area will never develop into maritime forest, but will remain a low thicket of vines, briars, and shrubs, similar to what composes the manipulated maritime shrub community today.

Lawns and Pathways – These areas appear to be maintained by regular mowing, foot traffic, and, in some cases, herbicide application. If these activities continue, little change will occur in these areas into the future. Some of the lawn grasses present may become somewhat invasive into the surrounding natural community, but probably to a limited degree.

Maritime Interdunal Wetland – Currently, this community is being held in a state of early succession by strong winds, salt spray, poor soils, and overwash. Therefore, these communities will retain a composition similar to that of today into the future. They are located away from the ocean and see less impact from salt spray and wind, so they may develop into climax maritime hardwood depressions (described below). However, the areas in which many of these wetlands occur are currently being pruned to maintain a view of the ocean. If this pruning continues into the future, communities will not develop into hardwood depressions, but will become a dense thicket of vines, briars, and shrubs.

Maritime Shrubland – This vegetation community is an intermediate stage between maritime grassland and maritime forest. As such, much of this community within the AL area will develop into maritime forest (described below) over time. However, the maritime shrubland community that exists in close proximity to the ocean may remain such because salt spray and strong winds limit its development further. If the island continues to accrete, the seaward shrub line will likely move outward as well. The existing shrubland, protected from salt spray and strong winds by new shrubs to seaward, would be able to develop into maritime forest.

Manipulated Maritime Shrubland – These areas are currently being pruned to maintain views of the ocean. If this pruning continues into the future, these areas are not likely to change significantly. The vine, briar, shrub thickets that exist today will most likely persist into the future much unchanged.

Hardwood Depression – This community generally occurrs within the maritime forest, away from significant impact by strong winds, salt spray, and overwash. This community, while in an early stage of succession, is likely to change in composition in the future. The overstory is likely to be replaced by black gum (*Nyssa biflora*), red maple (*Acer rubrum*), white ash (*Fraxinus americana*), and others. Midstory species may be composed of American hornbeam (*Carpinus caroliniana*), red bay, and wax myrtle. The herbaceous layer is typically sparse. If the AL area continues to accrete, maritime interdunal wetlands (now located in close proximity to the ocean) may be sufficiently protected to develop into hardwood depressions in the future.

Early Successional Maritime Forest – Though in an early stage of succession, this forest will continue to develop toward climax. Overstory species that occur in these areas will be replaced by live oak, laurel oak (*Q laurifolia*), magnolia (*Magnolia grandiflora*) and others. Midstory species composition will include southern red cedar, eastern red cedar (*J virginiana*), cabbage palm (*Sabal palmetto*), gallberry (*Ilex glabra*), red bay, and others. The understory, as it is now, will continue to be rather depauperate. Succession to climax maritime forest will likely to take hundreds of years. With accretion, the area encompassed by maritime forest will likely to increase with time as maritime shrub communities convert into forest.

5.5 Simulation of Storm Impacts in the AL Study Area

The study team, under the leadership of Dewberry, evaluated potential storm surge and wave impacts within the AL study area. Three scenarios were analyzed using state-of-the-art computer models developed for application in FEMA (2004) flood insurance studies: (1) Existing Conditions, (2) Scenario 1 – addition of a beneficial dune, and 3) Scenario 2 – reduction in vegetation density. The models provide a measure of storm surge and wave impacts across the AL area. These results were used to provide generalized (potential), damage estimates for oceanfront structures, which provides a means of relating potential damages among the three scenarios.

Storm Waves

Waves are generated by winds in the open ocean and grow in height in relation to the wind velocity, size of the generating area, and duration of the wind. Waves are superimposed on the tide/surge level and, upon reaching the coast, are influenced partly by water depth. This means the largest waves that can propagate over flooded lands are controlled by the elevation of the land. As waves approach the shoreline, they grow in height and then break, dissipating their wave energy across the shoreline. Beaches exist as the initial and primary wave energy dissipaters. But during storm surges, significant energy shifts further inland. Numerous post-storm damage assessments along barrier islands have observed a significant reduction in wave-induced damages where healthy dunes occur or the dry beach is wide so as to break up the incoming waves.

Waves associated with a particular storm surge will also be influenced by the vegetative surface over which the waves travel. As waves propagate inland, vegetation acts as an energy dissipater, reducing wave heights. Changes in vegetation cover and densities, either natural or manmade, will influence the frictional resistance of the vegetation to the waves. In general, denser and higher vegetation cover will reduce wave heights and potential wave damages along interior areas.

Methods

Modeling Input Data

All storm flood and wave modeling simulations were performed using the one-dimensional (1D) model WHAFIS (Wave Hazard Analysis for Flood Insurance Studies) as embedded in Dewberry's Coastal GeoFIRM Tools. The inputs to the models are terrain, vegetative cover, stillwater elevations (ie – 10-year and 100-year return-period surge levels), and starting wave conditions such as wave setup. This model has been commonly employed to determine flood elevations and flood zones for Flood Insurance Rate Maps (FIRMs) published by FEMA. The WHAFIS model computes water surface elevations and wave heights along a profile or transect which is oriented near-perpendicular to the shoreline. Multiple transects are used to develop a raster surface (or grid) representing the change in water levels and wave fields over the AL study area for a particular stillwater elevation (or predicted storm-surge levels).

Digital Elevation Model

A seamless digital elevation model (DEM) was developed, which represents the bathymetric and topographic surface of the nearshore, beach, and the AL area. The DEM allowed automated extraction of terrain data for each of the WHAFIS modeling transects along the Sullivan's Island shoreline. The DEM was created employing three data sets:

– Sullivan's Island 2008 beach and shoreline survey data (collected by CSE).
– NOAA 2006 LIDAR data for topographic coverage.
– NOAA Coastal Relief Model (CRM) for bathymetric coverage.

LIDAR data were used to augment areas not covered by the ground surveys. The CRM data were used to create the offshore portion of the DEM. The zero contour elevation, extracted from the ground survey, was used to identify the shoreline location and was used to "enforce" a common merge boundary between bathymetric and topographic sources. A final DEM with cell sizes of 10 ft by 10 ft was created and referenced to the National Vertical Datum of 1988 (NAVD'88). The existing terrain conditions represented by the DEM are shown in Figure 5.5.

Flood Levels and Wave Conditions

The 1D WHAFIS model (FEMA 1988, Divoky 2007) was used to determine total flooding levels and the depth-limited wave heights along computational transects. The model was run along 12 transects located in Reach B and Reach C as depicted in Figure 5.5. The transects extend across the AL study area and through approximately the first row of houses and parcels.

Other model parameters such as the ground elevations were extracted from the DEM along each transect. The stillwater, storm-tide elevations provided as input to the model were obtained from the FEMA (2004) Charleston County Flood Insurance Study (FIS) as described in Section 4.2 (Table 5 of the FIS). The 10-year and the 100-year stillwater elevations, 7.9 ft and 11 ft NAVD'88 (respectfully), were used to establish the base flood conditions for the WHAFIS modeling.

The NOAA-NOS offshore WIS wave station #346 nearest to Sullivan's Island was selected to determine the starting wave conditions and wave setup. Wave setup is defined as the increase in water level due to wave breaking and energy dissipation. The maximum wave height (H_s) recorded at this station (ie – H_s = 32.7 ft and T = 15 s) generates a wave setup, which agrees with the 100-year wave setup of 2.6 ft reported in the FEMA (2004) FIS. The maximum wave height was then adjusted to the equivalent deepwater wave height using linear wave theory equations.

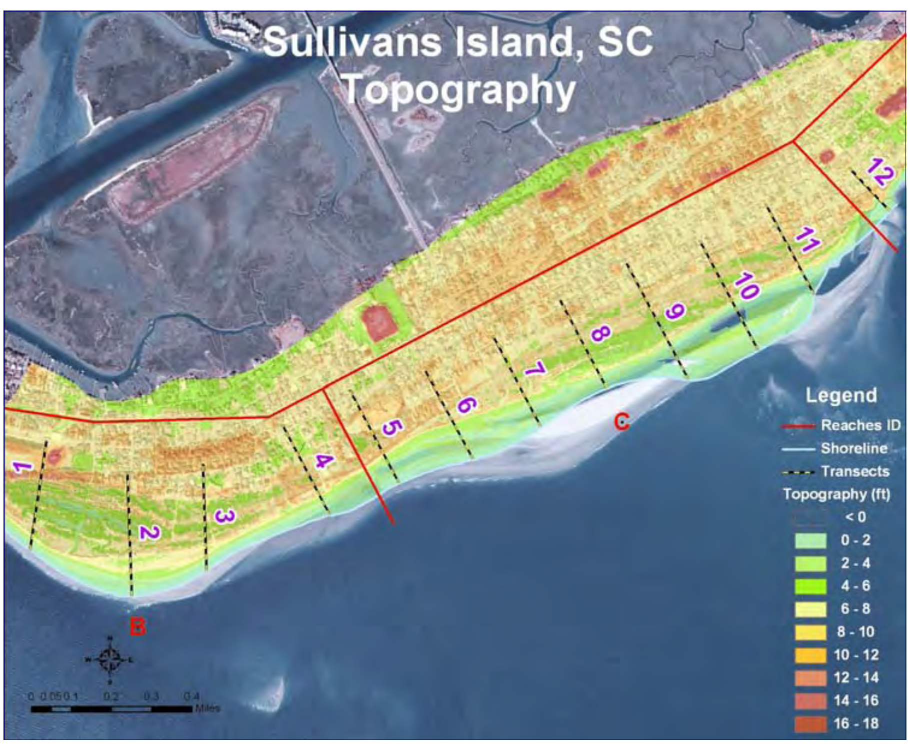


FIGURE 5.5.

Sullivan's Island digital elevation model (DEM) created and used for the WHAFIS modeling.

The 10-year starting wave conditions were determined by a rank order of the maximum-yearly observations and by subsequent extraction of a value corresponding to the 10-year return period following a frequency-of-occurrence function for the entry data. Using the USACE Shore Protection Manual (CERC 1984) methods, the 10-year wave setup was computed, which equaled 2.1 ft. Stillwater elevations, starting wave conditions and wave setup values, imputed in WHAFIS, are summarized in Table 5.1.

TABLE 5.1. Starting stillwater (SWL) and wave setup conditions used for the WHAFIS modeling.

	SWLs (ft)	H_s (ft)	T (s)	Wave Setup (ft)
100-year	11.0	31.5	15.0	2.6
10-year	7.9	23.2	14.3	2.1

Obstructions

To perform overland wave analyses and establish the magnitude of waves propagating inland, the locations and types of obstructions were identified. For this particular study, the vegetation represents the primary source for wave reduction over the AL study area. A further reduction in wave height was generated by the presence of the buildings located behind the vegetated dunes.

Obstructions were identified as polygons on base maps (GIS format) and then separately attributed. The location of vegetation community types, species and parameters were provided to Dewberry by Sabine & Waters (S&W). Representative parameters in feet (ft) for vegetation obstructions included: plant height, plant diameter, and plant spacing. The use of S&W vegetation data within Dewberry's GeoCoastal tool required a postprocessing of the vegetation parameters for each plant community to obtain averaged vegetation characteristics that were representative of the plant diameter, plant height, and plant spacing for each plant community.

Individual species and relative parameters were evaluated for all categories (overstory, midstory, understory and herbaceous) and among the category itself. In particular, each category was analyzed whether:

- The percent coverage of one particular plant type was dominant throughout all categories (overstory, midstory, understory, and herbaceous).
- The percent coverage of a few plant types was dominant throughout all categories.

- The percent coverage of all the plant types in one category was dominant compared with the other categories.

- Plants higher than 5 ft were considered of high priority, representing a more consistent obstruction to surge and wave propagation than smaller ones.

In general, if more than one plant type was dominant, a weighted average (based on the percent coverage) was used to determine representative vegetation parameters for corresponding polygon attributes. In addition to the field evaluation of the plant characteristics, photographs of each plant community (as provided by S&W) were used to validate the selected plant types and parameters used for the WHAFIS input.

Building obstructions were identified based on the SCDNR (2006) aerial orthophotos. In addition, building obstruction parameters used for input into WHAFIS were based on field information of representative structures. The location of obstruction polygons is depicted in Figure 5.6. This represents the existing land cover or vegetation and building obstructions used for the WHAFIS modeling input.

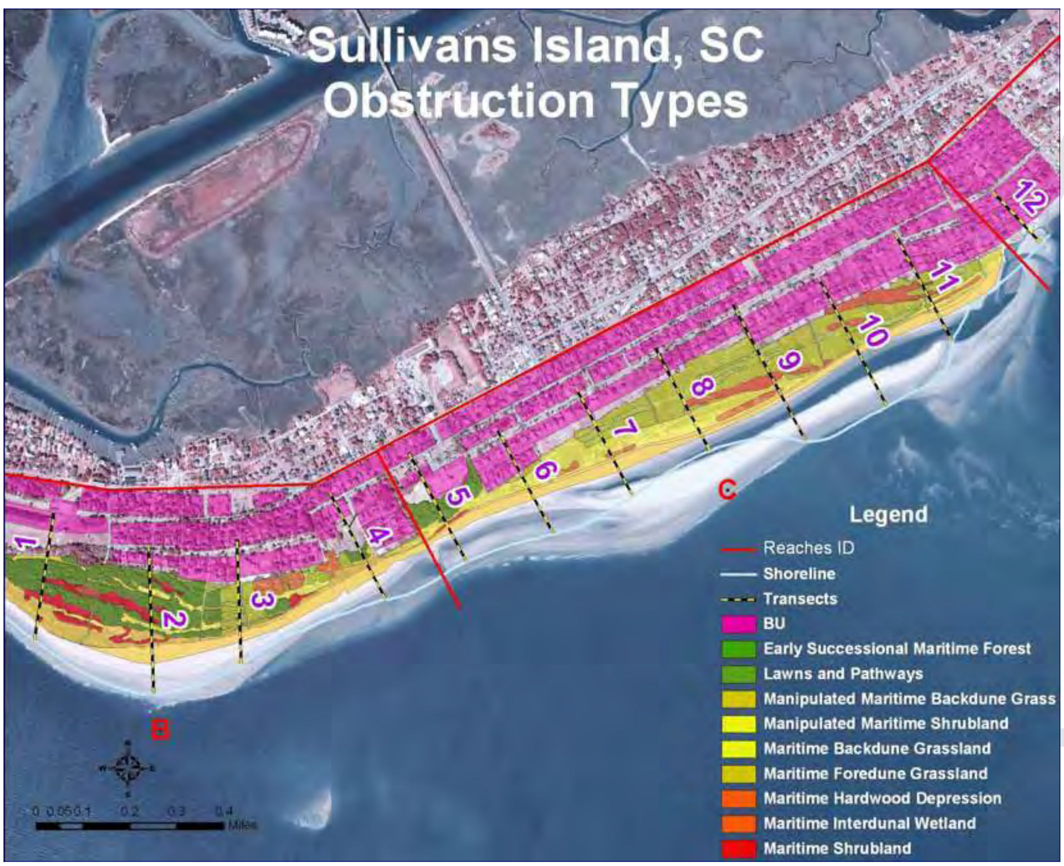


FIGURE 5.6. Sullivan's Island vegetation and building obstructions used for the WHAFIS model input.

Modeling Scenarios

Three scenarios were modeled to evaluate the vulnerability of the AL study area to storms and waves. The scenarios are as follows:

- *Existing Conditions*: existing ground and vegetation characteristics.
- *Scenario 1 – Addition of a Beneficial Dune*: a small dune feature was added to the current topography to show a continuous ridge through the AL study area.
- *Scenario 2 – Reduction in Vegetation Density*: vegetation parameters were altered to show removal of some forested and heavily wooded areas in favor of shrubs and open grass areas.

Modeling of Existing Conditions established a baseline condition of storm surge and wave hazards (ie – wave heights). This was accomplished by modeling the flood level and wave height that would exist during the 10-year and the 100-year storm events, given the morphology and the land use currently present at Sullivan's Island, particularly within the regions of the accreted land. Modeling of the two scenarios provided a means to identify the changes in flooding and wave propagation due to removal/change in vegetation or the presence of morphological obstacles, such as a low dune. For each scenario, the following results were determined:

1) *Total flooding depth* surface for the 10-year and the 100-year storm events.
2) *Wave height surface* for the 10-year and the 100-year storm events.

Both flooding depth and wave height surfaces were created by generating a triangulated irregular network (TIN) or digital surface from the modeled results interpolated from results at each transect. The TIN was then converted to a 10-ft-by-10-ft raster DEM for display over the AL area. The *total flooding depth* surface represents the flooding generated by adding wave setup to the stillwater elevation. In addition, the depth-limited wave height as computed by WHAFIS was added to determine what is referred to herein as "total flooding depth." To evaluate the impacts of the three scenarios on the wave fields, *wave height surfaces* were also generated.

Surge and Wave Modeling Results

This section provides results of computer simulations of flooding and waves over the AL study area under 10-year and 100-year storm events for three scenarios: (1) Existing Conditions, (2) Scenario 1 – addition of a beneficial dune, and (3) Scenario 2 – reduction in vegetation density. Results are illustrated in map form as a series of color-coded surfaces over the AL study area. There are a number of things to look for in the maps:

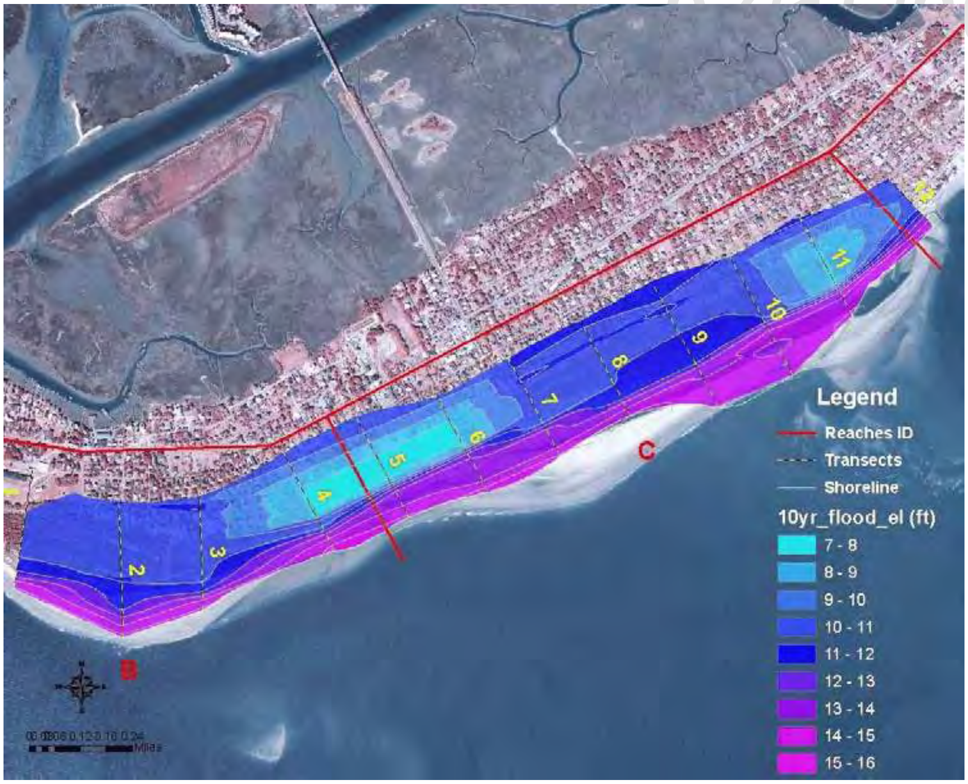
- Reduction in flood depths and wave heights across the AL area from sea to shore.
- Significant differences in levels between 10-year and 100-year storm events.
- Subtle changes in levels along shore due to variation in topography and vegetation cover within the AL area.
- Significant changes in levels from sea to shore where a continuous, low dune feature is added (Scenario 1).

The study team has also provided a set of maps which show the differences between various results to better illustrate the impacts of the two scenarios. These are particularly helpful for evaluating the relative protection as it exists presently compared with the scenario conditions.

Existing Conditions

The results of similarity of Existing Conditions (total flooding depth for the 10-year and 100-year storm events) are depicted in Figure 5.7.

For the 10-year event (Fig 5.7, upper), the total flooding depth decreased inland as a result of combined topographic relief and vegetation obstructions. Areas of high ground in proximity to the mid-regions of transects 4, 5, 6, and 11 dissipated the wave heights and limited the total flooding depth essentially to the stillwater flood elevation (ie – elevation with no wave setup and waves superimposed). The impact of different types of vegetation on the flooding depth was observed by comparing, for example, the results from transect 2 (AL – Reach B) with transect 9 (AL – Reach C). The area in proximity to transect 2, which is dominated by *maritime forest*, depicts flood depth reductions over shorter distances compared with transect 9, where *manipulated maritime shrubland* and *maritime interdunal wetland* allowed higher water levels to penetrate further inland. In addition, some wave regeneration occurred further inland on transect 9, possibly due to less frictional resistance of lower vegetation stands.



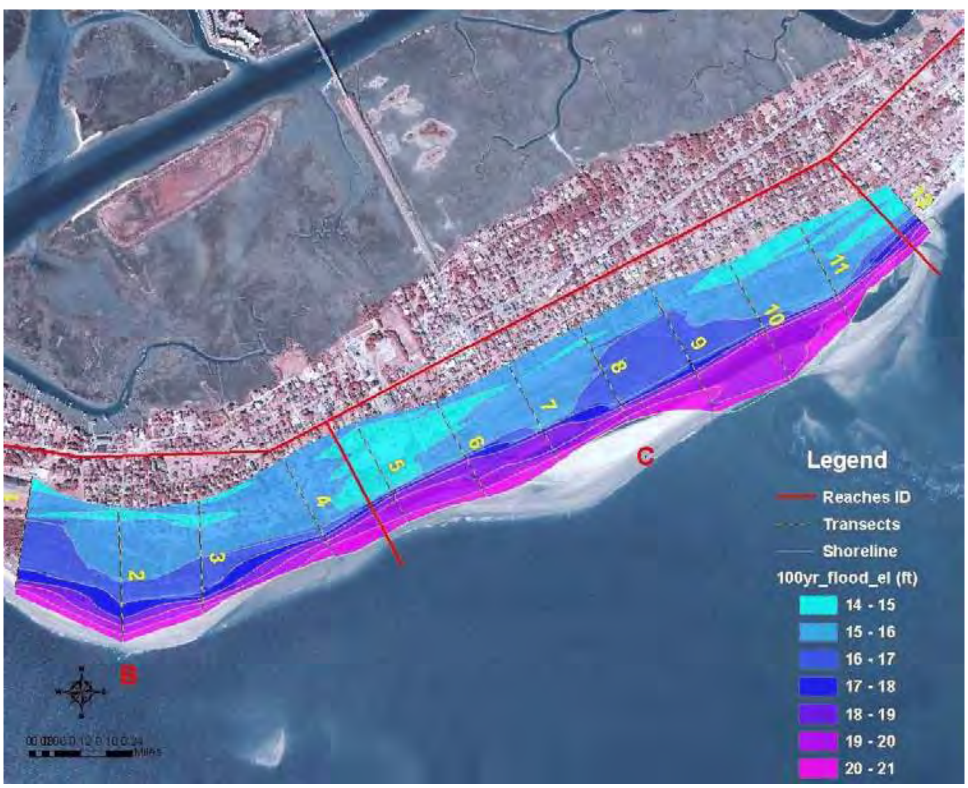


FIGURE 5.7. Existing conditions – predicted total flooding depth (ft NAVD'88).
[UPPER] 10-year event **[LOWER]** 100-year event

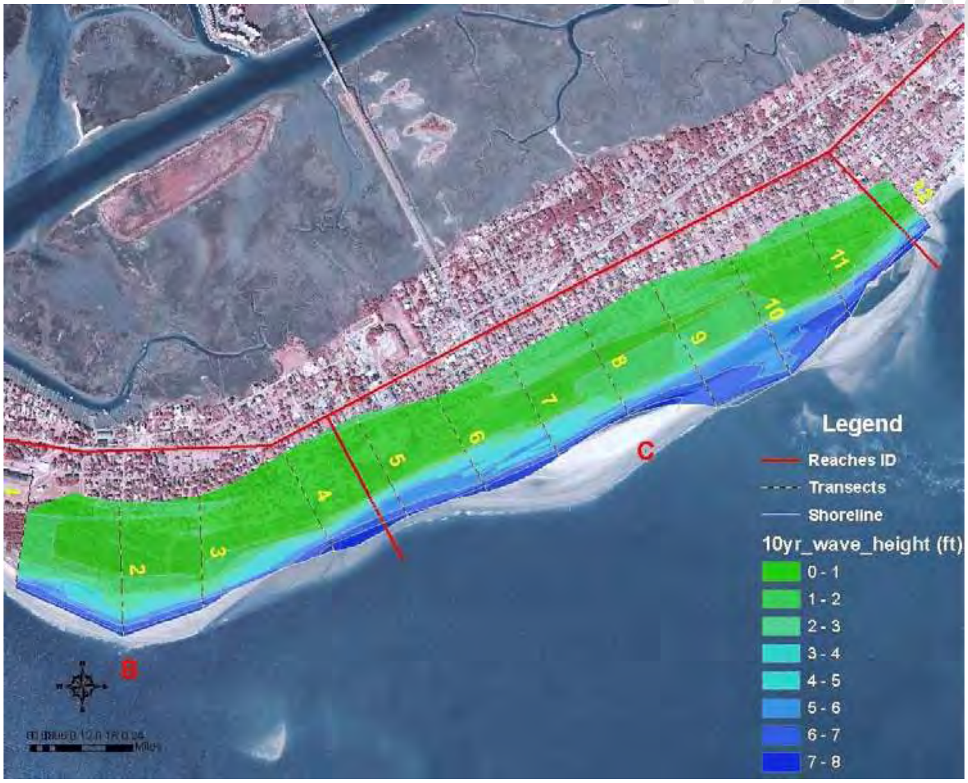
For the 100-year event (Fig 5.7, lower), the ground topography caused the greatest reduction in flood depths, particularly at transect 5, where the highest ground elevations are located. The impact of the vegetation for this simulation is further demonstrated given the higher depth of the water column. At transect 9, the 16-ft contour depth extends inland ~1,400 ft to reach the first row of buildings. At transect 2, the same water elevation only penetrates 800 ft from the shoreline and does not “reach” back-barrier structures to the same degree.

Similar patterns were observed in the distribution of the wave heights propagating inland at Sullivan’s Island over the AL study area. For the 10-year event (Fig 5.8, upper), the forested areas of Reach B yielded lower wave heights (cf – transect 2) compared with results within the shrub-dominated areas of Reach C (cf – transect 9). For the 100-year event (Fig 5.8, lower), higher water levels produced higher waves. Significant wave reduction was observed along transect 5 and transect 9 due to the higher topography. The rapid decrease in wave heights between transects 1 and 3 is attributed to the dense forest canopy.

Scenario 1 — Addition of a Beneficial Dune

For Scenario 1, a low dune ridge was added to the current topography. The objective of this modeling scenario was to assess the potential impact of a modest-sized dune on flood levels and waves across the AL area. With these new conditions, WHAFIS was re-run with the new dune geometry.

The study team used the existing topography and aerial photos of the AL area to identify an existing dune ridge dominated by grass vegetation. The ridge is sinuous and is positioned close to the seaward vegetation line in Reach C (eg – along transects 10 and 11) and portions of Reach B (eg – at transects 4, 5, 6). The ridge is positioned further inland along transects 1, 2, 7, 8, and 9. The vulnerability of the dune position with respect to the active beach, as well as existing development, allows evaluation of impacts for a range of dune positions without having to model numerous alternative dune placements. Recognizing that it would probably not be acceptable to introduce a high dune which meets FEMA recommendations for 100-year storm protection, **an arbitrary-sized dune limited to a maximum crest height of 14 ft NAVD was chosen for evaluation. This would increase the existing ground level by ~2–6 ft.**



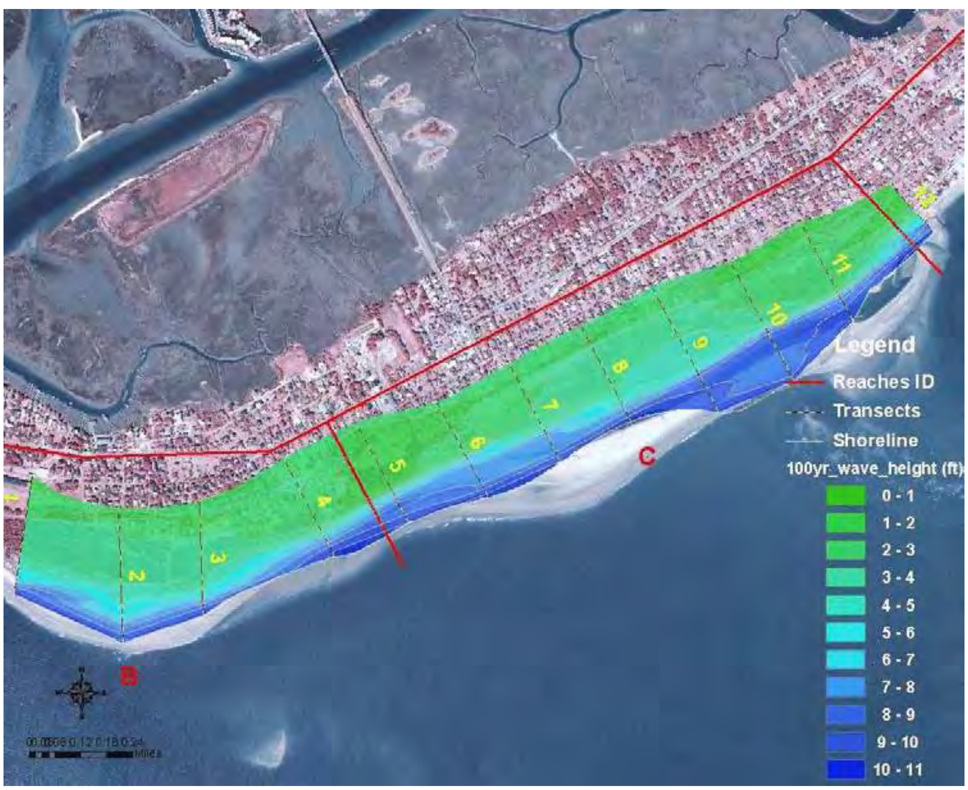


FIGURE 5.8. Existing conditions – wave height surface.
[UPPER] 10-year event **[LOWER]** 100-year event

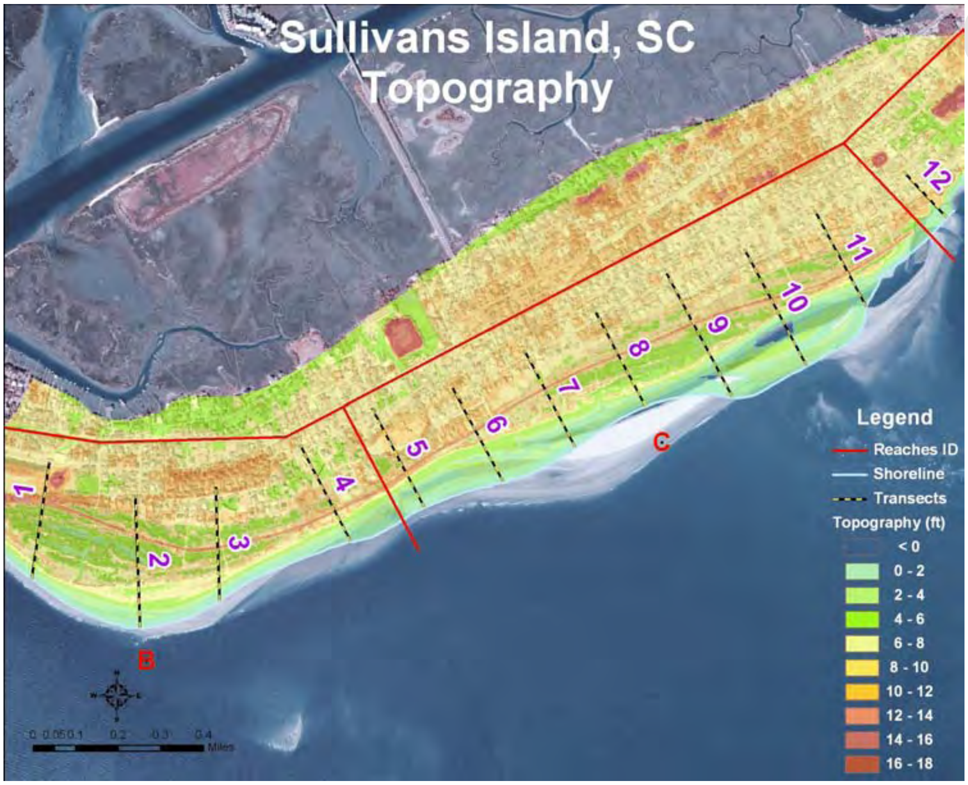
The dune geometry proposed under Scenario 1 assumes a base width of ~75 ft, a 1:5 (V:H) seaward slope, and a 1:3 (V:H) landward slope. A dune of these dimensions would require import of ~100,000 cubic yards (± 50 percent). The "Scenario 1" dune ridge was merged into the existing DEM (Fig 5.9, upper), and ground data were re-extracted at each profile. In addition, the vegetation parameters of transects 8, 9, 10 and 11 inputted to WHAFIS were adjusted to reflect plant types typical of dune environments (Fig 5.9, lower).

It is evident for both the 10-year (Fig 5.10, upper) and the 100-year (Fig 5.10, lower) modeled events that the added dune ridge, although relatively low, provides a significant obstacle to the propagation of waves across the AL area. Note the reductions in water surface elevations behind (or inland) of the dune ridge based on the WAHFIS results. The area behind the dune ridge was flooded by the stillwater under the assumption of flood waters "flanking" both ends of the island. The new slope gradient created by the added dune ridge reduced the flooding and no significant impacts were attributed to the changes in vegetation.

Figure 5.11 depicts the 10-year and the 100-year wave height surfaces for Scenario 1. The modeled wave heights were controlled by the 14-ft dune ridge and did not propagate past it with significant magnitude. Only a minimum level of wave regeneration occurred further inland (under the model). Seaward of the dune ridge, wave reduction was caused by the modified ground and the new seaward dune slope. As with the case observed for total flooding depth, no appreciable amount of reduction in wave heights was observed to be attributed to proposed dune vegetation. However, it is noted that the dune vegetation is necessary to preserve the dune ridge feature for future wave reduction benefits in addition to providing relevant coastal ecological habitats.

Scenario 2 — Reduction in Vegetation Density

The variations proposed within Scenario 2 involve substitution of vegetation communities, such as *manipulated maritime shrubland* and *maritime hardwood depressions*, with *maritime foredune grassland* and *maritime backdune grassland*. The vegetation parameters were changed only in the area east of transect 6 as proposed by this alternative. No changes in the topography were made for this scenario. The ground profile at each transect matches the elevation of the Existing Conditions scenario (Fig 5.12, upper). Modified vegetation communities are depicted in Figure 5.12 (lower).



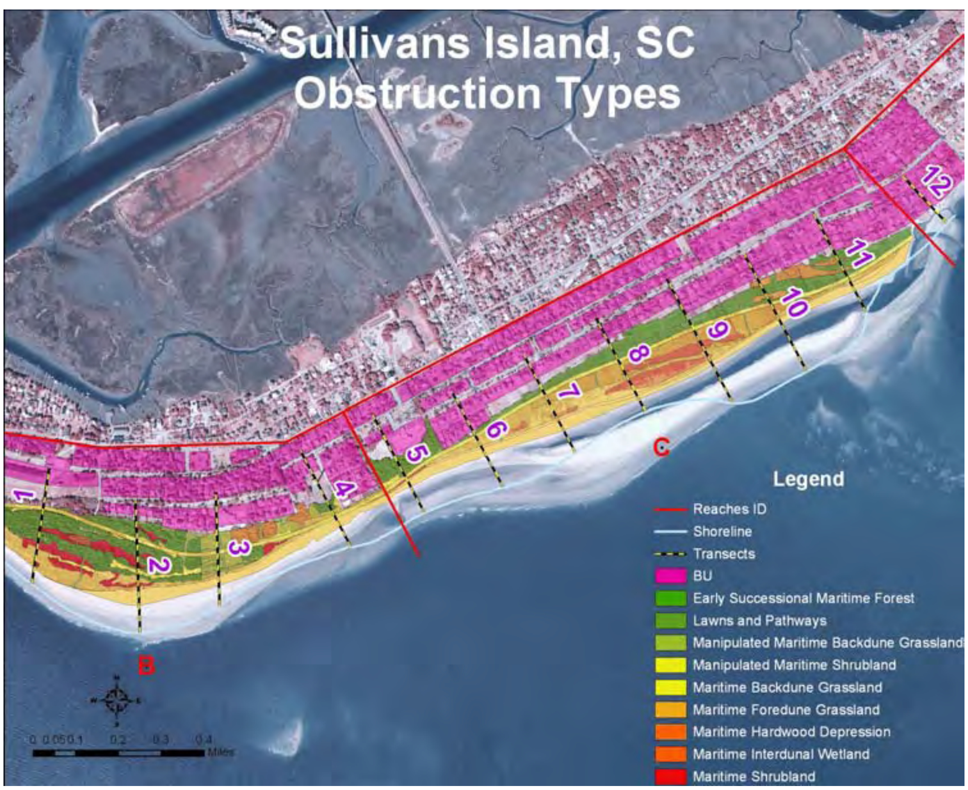


FIGURE 5.9. Scenario 1 – addition of a beneficial dune. **[UPPER]** Ground topography assumes a continuous, low dune ridge at ~14 ft NAVD running sinuously along the length of the AL study area. **[LOWER]** Adjusted vegetation parameters.

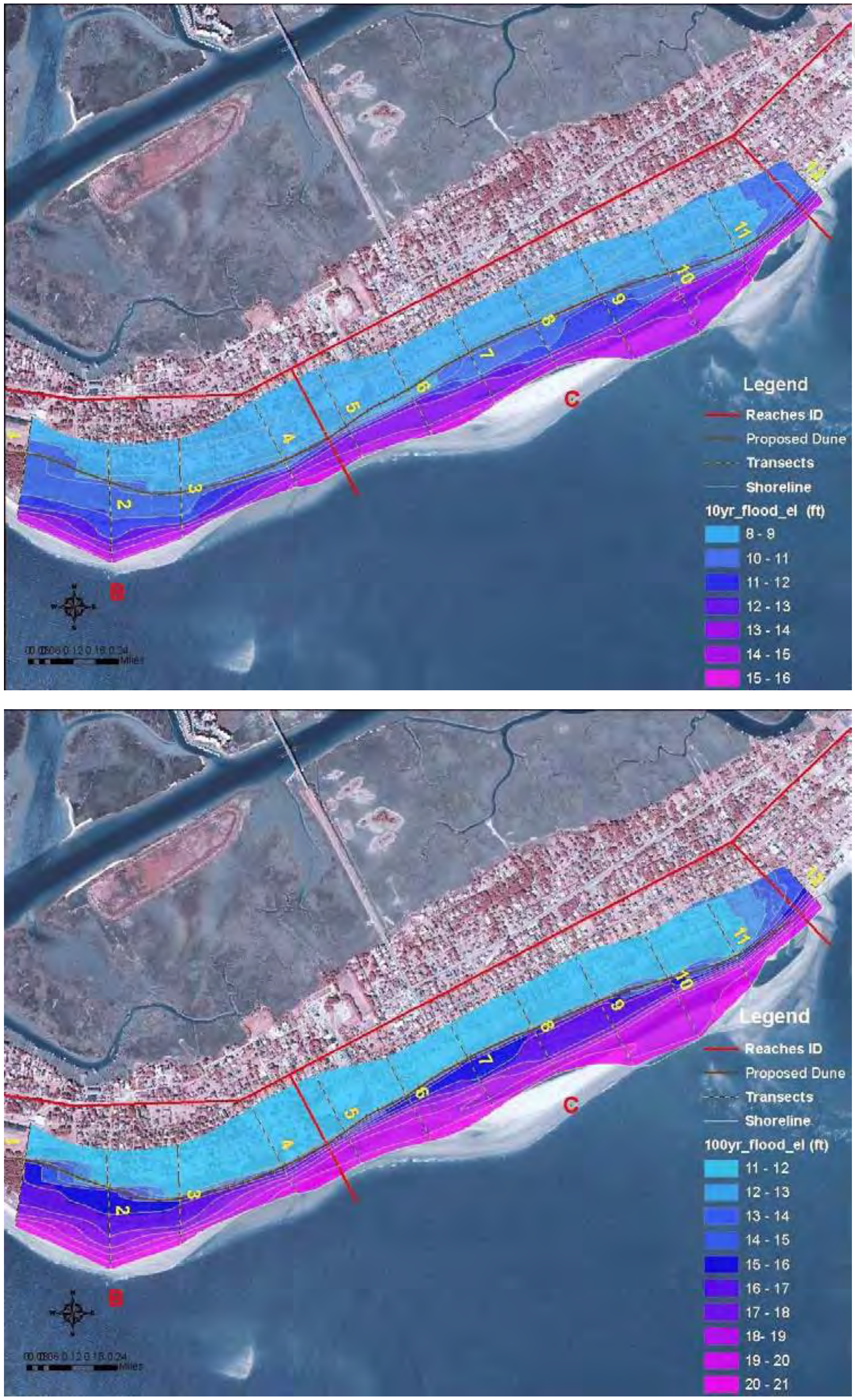
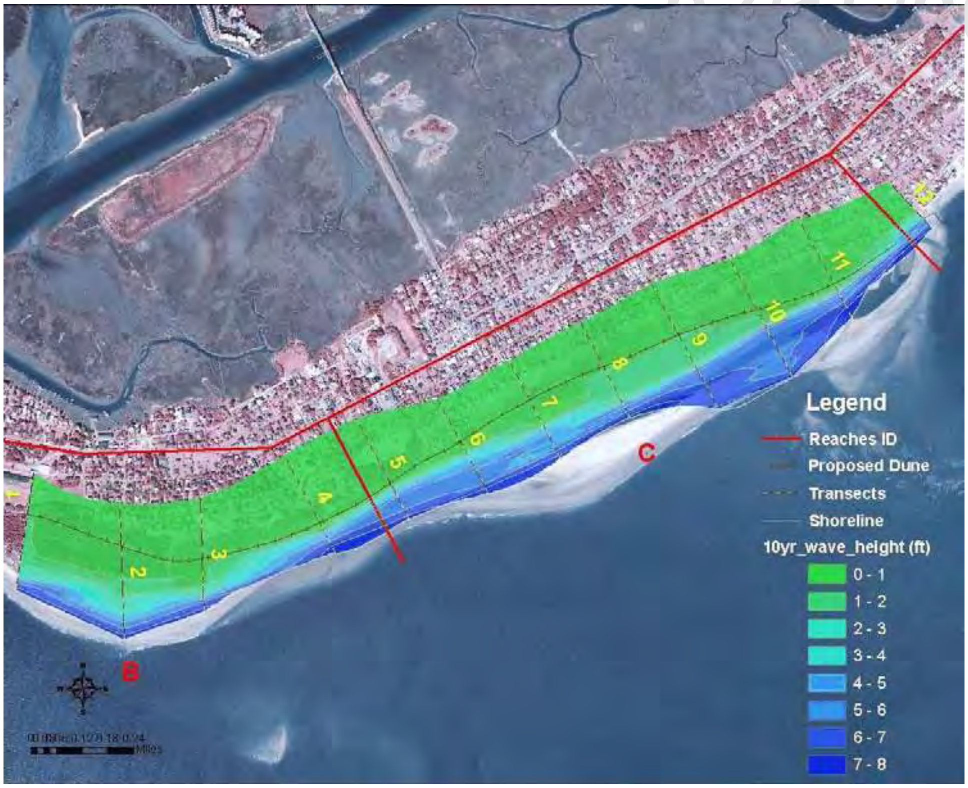


FIGURE 5.10. Scenario 1 – total flooding depth. The distinct reduction in water levels along the interior half of the AL study area is the result of the presence of the dune ridge at ~14-ft NAVD assumed under this scenario.

[UPPER] 10-year event **[LOWER]** 100-year event



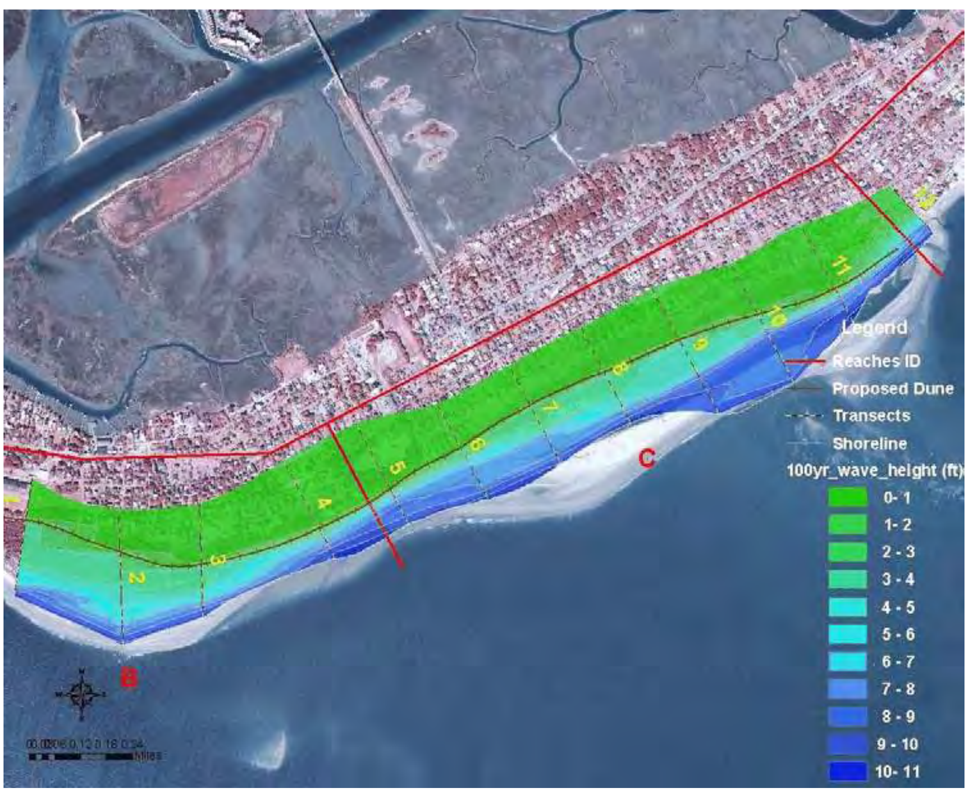
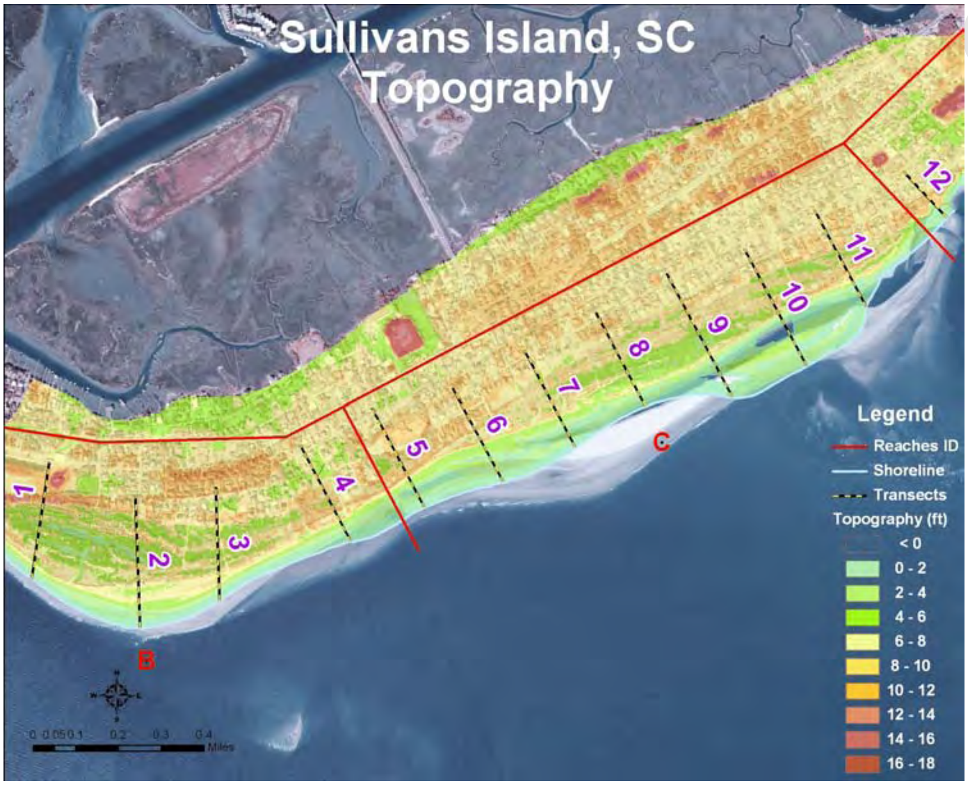


FIGURE 5.11. Scenario 1 – wave height surface.
[UPPER] 10-year event **[LOWER]** 100-year event



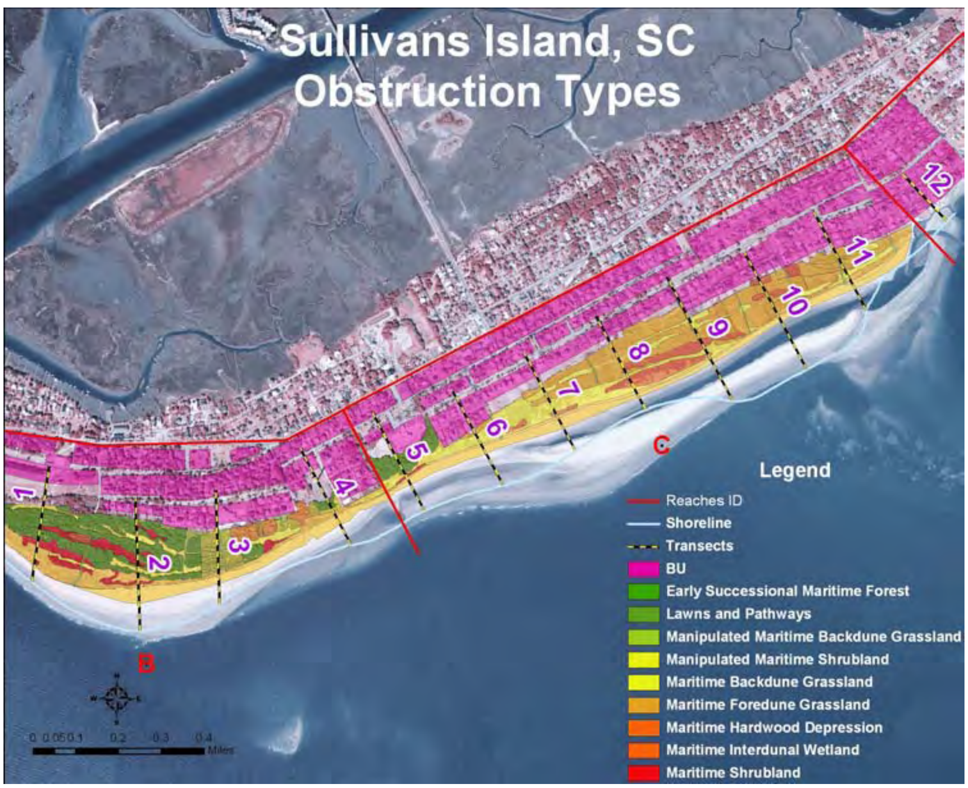


FIGURE 5.12. Scenario 2 – reduction in vegetation density. **[UPPER]** Topography which is assumed to be the same as Existing Conditions. **[LOWER]** Vegetation communities including modifications east of transect 6 – substitution of manipulated maritime shrubland (eg – pruned myrtle) and maritime hardwood depressions with maritime grasslands.

The total flooding surfaces for the 10-year and the 100-year events under Scenario 2 are depicted in Figure 5.13. There is no difference in either of the surfaces for the area between transect 1 and transect 6 compared with Existing Conditions results (depicted in Fig 5.7). In the area between transect 6 and transect 11, the modified vegetation parameters do not generate significant changes in flooding depths for the 10-year event (eg – a slight increase of ~0.3 ft, mostly in the vicinity of transect 10).

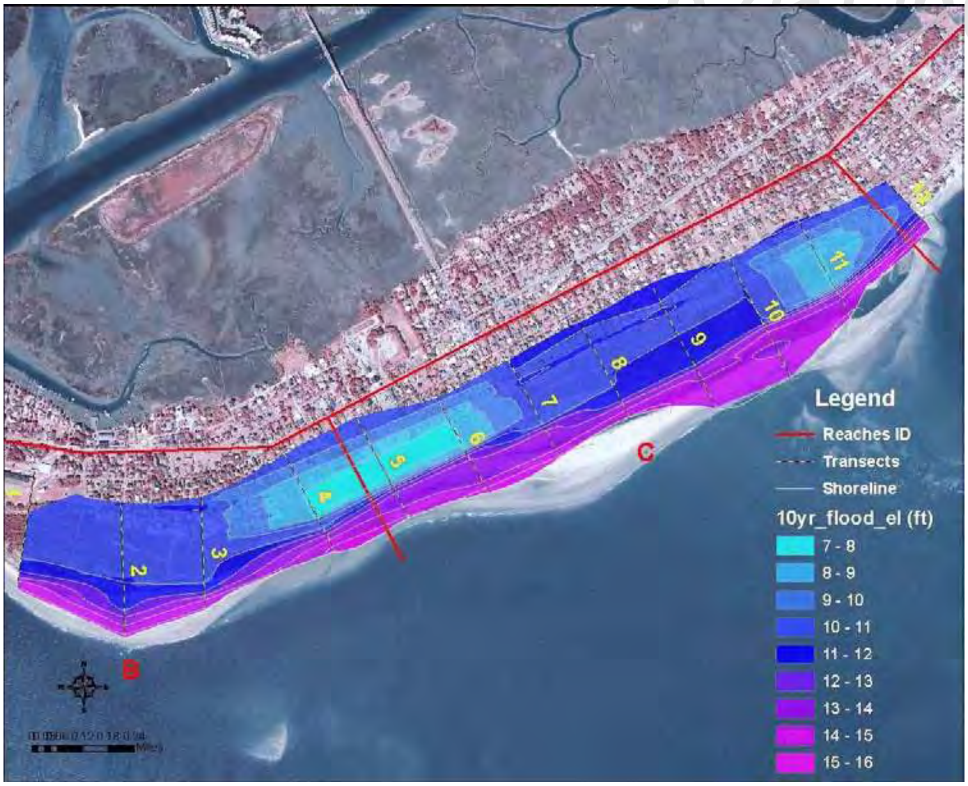
The change in vegetation parameters have a more significant impact on the total flooding for the 100-year event. Inland flood levels propagate further inland and are generally higher in the AL study area for Scenario 2 than in the Existing Conditions scenario. An increase of ~1 ft was observed, and an area of larger waves is closer to the first rows of buildings under Scenario 2 conditions.

The same conclusion can be reached when looking at the pattern of wave heights. For the 10-year event (Fig 5.14, upper), wave heights within the 1–2 ft range extended well beyond the first row of buildings at transect 10, whereas they were just approaching the first row under the Existing Conditions scenario. The 100-year event (Fig 5.14, lower) also indicates waves within the 3–4 ft height range were present as far inland as the first row of buildings and were approaching the second row.

Change Detection Grids

Change detection grids are a means of comparing the results of two model runs. A "change" surface is created by calculating the differences in magnitude between two surfaces using the computed raster values at each grid point. They are useful in identifying regional differences between the total flooding surfaces and wave height surfaces under each scenario. Raster surface differences between Scenario 1 and the Existing Conditions scenario are depicted in Figure 5.15 (differences in total flood depth) and in Figure 5.16 (differences in wave heights). Obviously, negative values of change indicate a favorable response under a particular scenario.

For example, on the landward side of the dune ridge (Scenario 1), the negative differences depict significant reductions in flooding levels and waves caused by the presence of the low dune. Scenario 1 clearly shows that even a small dune feature will reduce flood and wave hazards to back barrier development landward of the AL study area. For example, the total flood depth under 10-year and 100-year event conditions is potentially reduced by 2–4 ft landward of the introduced dune feature. Wave heights behind the dune are reduced by 1–2 ft under Scenario 1 compared with Existing Conditions.



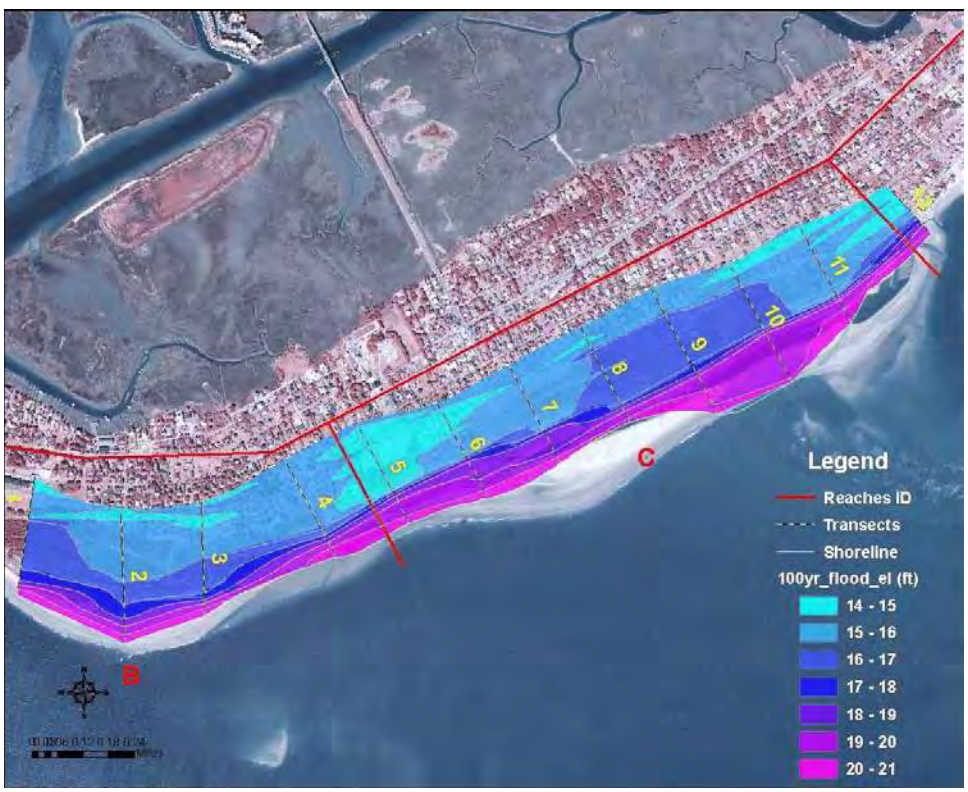


FIGURE 5.13. Scenario 2 – total flooding surface.
[UPPER] 10-year event **[LOWER]** 100-year event

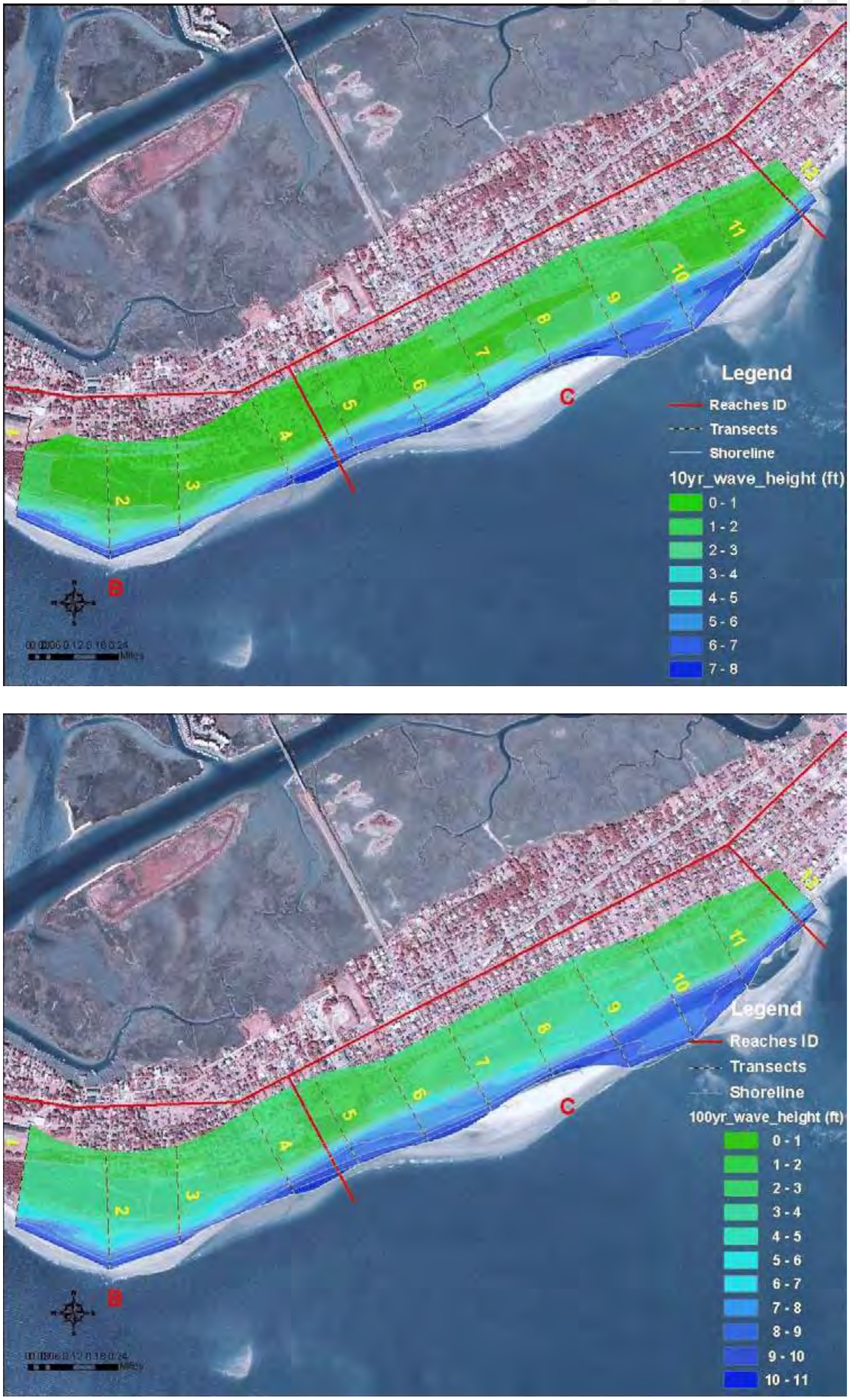
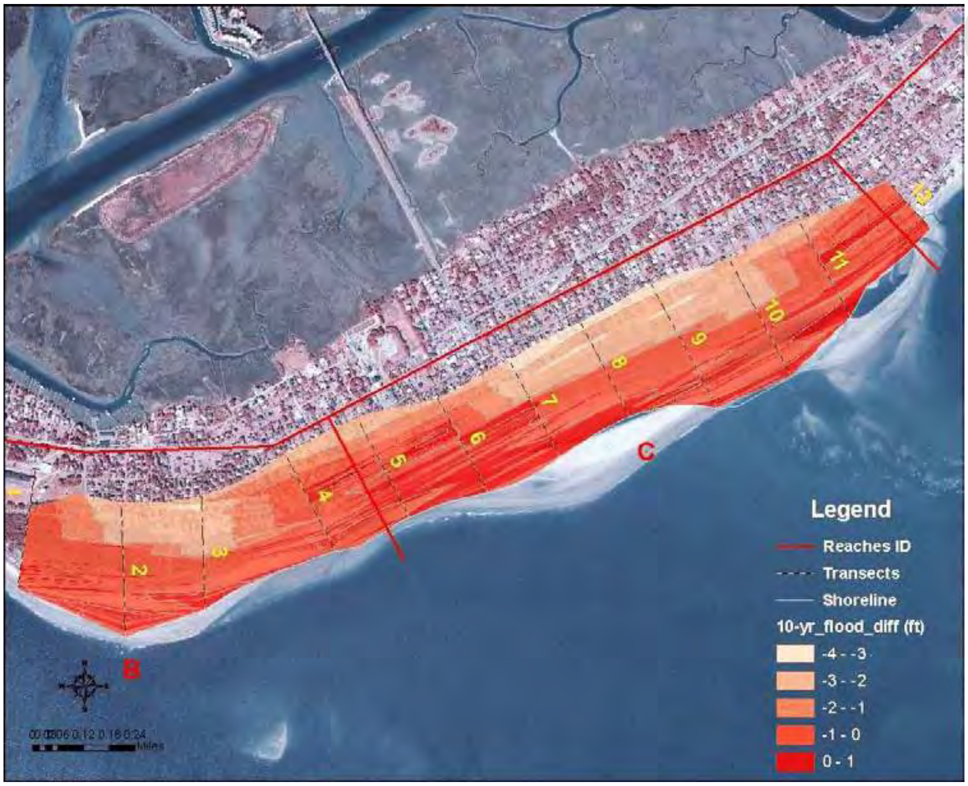


FIGURE 5.14. Scenario 2 – wave height surface.
[UPPER] 10-year event **[LOWER]** 100-year event



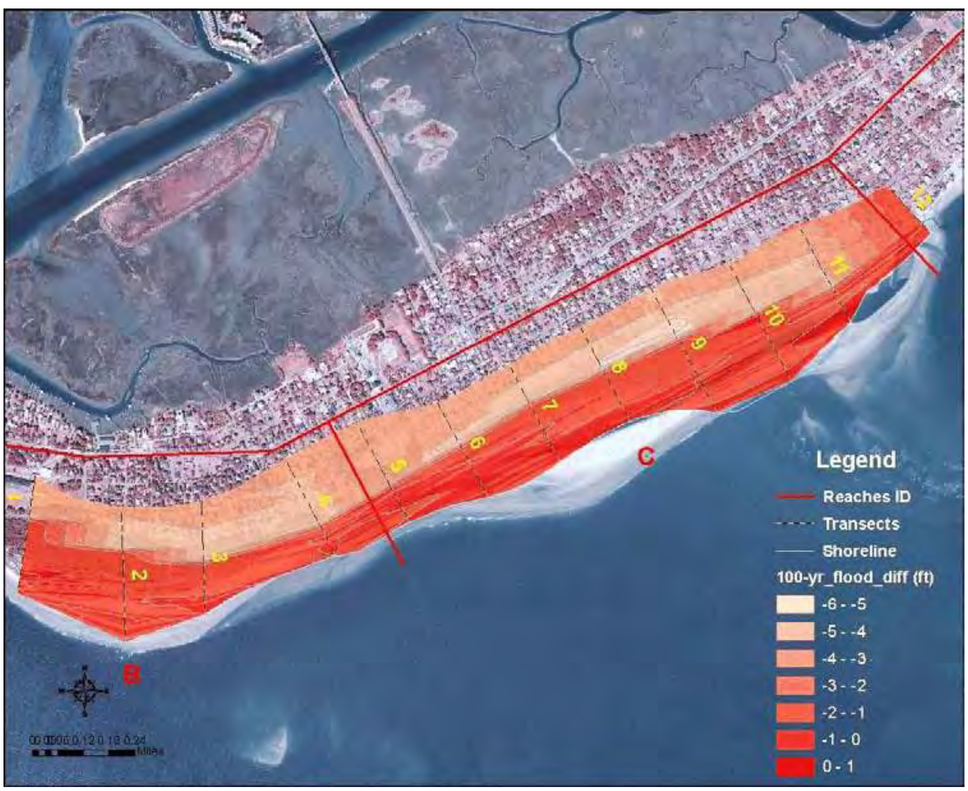


FIGURE 5.15. Change detection grids – difference in total flood depths between Scenario 1 and Existing Conditions.

[UPPER] 10-year event **[LOWER]** 100-year event

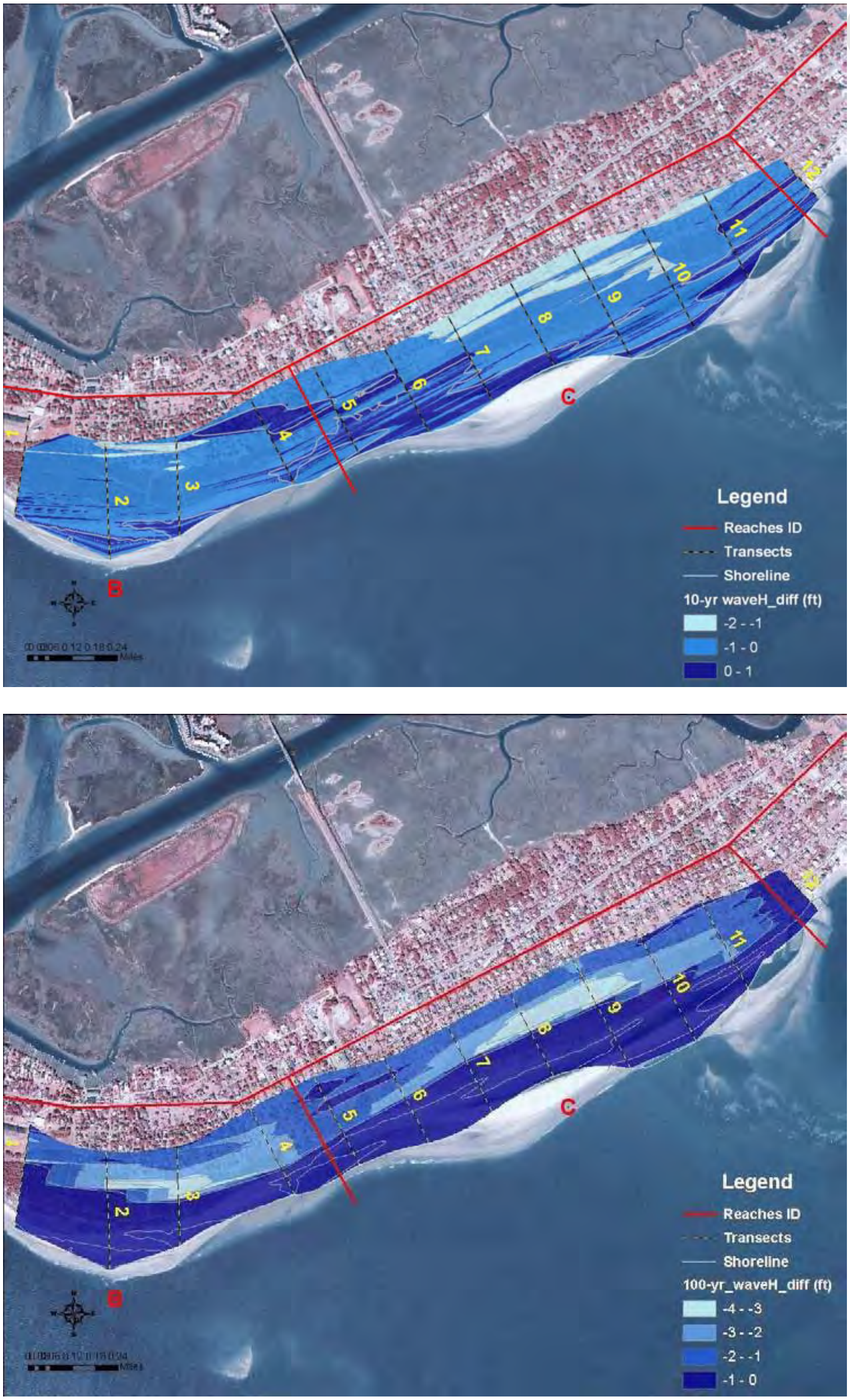


FIGURE 5.16. Change detection grids – difference in wave heights between Scenario 1 and Existing Conditions.

[UPPER] 10-year event **[LOWER]** 100-year event

Raster surface differences between Scenario 2 and the Existing Conditions scenario are depicted in Figure 5.17 (differences in total flood depths) and in Figure 5.18 (differences in wave heights).

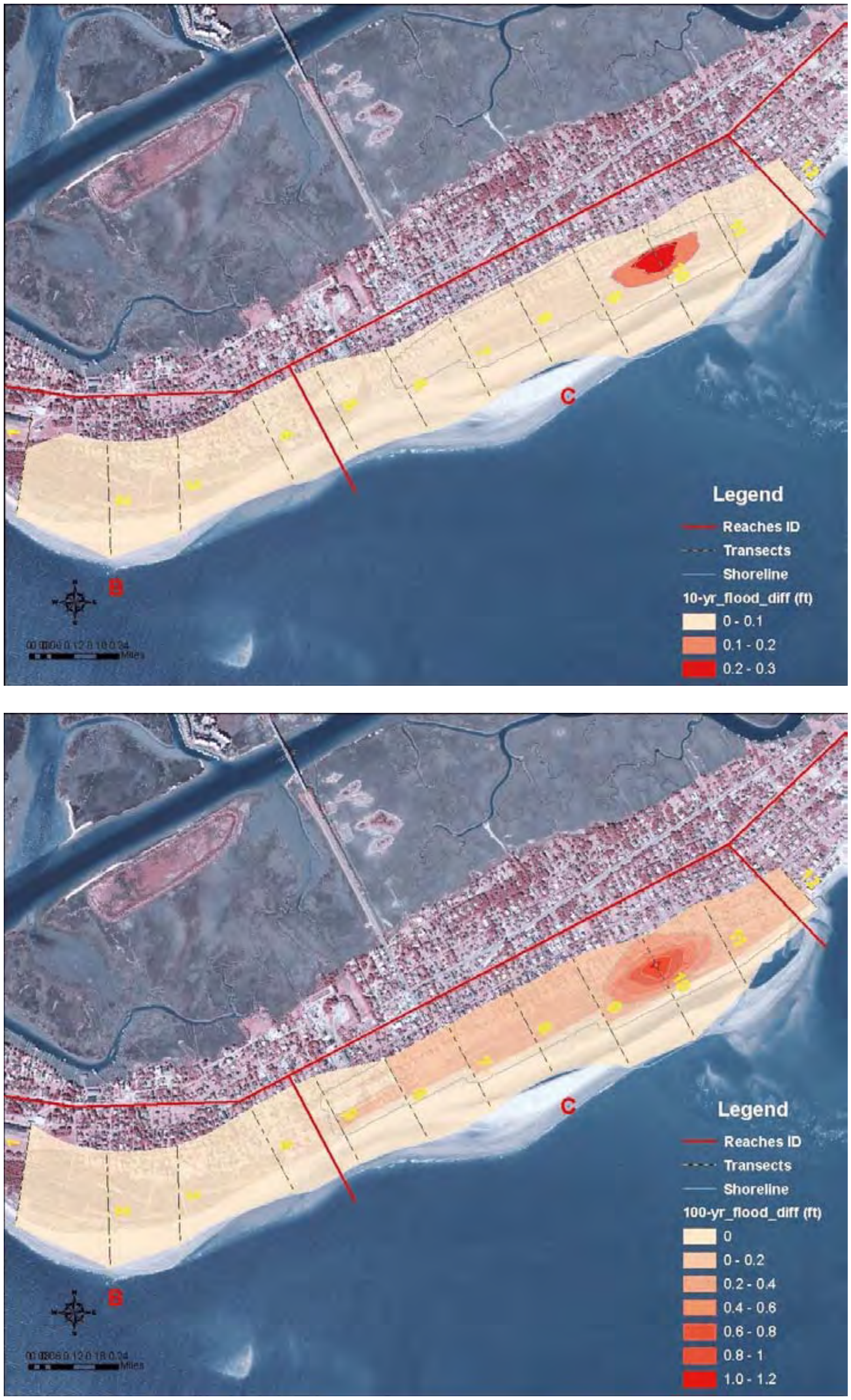
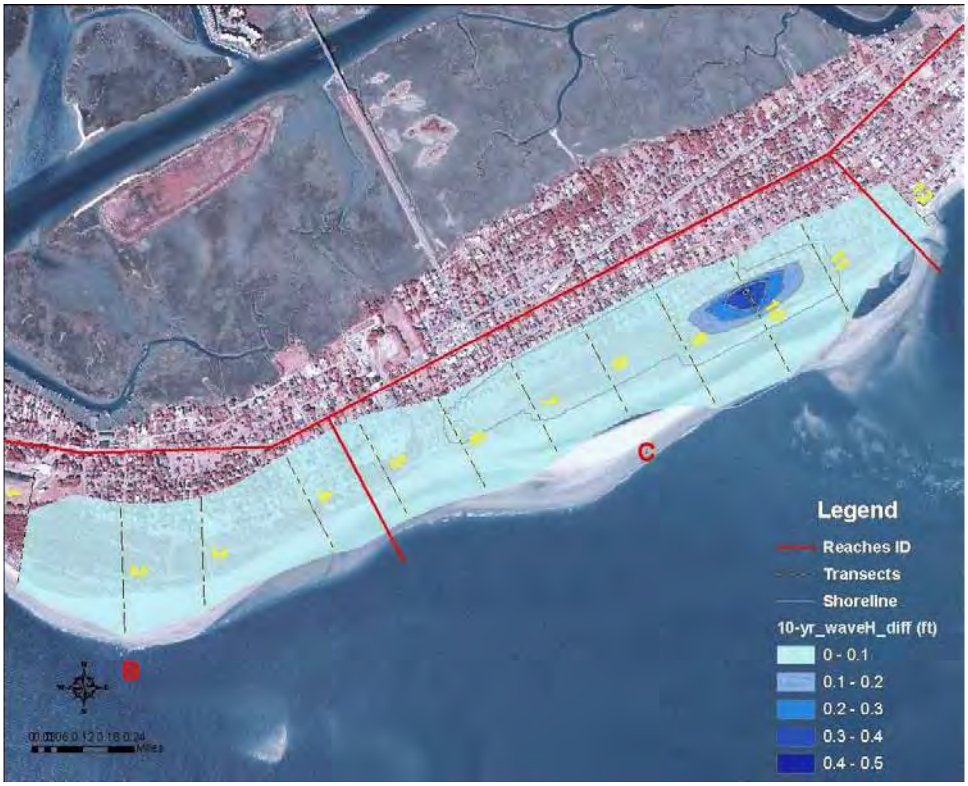


FIGURE 5.17. Change detection grids – difference in total flood depths between Scenario 2 and Existing Conditions.
[UPPER] 10-year event **[LOWER]** 100-year event



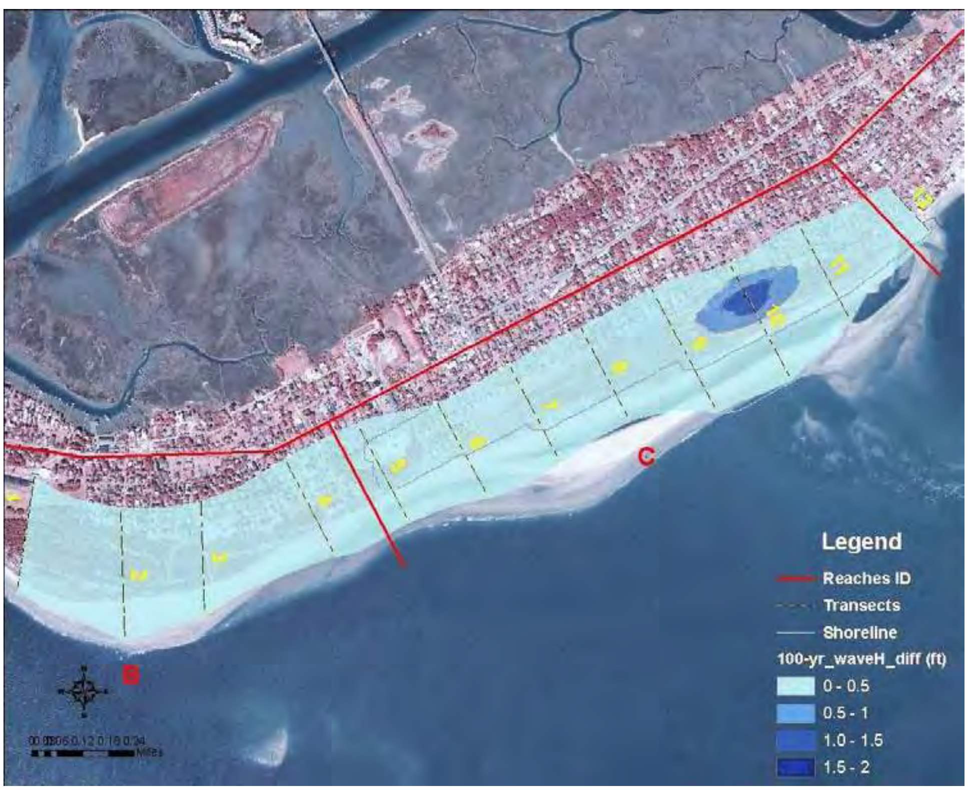


FIGURE 5.18. Change detection grids – difference in wave heights between Scenario 2 and Existing Conditions.

[UPPER] 10-year event **[LOWER]** 100-year event

Changes in vegetation parameters have a more significant impact on the 100-year scenarios. At transect 10, an area where the *manipulated maritime shrubland* and *maritime hardwood depression* have been substituted with *maritime foredune* and backdune grassland, a relatively small increase in total flood depth of ~0.3 ft was observed for the 10-year event. An increase of ~1.1 ft was observed in the total flood depth difference for the 100-year event. Differences in wave heights show an increase of ~0.5 ft for the 10-year event and ~1.6 ft for the 100-year event.

Therefore, changes in vegetation that substitute existing plant types with smaller and less flow-resistant types tend to increase flooding depths and wave heights. In addition, these impacts are more significant in the presence of higher water levels. Of further interest is that less resistant vegetation allows higher flooding and larger waves closer to developed areas, increasing the flooding hazards and potential damages inland.

Storm-Damage Analysis

The potential severity of damages to structures located within flood-prone coastal areas adjacent to the AL study area is dependent upon the hazards from flood water and wave levels. These hazards are recognized in FEMA's National Flood Insurance Program, which establishes more stringent building criteria in the high-hazard coastal zones subject to wave inputs. These coastal high-velocity zones, or "VE" zones, define areas where wave heights in storms are expected to be higher than 3 ft.

Adjacent to VE zones are "AE" zones, where waves smaller than 3 ft have been observed to occur. Evidence from both laboratory tests and field surveys (ie – damages after Hurricane *Katrina*) show that waves as small as 1.5 ft cause significant structural damage or failure. Consequently, in 2007, FEMA introduced the LiMWA or *Limit of Moderate Wave Action* as the landward boundary of the 1.5-ft wave. With the addition of the LiMWA on flood advisory maps, FEMA recommends the enforcement of building criteria similar to the standards used in VE zones, up to the LiMWA boundary.

Recognizing that structural damages can be caused by smaller waves, the Team (led by Dewberry) prepared an assessment of potential wave damages under different AL alternatives. Potential coastal storm damages were estimated using methods and guidelines recommended by the USACE (2002). Probable economic losses due to 10-year and 100-year storm events were estimated by mathematical functions that link storm parameters, such as wave crest height or stillwater flooding depth, to the percentage of damage to the structure.

The USACE (2002) methodology suggests that "if both waves and inundation cause damages, the rule {should} be to only use the damages caused by waves" to be consistent with the management practices within VE zones. The water level used for the calculation of the damages is described as the *"difference between the top of the wave (crest) and the bottom of the lowest horizontal structural members."* As previously described, the top of the wave crest is determined as the total flooding depth, which accounts for the stillwater level, plus wave setup and wave height.

To develop a regional estimate of damages, 14 parcels on Sullivan's Island, adjacent to the AL study area (Fig 5.19), were selected to represent typical island residential structures. The elevation of the bottom of the lowest horizontal member, first floor, and other relevant site-specific information were obtained from the *Elevation Certificates* provided by the town of Sullivan's Island. Elevations of the lowest horizontal member for this study ranged between 14.4 ft and 17.9 ft (referenced to NAVD'88).

FIGURE 5.19. Representative parcels selected for the computation of structural damages for the Sullivan's Island AL study area. Data for each parcel were extracted from official elevation certificates on file with the town of Sullivan's Island.

The Team's assessment of potential storm damages was performed for the 10-year and the 100-year storms and for the three scenarios as described in Section 5.5. The "damaging" wave heights were computed by calculating the difference between the top of the wave crest and the bottom of the lowest horizontal member. This elevation difference was used with the damage functions (USACE 2002) to determine the "percent" damage to the structure(s).

Existing Conditions

Under Existing Conditions, the potential damage increased with higher flood levels as expected — damages ranged between 0-40 percent for the 10-year event and 40-85 percent for the 100-year event (see percent damage for each structure as shown on Fig 5.20). The variability from one structure to another under each scenario is the result of the different elevation of a structures' structural member in relation to flood and wave levels.

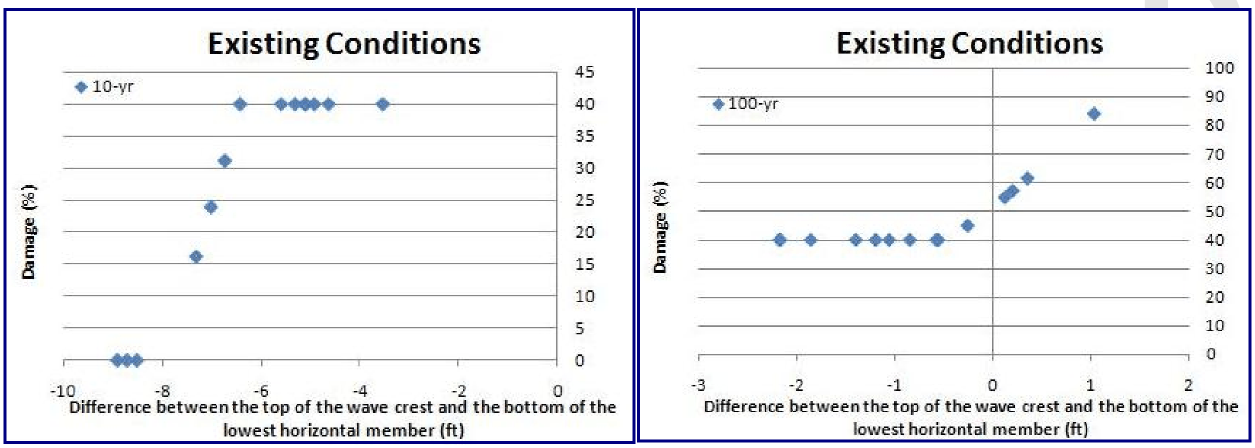


FIGURE 5.20. Percentage of structural damages under Existing Conditions. **[LEFT]** 10-year event **[RIGHT]** 100-year event

Scenario 1 – Addition of a Beneficial Dune

Under Scenario 1, addition of a low dune ridge reduces the water levels on its landward side, by significantly reducing wave setup. All but one of the structures evaluated had **reductions** in potential wave damages by over 20 percent for the 10-year event (Fig 5.21, left). Likewise, potential wave damages for the 100-year event were sustained to 40 percent versus the higher levels (ie – 40-85 percent) calculated under Existing Conditions (Fig 5.21, right).

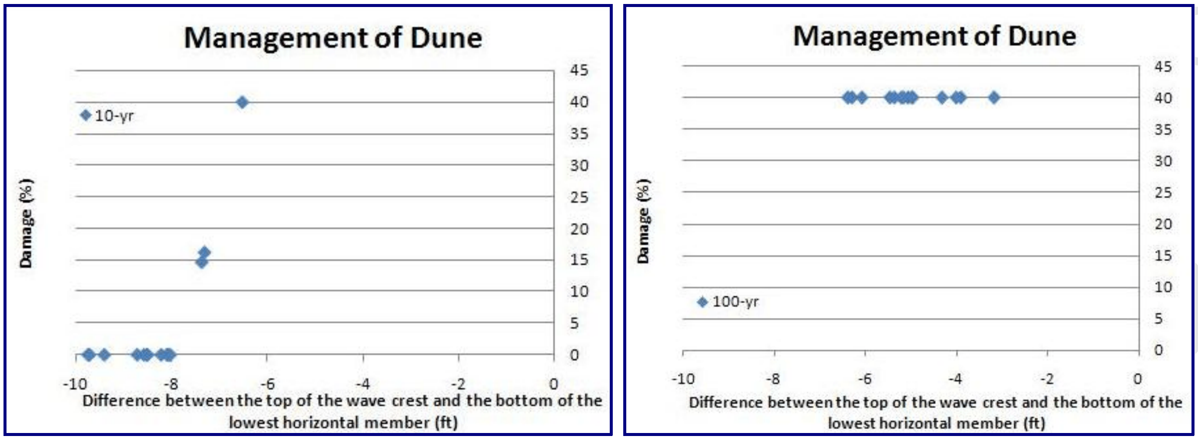


FIGURE 5.21. Percentage of structural damages under Scenario 1 – addition of a beneficial dune.
[LEFT] 10-year event **[RIGHT]** 100-year event

Scenario 2 – Reduction in Vegetation Density

Under Scenario 2, the modeling of proposed substitute vegetation communities such as *manipulated maritime shrubland* and *maritime hardwood depressions* with *maritime foredune grassland and backdune grassland* showed an increase in wave heights of 1-2 ft for the 10-year event and 3-4 ft range for the 100-year conditions. This difference in wave heights for the 10-year event was not significant enough to change damage percentages between Existing Conditions and Scenario 2. However, for the higher flood level 100-year event, the larger difference in wave heights (generated by the less resistant vegetation proposed within Scenario 2) increased wave hazards, particularly for one parcel (and structure) located exactly where the vegetation changes were proposed. The structure was at a high damage risk (83.9 percent) in the Existing Conditions scenario. For Scenario 2, this structure is potentially subject to 100 percent damage when modeled with the proposed vegetation community changes (Fig 5.22).

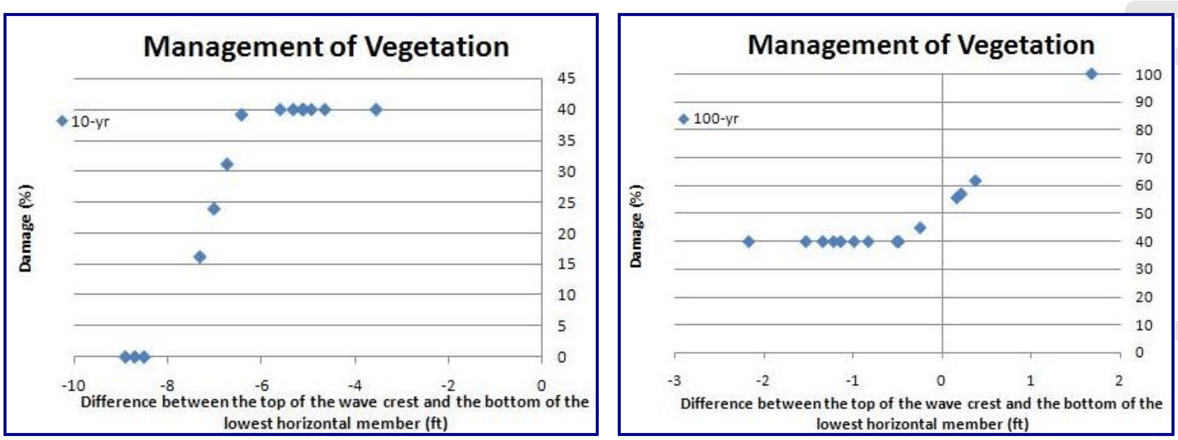


FIGURE 5.22. Percentage of structural damages under Scenario 2 – reduction in vegetation density.
[LEFT] 10-year event **[RIGHT]** 100-year event

Summary – Model Simulations of Storm Impacts

Based on the this assessment, potential damages attributed to wave hazards differ under the three AL management scenarios. While 0 percent wave damages cannot be achieved, strategies as outlined in Scenario 1 and Scenario 2 are expected to have an impact on wave heights and subsequent damages. Scenario 1 (with the low dune ridge feature added) significantly reduces wave heights along oceanfront properties by over 20 percent for over 50 percent of the structures fronting the AL area. Scenario 2 (reduction in vegetation density via alteration in existing vegetation communities), although beneficial for other management objectives, could potentially increase wave hazards and damages to structures adjacent to these modifications. However, we note that the potential for increasing wave hazards under a particular management strategy such as Scenario 2 (ie – involving changes in land cover) is more relevant to large, much less probable, flooding events than smaller ones. For smaller events, such as the 10-year event, land-use change-management strategies, such as Scenario 2, do not appear to have a significant effect on wave damages.

5.6 Summary — Future Changes — Land Evolution

Based on the results of the present analyses, the study team anticipates the following future changes and land evolution within the accreted land over the next ~40 years.

- Continued seaward growth of the shoreline in Reach B and Reach C by way of inlet sand-bypassing from the Isle of Palms and Breach Inlet.

- The **<u>average</u>** rate of accretion (historically of the order 10 ft per year) is expected to decline in relation to the rate of SLR, but not reverse between now and the year 2050.

- Sea level is expected to rise at an accelerated rate this century compared with the 20th century (NRC 1987, IPCC 2007).

- Under the most probable SLR scenarios (approximate doubling of the 20th century rate), the sand supply to Sullivan's Island is likely to keep pace and produce continued accretion, but at a lower rate of change (cf – Kana et al 1984), thus leaving the existing AL area intact.

- Incrementally higher sea levels (order of 1–2 ft) will give rise to comparably higher storm tides and waves, or more frequent flooding at a particular elevation.

- The accreted land is likely to remain stable (but subject to occasional flooding), thus allowing existing vegetation to mature, grow in height, and transition from grass to shrub-dominated types, shrub to tree-dominated types, or immature forest to mature forest types. Specific transformations of vegetation succession are outlined in Section 5.4.

- Dunes within the AL area are not expected to gain elevation because they are presently stabilized by vegetation. Incipient dunes along the seaward edge of the AL area will only gain significant height if the shoreline remains relatively stable, neither eroding nor accreting.

- Typical land elevations across the AL area are expected to remain below the +10 ft NAVD contour with isolated dunes in limited sections reaching ~12 ft NAVD (~12 ft above mean sea level). Elevations in these ranges will be exceeded during the 100-year storm as well as during some more frequent storms. In general, the AL area will sustain only minor local flooding during a 10-year event, even factoring in a 1–2 ft sea-level rise.

- The nature of vegetation within the AL area will make some portions more susceptible to fire. Buildup of understory vegetation provides a ready fuel source which, if not controlled, can lead to catastrophic results. Section 6 discusses the role of controlled burning in reducing the threat of uncontrolled natural fires as well as enhancement of habitats.

- Without some form of vegetation management, the majority of the accreted land will evolve into early successional maritime forest. As the forest matures and creates a thicker overstory, the midstory and understory vegetation will decline. With management, this process can be accelerated in some portions of the AL area and can be retarded or prevented in other sections.

- The study team (under Dewberry's leadership) developed computer simulation models of storm tides and wave impacts across the accreted land area. Three scenarios were evaluated for 10-year and 100-year storms:

- Existing Conditions – topography and vegetation cover as is.
- Scenario 1 (Addition of a Beneficial Dune) – addition of a continuous, low dune at ~14 ft NAVD high and ~75 ft wide (at base) over the length of the AL area. The relief of the dune would be 2–6 ft higher than existing topography.
- Scenario 2 (Reduction in Vegetation Density) – maintenance of low shrub and grass vegetation along Reach C (east half of the AL area).

• Results of the model simulations showed the following:

- Addition of a single, low dune ridge through the AL area several feet higher than existing topography has the effect of reducing potential flood levels by 2–4 ft along the first row of houses compared with Existing Conditions. Wave heights during floods would be ~1–2 ft lower along developed property under Scenario 1 compared with Existing Conditions.
- Pruning of vegetation to maintain grass and low shrub habitats under Scenario 2 has a relatively small, but negative impact on flood depths and waves during the 10-year and 100-year storm events.
- Storm-tide levels would increase incrementally 0.3–1.1 ft along backshore areas under Scenario 2 (compared with Existing Conditions). Wave heights would be ~0.5 ft to ~1.6 ft higher for the 10-year and 100-year events (respectively).
- Even a relatively small dune constructed at elevation 14 ft NAVD'88 along the AL area has a significant impact on flood and wave heights along the first row of houses resulting in potential damage reductions of the order 50 percent compared with Existing Conditions.
- The model results show that manipulation of vegetation has only an incremental impact on potential damages for frequent storms (ie – 10-year return period), but a significant impact during rare events (ie – 100-year return period). The potential adverse impact of thinner, lower vegetation on storm damages is small relative to the potential positive impact of a continuous dune constructed 2–6 ft above the existing AL study area elevations.

6.0 MANAGEMENT ALTERNATIVES

The team of CSE–S&W–Dewberry has evaluated the accreted land (AL) area of Sullivan's Island and has described its history, present condition, and expected future changes with respect to the shoreline, dunes and vegetation, as well as the flood potential under 10-year and 100-year storm events. The AL area comprises nearly 190 acres of low dunes and swales that have formed within the last ~70 years. Excess sand supplied by way of littoral transport from Isle of Palms and Breach Inlet accounts for the buildup of the AL area. Average shoreline change has been ~10 ft/yr with the likelihood of continued accretion through 2050 even under probable SLR scenarios (Kana et al 1984, IPCC 2007).

Regardless of the future rate of accretion, the existing land is expected to remain stable (with occasional flooding and inundation during major storm events) and to continue to support a diverse vegetative community. With upward of nine distinct vegetation habitats, from grass-lands to forests, there will be a continued shift from pioneering, low species (eg – dune grasses) to shrub vegetation and, ultimately, maritime forest.

The future transformation of the AL can be seen by visiting the east and west halves of the area (Fig 6.1). Land west of the Charleston jetty (referenced as Reach B herein) accreted rapidly between the 1940s and 1970s and is well established today. Its predominant vegetation is early maritime forest with a dense canopy of trees reaching more than 40 ft in height. By comparison, the eastern half of the AL (Reach C – east of the jetty) did not begin accreting rapidly until the 1970s. As a result of its younger age, vegetation tends to be dominated by shrubs and small trees reaching heights of the order 15–25 ft. Pruning along some sections of Reach C has maintained a shrub/tree height of the order 5–10 ft. If left to natural succession processes, Reach C will likely look much like Reach B two or three decades from now.

Nearby undeveloped barrier islands also offer examples of how the Sullivan's Island AL will look decades from now. Bull Island and Capers Island exhibit densely vegetated beach ridges extending over 1,500 ft inland (Fig 6.2). Both of these islands have been erosional during much of the 20th century (Kana and Gaudiano 2008). However, in earlier times, accretion allowed similar vegetation succession. Interior sheltered areas representing former shorelines were transformed from grasslands to maritime forest, and the forest continued to mature long after the accreted shorelines began to retreat. This, of course, accounts for situations where mature trees can be seen perched along eroding escarpments or littering the beach with their exposed root masses (Fig 6.2). In short, the AL is sufficiently wide to provide sheltered interior areas where trees can mature over many years before erosion poses a direct threat to the land.

FIGURE 6.1. Typical vegetation cover in Reach B (west half of AL) and Reach C (east half of AL) in 2008.

FIGURE 6.2. Aerial photo of Capers Island in 17 February 2007 showing mature maritime forest up to the seaward edge of the island and downed trees littering the active beach. (Photo by TW Kana)

Visual Impacts – While no attempt is made here to illustrate the rate of change in the height of successional vegetation, it is realistic to expect that grassland habitats will typically produce visual barriers of the order 5 ft high; shrubland communities grow to ~20-ft heights; and maritime forest grows to well over 50-ft heights. It should be apparent that views of the ocean are a function of three factors: (1) height of the vantage point, (2) distance to the beach, and (3) height of the intervening landscape. Ocean views will be blocked when the elevation of the vegetation (or dune) equals the elevation of the vantage point. Typical first-floor and second-floor vantage points would be ~20 ft and ~30 ft above mean sea level (respectively). Based on these parameters and the typical AL land elevations of 8–12 ft above mean sea level, shrub vegetation of the order 10 ft or higher is likely to block views from the first-floor level of most existing homes along the oceanfront. Modest-sized dunes with 10 ft or more of relief are similarly likely to block first-floor views even if grass remains the dominant vegetation type along their crests. Forest vegetation, if not thinned or eliminated along broad corridors, is expected to block ocean views from any first- or second-story vantage point.

The Team's analysis of the AL and review of the literature on barrier island evolution and vegetation succession confirms that the Sullivan's Island situation is not typical of most East Coast barrier islands. However, in settings like South Carolina and Georgia, where there is abundant sediment released from ebb-tidal deltas, prolonged periods of barrier-island accretion have occurred. Accreting beach ridges have allowed maritime forest to evolve and provide a dense cover over the land. The present review confirms that the land and its vegetation will not remain static into the future. This, of course, has direct implications for any management alternative for the area.

6.1 Management Approaches

Drawing on the results of Sections 2–5, the Team outlines four general management approaches as presented in the beginning of the report:

1) Do nothing and allow the AL to evolve naturally.

2) Continue present practices which include vegetation controls such as pruning to maintain the views (at the discretion of individual property owners subject to existing Town ordinance – Appendix 2).

3) Implement more extensive management of vegetation to address goals and objectives of the community.

4) Modify the topography for purposes of reducing potential storm damages and implement expanded management of vegetation to address the goals and objectives of the community.

Each of the above-listed management approaches has advantages and disadvantages depending on the objective to be emphasized.

In the following sections, the Team outlines a number of potential impacts of each approach with respect to nine variables including: barrier-island ecology, storm-damage reduction, ocean views, beach access and public safety, fire, pests, property values, relative cost of implementation, and construction requirements. Also described in detail are some specific management alternatives that could be implemented (eg – dune enhancement, fire management, creation of ponds, etc).

While the Team does not believe there is one ideal management approach for the AL, an example natural area from another barrier island illustrates what Sullivan's Island could look like along the oceanfront with some degree of management. Figure 6.3 illustrates a diversity of habitats along an accreting spit at Hunting Island. This example includes open grassland habitat interspersed with shrub vegetation, an interior wetland and open-pond habitat, and early maritime forest. Compared with the forested beach ridges of Capers Island (see Fig 6.2), this portion of Hunting Island contains a greater diversity of habitats and, therefore, can attract and maintain a greater diversity of wildlife. The Hunting Island example also offers more visual interest to beach goers.

FIGURE 6.3. Example of accreted land exhibiting a variety of habitats in close proximity including forest hammocks, freshwater pond, and grassland habitat backed by mature maritime forest. (Hunting Island, SC – 31 May 2008 – Photo by TW Kana)

Alternative 1 – Do Nothing and Allow the AL to Evolve Naturally

Alternative 1 assumes negligible alteration of the existing AL by artificial means. Paths would be maintained by pedestrian use and minor pruning of overhanging branches along the edge, but would otherwise be left untouched. Existing conditions and habitats would change naturally in relation to the rate of vegetation growth. Over time, the upper-story tree canopy would expand and become the dominant vista across the entire AL. Paths would become sheltered by overhanging limbs of live oak, palmettos, and pines, among other maritime forest species.

Barrier Island Ecology & Habitat Diversity	Nine distinct habitats now will likely transform to predominantly forest habitats as tree canopy expands. Shrubland and grassland habitat area will diminish. Wetland areas will shrink as organic detritus and sediments accumulate and build up substrate.
	Forest species will increase.
	Understory vegetation will decrease.
Storm Damage Reduction	Improved storm surge and wave attenuation due to presence of trees.
	Incrementally reduced potential storm damage to developed property compared with present conditions.
Ocean Views	Continually diminish until eliminated for all oceanfront properties facing the AL.
Beach Access & Public Safety	Access will diminish unless paths are maintained. Expanded tree cover with less understory vegetation will provide hiding places and escape routes for criminal activity and potentially reduce public safety.
Fire	Threat of fire will diminish over time in relation to decreased understory vegetation (see section 6.2 for a detailed discussion of fire threats and management options).
Pests	Rodent problems will decline in relation to decreased understory vegetation.
Property Values	Loss of ocean views is expected to have a negative impact on property values and the local tax base as "oceanfront" homes are compared with interior island homes on other SC beach resorts. Rental rates are expected to be negatively impacted relative to rates for oceanfront property with unimpeded views. Reduction in oceanfront property values (or the rate of rise relative to competing properties on other barrier islands) may adversely impact municipal budgets.
Cost of Implementation	Negligible
Construction Requirements	None

Alternative 2 – Continue Present Practice

Alternative 2 assumes no change in the existing Town ordinance for pruning by individual property owners. Over time, pruned swaths would be flanked by higher stands of forest vegetation. As the tree canopies of unpruned areas expand, they would tend to narrow the ocean vistas across pruned areas.

Barrier Island Ecology & Habitat Density	Continued pruning will prevent maritime forest from developing in these areas. This will maintain altered shrubland habitat and (compared with Alternative 1) preserve a greater number of distinct habitats. Shrubland areas presently not pruned will transform into maritime forest with the result being shore-perpendicular bands of pruned shrubs paralleling unpruned forest (see Fig 1.3).
	Pruned areas will maintain bands of dense understory vegetation as vegetative growth is forced laterally via the pruning process.
Storm Damage Reduction	Pruning will result in a lower shrub cover and incrementally higher storm surge and damaging waves compared with unpruned vegetation (the impact will be relatively small for most storms and only become significant during rare storms such as a 100 year event, as described in Section 5.2).
Ocean Views	Views will be maintained along pruned corridors, but are expected to diminish as adjacent unpruned swaths develop higher vegetative cover.
Beach Access & Public Safety	Pruning shrub vegetation along paths will improve access and leave a dense, understory edge. This may reduce convenient hiding places and inhibit escape from paths, thus increasing public safety. Low vegetation along broad paths will allow users better visibility to see potential dangers and be seen by others, thus leading to a greater sense of security along access paths.
Fire	Threat of fire will remain similar to present conditions because of continued presence of dense, understory vegetation along pruned swaths. (See Section 6.2 for discussion of fire threats and management options.)
Pests	Rodent problems will remain the same or increase because of the expansion of dense understory vegetative cover
Property Values	Maintenance of ocean views across pruned corridors is expected to have a positive impact on property values and the local tax base. However, as adjacent unpruned swaths develop higher vegetation, the artificial character of pruned strips between development and the ocean will become more apparent, possibly adversely impacting property values compared with other barrier-island oceanfront properties.
Cost of Implementation	Present costs are mainly borne by individual property owners. Those costs are expected to increase as sections of grassland habitat become shrubland habitat. Some property owners who have not engaged in pruning, because their vegetative cover is presently lower density, may consider pruning in the future as their ocean views diminish.
Construction Requirements	Same as present with debris removal and disposal being a significant part of the cost.

Alternative 3 – Implement More Extensive Management of Vegetation

Alternative 3 assumes that a "naturalized" landscape plan could be developed for the AL whereby the suite of three broad vegetation communities (grassland, shrubland, and forest) could be maintained with negligible alteration of the topography. Unlike Alternative 2 which would tend to create shore-perpendicular bands of pruned and unpruned vegetation depending on an individual owner's preference, Alternative 3 would seek to create an interesting diverse landscape, where open grassland areas are interspersed with shrub and forest hammocks (see Fig 6.3). Some areas that are presently early successional forest would be cleared of trees and replanted with grasses, particularly along access trails.

A particular mix of vegetation communities would be defined as the target and specific landscape plans for implementation would be developed. For example, if the target mix is 35 percent grassland, 25 percent shrubland, and 40 percent maritime forest, the present inventory of vegetation communities would allow estimates of how much of each must be removed or added to achieve and maintain the target quantities. Once a basic landscape plan is developed and implemented, annual maintenance would be required.

Alternative 3 (continued)

Barrier Island Ecology & Habitat Diversity	Maintain or increase habitat diversity by converting some shrubland to grassland and some forest areas to shrubland, thus inhibiting development of continuous maritime forest over the majority of the AL.
	Possibility of creating maritime forest hammocks interspersed with shrubland and grassland habitat in close proximity which would attract a greater diversity of animal species.
Storm Damage Reduction	Any reduction in vegetation density increases the storm damage potential. However, the effect is relatively small for most storms and only becomes significant for large storms such as 100-year events. (See discussion in Section 5.5.)
Ocean Views	Views through corridors between maritime forest hammocks would be maintained. Maintenance of broad paths flanked by strips of grassland habitat and pockets of shrubs would provide visual interest for pedestrians accessing the beach.
Beach Access & Public Safety	Open pathways would improve emergency access and general access while increasing public safety by reducing hiding areas for criminal activity.
Fire	Potentially lessens risk of fire by reducing the areas of dense understory vegetation and flamable species such as waxed myrtle. Provides fire breaks along grassland strips and wide pathways.
Pests	Reduces rodent problem by reducing areas of dense undergrowth.
Property Values	Maintenance of ocean views and a variety of vistas associated with a mix of forest, shrub, and grassland habitat would likely have a positive impact on property values. However, the relatively great distance to the ocean, regardless of vegetation cover, adversely impacts property values in comparison with traditional oceanfront property set back lesser distances from the beach.
Cost of Implementation	Would require initial removal of extensive areas of woody vegetation and replanting with grassland areas. Some minor earthworks would be required for efficient removal of root mats where there is dense understory or altered shrubland at present.
	After initial vegetation removal to leave hammocks of forest and shrub habitat flanked by grassland habitat, ongoing maintenance would be required.
	Cost of implementation will depend on the number of acres of land that require vegetation modification to achieve the goals and objectives of the community.
Construction Requirements	More extensive than present practice because of the initial work to convert some forest areas to grasslands or shublands.
	Heavy equipment would be required for initial work and tree removal. Subsequent maintenance would be accomplished with small, less obtrusive equipment.

Alternative 4 – Modify Topography & Implement Expanded Management of Vegetation

Alternative 4 assumes that a "naturalized" landscape plan includes modification of the topography. Such modifications are assumed to include at least one continuous dune ridge paralleling the shoreline, which provides improved storm-surge protection. The degree of surge and wave height reduction is simply a function of the scale of the dune feature. Other topographic modifications are assumed to include limited excavation of existing swales for purposes of creating open-water ponds to add habitat for waterfowl, provide an attractive amenity for the community, reduce the mosquito population associated with existing wet areas, and improve ocean vistas (see Fig 6.3). Initial costs would include earth moving, tree removal, and replanting of altered areas (similar to Alternative 3). After the initial landscape is developed, it would require ongoing maintenance similar to Alternative 3.

Alternative 4 (continued)

Barrier Island Ecology & Habitat Diversity	Same impacts as Alternative 3.
	Provides interest in the form of greater topography.
	Addition of open-water ponds expands the suite of habitats and wildlife, thus increasing diversity.
Storm Damage Reduction	Addition of a continuous dune ridge of any dimension, superimposed on existing topography, improves storm-surge protection and reduces potential storm damages. The degree of storm-damage reduction is significant even with a dune crest at 14 ft above mean sea level (see Section 5.5). The impact of increased dune elevation on storm-surge attenuation is much greater than the effect of higher vegetation.
Ocean Views	Same impacts as Alternative 3.
	Offers new views over ponds for a greater variety of vistas
Beach Access & Public Safety	Same impacts as Alternative 3.
Fire	Improved impacts compared with Alternative 3 because of the addition of ponds, which form a natural barrier and water supply in the event of fire.
Pests	Same impacts as Alternative 3.
Property Values	Improved impacts compared with Alternative 3 because of added storm-surge protection and the added amenity of ponds, which enhance the landscape.
Cost of Implementation	Vegetation changes would entail similar costs as Alternative 3.
	Alteration of topography involves earth moving, which could be limited to construction of a simple low dune (see Section 5.5) or could involve more extensive sculpting of the land and construction of multiple dune ridges. Excavation for ponds could provide the sand for dune construction, thus minimizing transportation costs.
	Accreted shoals along the beach are another potential sand source (subject to federal and state permits). Earthworks landward of state jurisdictional lines would involve less time and expense in securing necessary approvals.
Construction Requirements	Modification of topography would involve excavation and filling along with vegetation removal and replanting.
	Ponds and dunes could be constructed entirely using land-based equipment with the major work occurring during winter. Projects involving dozens of acres and 100,000–400,000 cy of earthworks could be accomplished in a relatively short time frame (1–3 months.
	Replanting and establishment of grass vegetation could be accomplished in 1–2 growing seasons.

6.2 Specific Management Elements

To assist the community in evaluating the advantages and disadvantages of the four broad alternatives, the Team offers the following discussion of certain specific management elements: fire control, pest control, bird habitat enhancement, vegetation removal, and dune construction. Some background information is included as necessary to aid the discussion.

Fire Control

Fire has played a major role in determining the distribution of plants and animals in the southeastern United States. Some communities, such as the longleaf pine-wiregrass habitat, require periodic fire to survive. The natural occurrence of fire from events such as lightning results in upland burns every three to five years. Barrier-island maritime forests may burn less frequently. However, the basic premise of fire ecology is that the fire is neither innately destructive nor constructive. It is an agent of change.

Change is a biologically necessary component of a healthy ecosystem. Early man learned to use fire as a tool for hunting and clearing land for crop production. Today's resource managers have learned to use fire to manipulate change to meet the needs of plant and animal communities. Its prudent use can achieve a variety of habitat changes depending on the timing, frequency, and intensity of the fire. Man's use of fire as a tool is referred to as prescribed burning.

A single prescribed burn can produce multiple impacts. The fire can be used to reduce wildfire hazard by reducing the fuel load on the ground. The same fire can also improve access in woods and improve wildlife habitat. Proper use of prescribed fire requires knowledge of how fire affects vegetation, wildlife, soil, water, and air. Burning techniques can be varied to achieve different results.

Fire may injure or kill part or all of a plant depending on how intense the fire is and how long the plant is exposed to high temperatures. Bark thickness and stem diameter will influence a plant's susceptibility to damage. In general, small trees of any species are more easily damaged by fire than large ones. On average, hardwood trees are more susceptible to fire damage than pine trees. The thicker bark and better insulating qualities of pine trees have adapted to a presence of fire and provide protection for them. Pine trees with a diameter of three inches or more usually have enough bark to protect them against damage from most prescribed fires. The needles however are very susceptible to temperatures above 135°F. Pine needles will survive temperatures of 130°F for about five minutes.

Fortunately, the high temperatures generated by the forest floor fuels cool rapidly from the flame zone. Adequate wind can help dissipate the heat before the needles are scorched. Southern pine will usually survive complete crown scorch as long as the terminal bud is not damaged. A dense layer of needles surrounds the terminal bud to prevent its loss during fire. Severe needle scorch, while not killing the tree, may retard growth for a year or more and can make it more susceptible to drought and beetle attack.

Resource managers can use the kill and scorch qualities of fire to achieve a variety of results. Understory vegetation can be kept low with frequent fires, and some species can be removed from the stand by burning during the growing season. Mast-producing species can be maintained close to the ground where they are more available to wildlife. Longleaf pine seedlings are often stimulated with fire to grow from the grass stage into saplings. Invasive non-native species are often fire-intolerant and can be controlled effectively and inexpensively with prescribed burns. In addition, many rare and endangered species of plants are fire-dependent for a portion of their reproductive cycle. These species can be reintroduced into an area and maintained with the correct timing and frequency of fire. Prescribed burning is also a very effective practice used in marsh and moist-soil management. Prescribed burning accomplishes several objectives (Whitman and Meredith 1987), including:

- Maintaining successional stages so that desirable annuals are more abundant than herbaceous perennials and woody species.
- Removing matted vegetation produced in previous growing seasons and releasing nutrients, thereby encouraging the germination of valued food plants.
- Increasing seed availability in dense vegetation.
- Facilitating and improving the effectiveness of mechanical manipulations.

Prescribed fire can also be used to discourage weeds or invasive plants from taking over, by killing off their early growth and giving native plants a chance to compete. Cattails occasionally spread aggressively and can completely choke a wetland. A winter or early spring burn following a drawdown can reduce cattail cover in a pond, temporarily creating an open-water area. However, by the end of summer the cattails will have returned unless the burned area can be flooded with 3-4 ft of water during spring and early summer.

Various national wildlife refuges (NWR) – such as Mackay Island NWR in northeastern North Carolina and southeastern Virginia, Lee Metcalf NWR in Montana, and Arthur R. Marshall Loxahatchee NWR in Florida – are just a few NWRs that utilize prescribed burning in their moist-soil management practices.

Selecting the proper size, frequency, and timing of burns is crucial to the successful use of fire to improve wildlife habitat. Experienced, prescribed fire managers should be able to predict the changes that will occur in the vegetative composition of the stand. Prescriptions should also recognize the biological requirements such as nesting times of the preferred wildlife species.

Proper planning is not only important when considering fuel hazard reduction and vegetative manipulation but also is crucial to controlling the detrimental effects of fire, such as the reduction in air quality from smoke. Wind direction and speed are critical to maintaining control of the intensity and duration of the fire as well as determining the direction and impact of smoke. Potential off-site impacts, such as downstream water quality, should also be carefully considered as well as on-site impacts to soil and aesthetics. Public opinion must also play an essential role in the wise use of fire. The general public is concerned about the deterioration of the environment, and wind speed, smoke lifting conditions, surrounding road systems, urban areas, and health facilities make smoke management a primary concern of the fire manager.

Control of the limits of the fire's extent is generally accomplished through the careful and planned placement of firebreaks. Permanent firebreaks can be used as access roads and wildlife strips, especially if they are seeded with wildlife food. Weather conditions must also be monitored prior to and during the fire. Wind direction and speed are critical to maintaining control of the intensity and duration of the fire as well as determining the direction and impact of smoke. Humidity levels and fuel moisture levels are crucial to determining how hot the fire becomes and how much fuel is consumed. Low humidity levels can create "spot-over" problems that may lead to fire-control issues. Postfire weather conditions must also be monitored to avoid problems of flare-ups and smoke settling on highways or urban areas because of an inversion.

Prescribed fire is one of the most valuable and cost-effective, forest management tools available. It is a tool that must be understood and carefully implemented. However, its benefits are substantial to the aesthetics, health, and protection of the ecosystem.

Fires on barrier islands are ignited naturally by lightning strike; however, humans have been setting fire to the natural community for more than 5,000 years (Bellis 1995). Much maritime vegetation has adapted to fire and may play only a small role in the vegetation community dynamics on barrier islands (McPherson 1988). Typically, closed-canopy maritime forests have a dense canopy with a moderately dense shrub layer and a sparse herbaceous layer. These conditions tend to retain ground moisture. With high moisture levels, forest fires tend to be low, cool, and smoldering. Crown fires are rare (Bellis 1995). Conversely, pine-dominated forests tend to be drier and contain better quality fuels, resulting in intense, fast-moving fires which often crown.

The overstory within the AL study area at Sullivan's Island is dominated by hardwood species, not pine. Therefore, under normal conditions, forest fires would be low, slow, and should pose minimal threat to public safety. Prescribed fire would be an effective management tool for the AL area and could be safely applied. Periodic prescribed burns of the maritime forest would reduce understory vegetation, improving views into the forest. On the north end, where shrub vegetation dominates, fire would also reduce shrub growth, improving views of the ocean for front-row residents. Periodic burns would reduce hazardous fuel loads.

However, fire is often feared and misunderstood by the general public. During a prescribed burn within the Sullivan's Island AL area, flames and smoke would be easily seen from residences, and smoke would be present for several days following the burn. For several months following the burn, the area would appear black and charred, which may be unappealing for residents. Given these drawbacks, the use of fire at Sullivan's Island should be considered carefully and may necessitate the full support of island residents before undertaking. Controlled burns are one management alternative that should be considered by the community before finalizing the Accreted Land Management Plan.

Pest Control

The principal pests in the AL at present are mosquitos and rats. Mosquitos generally require standing stagnant water to propagate. Therefore, elimination of isolated puddles, standing water in oil drums, and so forth, will reduce infestations. Existing swales between dunes (maritime interdunal wetland and maritime hardwood depressions) create more sites suitable for mosquito breeding. If these isolated depressions can be linked to open-water ponds, they will tend to drain and become less attractive to mosquitos. Open-water ponds are not suitable for mosquito breeding because there is too much water motion. Alternative 4 would have the greatest impact on mosquito reduction. Alternatives 2 and 3 provide a measure of relief by creating more open-grass areas. Mosquito populations are generally very high in maritime forests on undeveloped barrier islands (like Capers Island) because of the presence of numerous pockets of standing water. This condition would persist and likely worsen under Alternative 1.

Rats have been an increasing nuisance within the AL according to informal communications with residents. While the Team did not observe rats during the surveys, their presence is not surprising, given the large areas of dense understory vegetation which provides shelter from larger predator animals. Public use of the AL also introduces food scraps and related litter which attract pests. Various bates (pesticides) are available for control, but this approach may be harmful to other wildlife. As Section 6.1 outlines, present management practices (Alternative 2) tends to increase the potential for rodent problems because of the maintenance and expansion of understory vegetation. Alternatives 1, 2, and 3 would all tend to reduce the rodent problem by way of reducing the amount of understory vegetation.

Bird Habitat Enhancement

The AL is an attractive bird habitat because of its diversity of vegetative communities. With habitat diversity comes bird diversity, ranging from shorebirds utilizing open beach and grassland areas to forest species (eg – painted buntings). Any alternatives which maintain habitat diversity will have a positive impact on the bird community. Alternative 1, therefore, would be the least likely to expand the diversity of bird populations. Alternative 4 would likely offer the greatest increase in bird species because open-water ponds would attract ducks and other species that utilize pond habitat.

Vegetation Removal

Land clearing is disruptive to existing habitats, but short-lived in its impacts. Replanting, combined with natural propagation of seeds from adjacent plant communities, quickly re-establishes vegetative cover over any land sheltered from direct effects of ocean spray. All, but Alternative 1 involve some form of vegetation thinning or removal. Thinning and pruning is a recommended management technique which promotes healthy growth of plants. The activity could be implemented in such a way as to recycle chips back to the soil or be used as mulch along paths to inhibit regrowth. Where shrubs and trees have to be removed (Alternatives 3 and 4), heavier equipment such as bulldozers and mulching machines would facilitate the work.

Dune and Pond Construction

Dunes along the oceanfront represent a primary line of defense during storms. As discussed throughout this report, existing topography over the AL is low relief with few areas exceeding

12 ft above mean sea level. With average land elevations around 8-9 ft, the AL would provide significantly improved storm-surge protection if even a low dune were constructed. Scenario 1 in Section 5.5 described the potential impact of a dune 75 ft wide at the base with a crest elevation at ~14 ft above mean sea level. Such a dune would require the equivalent of about one-half dump truck load of sand per foot of shoreline or ~100,000 cy total if it is placed along an existing low ridge. Volumes of this order are presently available as attached shoals (sand bars) along the beach. An alternative sand source could be low areas within the AL. Excavations of low areas could be configured to leave shaped ponds within or adjacent to maritime interdunal wetlands or hardwood depressions. Assuming the optimum excavation depth for open-water ponds is a couple of feet below mean sea level, removal of 100,000 cy could create ponds totaling ~8–12 acres. Obviously, greater excavation volumes could increase these totals while offering a larger protective dune. Costs of earthmoving for projects of this nature are typically in the range of $5–$10 per cubic yard.

6.3 Funding Sources and Community Assistance Grants

As part of the Team's work for the Town, funding sources and grants were investigated that may be available to the Town in connection with management of the accreted land (Appendix 11). Some funding sources are associated with wildlife enhancement. An idea that the Team is developing includes establishment of an Audubon-sponsored nature/interpretive center near the western end of the AL area. Given the number of bird species observed in the area and the strategic location of the AL along the East Coast flyway, a nature center would be an asset for the Charleston region as well as for the town of Sullivan's Island.

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7.0 MANAGEMENT RECOMMENDATIONS

Following a series of Town Council meetings and two community forums (4 August and 7 December 2009) where the results of the study were presented, a consensus approach was developed. The Town Council directed the Team to divide the AL into several **planning units** and to outline future management goals, recommendations, and implementation strategies for each unit.

The consensus strategy for the AL, based on input from the community, is a combination of Alternative 1 and Alternative 3 as most appropriate for the specific conditions of the AL. In some areas, it is deemed most appropriate to allow the AL to evolve naturally with minimal modification of vegetation, particularly where existing vegetation has matured and is approaching climax maritime forest. In other areas, it is deemed most appropriate to implement extensive vegetation management and actively control the distribution (percent) of various barrier-island habitats for benefit of the community and wildlife.

Key findings of the study, as reflected in the consensus management approach, include:

1) The western end of the AL contains more mature vegetation, which favors a more passive approach, allowing future vegetation to evolve in a continued natural succession.

2) The eastern end of the AL contains less mature vegetation and adversely altered habitat (eg – near-monoculture of pruned wax myrtle), which favors a more active approach, including conversion of some scrub shrubland to grassland.

3) Fire poses a threat, which can be best managed by means of open buffer zones, wider pathways, and less undergrowth so as to create numerous fire breaks.

4) Dense undergrowth (the result of years of pruning), which predominates in some sections of the AL, provides attractive habitat for rodents and should be reduced for purposes of controlling rat populations.

5) Invasive species have been introduced to the area and should be eradicated because they impair ecological function and diminish the beauty of the AL.

6) Some management practices recommended herein may be subject to federal or state regulation depending on the type and location of the activity. Several agencies have jurisdiction within portions of the AL.

7) Manipulation of topography should be avoided in favor of vegetation management based on the consensus of the community.

Management recommendations and guidelines are presented for fire, rodents, and invasive species. Federal and state regulations are then reviewed as they may apply in some way to management of each planning unit. This is followed by delineation of four recommended planning units within the AL and recommended implementation strategies.

7.1 Recommended Planning Units

In consultation with Town officials, four planning units are delineated within the AL as illustrated in Figure 7.1. The units and their general boundaries are as follows.

Planning Unit #1 – Fort Moultrie

Extends from the western end of the AL at Fort Moultrie (vicinity of station 13) and terminates near station 17. Unit #1 encompasses ~35.8 acres of established shrub land and maritime forest as well as additional acreage of foredune grassland along the seaward edge.

Planning Unit #2 – Sand Dunes Club

Extends from 1715 Atlantic Avenue to the lighthouse property between station 18 and station 18½. Unit #2 encompasses ~18.6 acres of established vegetation and pathways, as well as additional acreage of foredune grassland along the seaward edge.

Planning Unit #3 – Sullivan's Island Elementary School

Includes three sub units:

Unit #3A extends from station 18½ to the western school boundary line;
Unit #3B extends along the school property; and
Unit #3C extends from the eastern school boundary line to station 22.

Unit #3 encompasses 10.1 acres of maritime forest and grassland with additional acreage of foredune grassland seaward of the established shrub line.

Planning Unit #4 – Bayonne Avenue

Extends from station 22½ to station 29. Unit #4 encompasses 63.9 acres of established vegetation, 50 percent of which is manipulated shrubland. It includes additional acreage of foredune grassland along its seaward edge which is not included in the acreage totals.

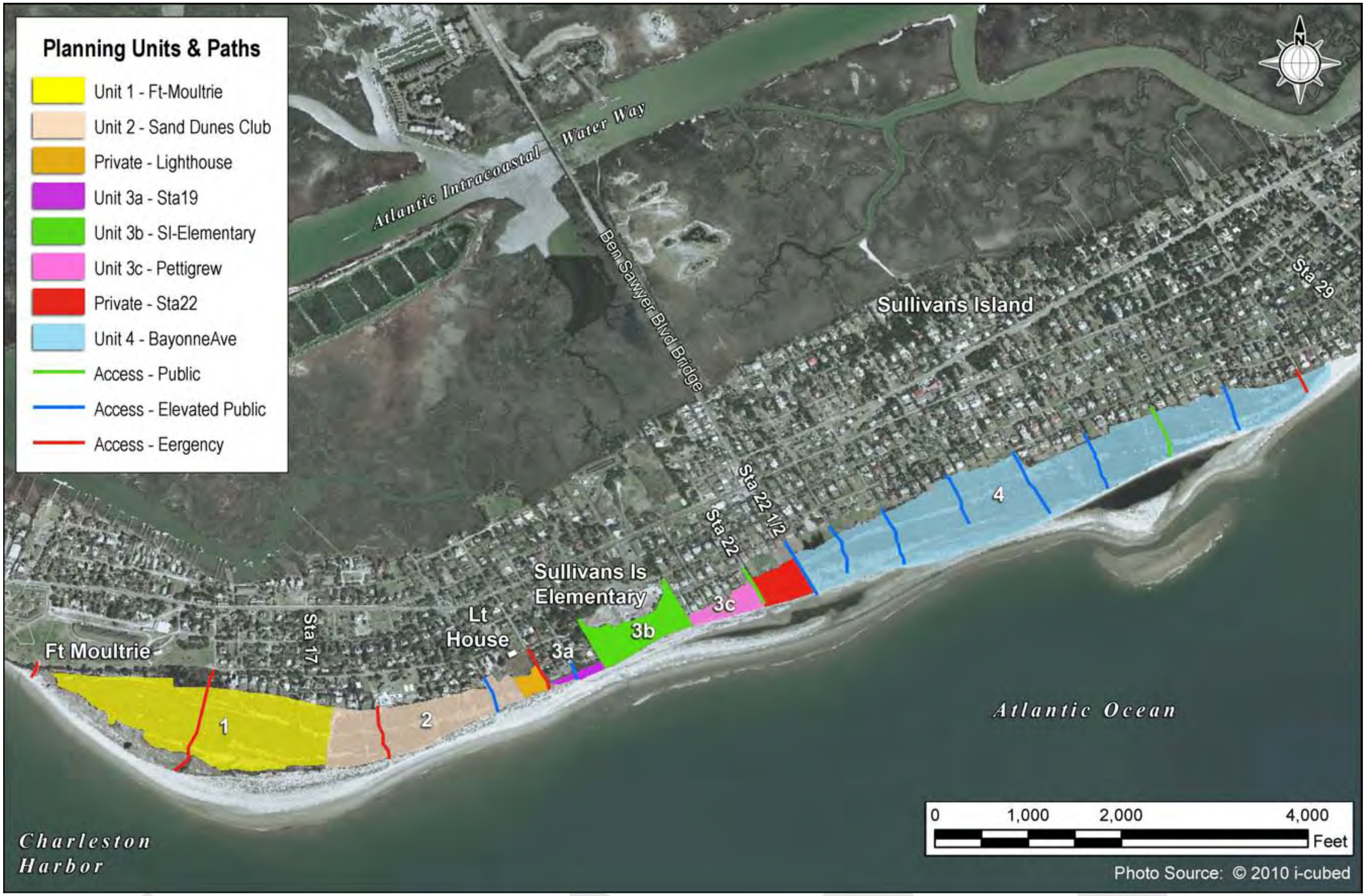


FIGURE 7.1. Four planning units as delineated within the AL. Grasslands immediately seaward of each colored boundary are an integral part of each unit, but are excluded in the area calculations and target area percentages because of uncertainties in the grassland boundary. Image is from March 2008.

The land areas of planning units 1–4 are computed for the conditions of March 2008 which coincide with the most recent controlled vertical aerial photograph. The seaward edge was delineated along the seaward shrub line which tends to be distinct on the image. This underestimates the total acreage within the AL because it excludes the seaward maritime grassland areas. However, by using the seaward shrub line as it exists in a recent year, areas can be reproduced more consistently by other investigators. The seaward grassland areas lack distinct seaward boundaries and fluctuate as the beach changes. As of March 2008, the AL encompassed 135.6 acres landward of the distinct shrub line along the ocean side of the tract. This area serves as the reference total acreage in subsequent percentage determinations. There were an additional ~34.5 acres of foredune grasslands and incipient dunes along the seaward edge of the AL in March 2008.

Table 7.1 summarizes the planning unit areas and vegetation zonation areas by habitat for conditions in March 2008 to January 2009 (ie – period of imagery and field data collection). The planning units are illustrated in Figure 7.1.

7.2 Fire, Beach Access Pathways, and Buffer Areas

While the risk of wildfire within the accreted area is fairly low, measures should be taken to limit the spread of accidental fire within the AL and protect adjacent properties should a wildfire occur. A common and effective method for limiting the spread of wildfire is the use of firebreaks. Within the accreted area, beach-access pathways and an inland buffer will serve the purpose.

This study identified three types of beach-access pathways: natural, elevated, and emergency (Fig 7.2). Natural, beach-access pathways should be maintained as bare sand, or with low-growing herbaceous vegetation, with a minimum width of 15 ft. Elevated pathways are those that have wooden board walks. To protect the boardwalks and stop fire from crossing the path, 8 ft to either side of elevated access pathways should be bare sand or low-growing herbaceous vegetation. Emergency access pathways are designed to permit access by emergency vehicles and should be maintained with a minimum width of 50 ft. Maintenance of all pathways involves periodic bush-hogging (to maintain low herbaceous vegetation) and trimming of bordering trees and shrubs.

Tables 7.1. Vegetation community areas by planning unit within the Sullivan's Island AL measured to the seaward shrub line, based on conditions of March 2008 to January 2009 (period encompassing most recent vertical aerial images and ground-truth field data collection for the present report).

Vegetation Community Areas By Planning Unit								
Vegetation Community	Unit 1 *Fort Moultrie*	Unit 2 *Sand Dunes Club*	Private *Lighthouse*	Unit 3a *STA 19*	Unit 3b *SI Elementary*	Unit 3c *Pettigrew*	Private *STA 22*	Unit 4 *Bayonne Avenue*
Total Zone Area - Excluding Foredune Grassland (sq ft)	*1,558,503*	*811,523*	*56,842*	*37,232*	*345,096*	*142,570*	*171,739*	*2,782,320*
Total Zone Area (acres)	***35.77***	***18.63***	***1.30***	***0.86***	***7.93***	***3.27***	***3.92***	***63.87***
EARLY SUCCESSIONAL MARITIME FOREST	20.55	2.42	0.54		5.13			
MANIPULATED MARITIME BACKDUNE GRASSLAND		1.20						4.82
MANIPULATED MARITIME SHRUBLAND		5.33				0.51		32.41
MARITIME BACKDUNE GRASSLAND	3.87	1.67	0.40	0.64	2.00	2.33	3.05	9.49
MARITIME FOREDUNE GRASSLAND	1.59	2.19	0.36	0.22	0.48	0.43	0.33	3.71
MARITIME HARDWOOD DEPRESSION		3.43						1.01
MARITIME INTERDUNAL WETLAND	3.75						0.40	8.00
MARITIME SHRUBLAND	5.50	1.00			0.32			3.21
PATHWAYS & LAWNS	0.51	1.39					0.14	1.22

Vegetation Community Area Percentages By Planning Unit								
Vegetation Community	Unit 1 *Fort Moultrie*	Unit 2 *Sand Dunes Club*	Private *Lighthouse*	Unit 3a *STA 19*	Unit 3b *SI Elementary*	Unit 3c *Pettigrew*	Private *STA 22*	Unit 4 *Bayonne Avenue*
EARLY SUCCESSIONAL MARITIME FOREST	57.5%	13.0%	41.5%		64.7%			
MANIPULATED MARITIME BACKDUNE GRASSLAND		6.4%						7.5%
MANIPULATED MARITIME SHRUBLAND		28.6%				15.6%		50.7%
MARITIME BACKDUNE GRASSLAND	10.8%	9.0%	30.8%	74.4%	25.2%	71.3%	77.8%	14.9%
MARITIME FOREDUNE GRASSLAND	4.4%	11.8%	27.7%	25.6%	6.1%	13.1%	8.4%	5.8%
MARITIME HARDWOOD DEPRESSION		18.4%						1.6%
MARITIME INTERDUNAL WETLAND	10.5%						10.2%	12.5%
MARITIME SHRUBLAND	15.4%	5.4%			4.0%			5.0%
PATHWAYS & LAWNS	1.4%	7.5%					3.6%	1.9%

A 32-foot buffer should be created along the inland property line of the accreted area. This buffer will serve as a firebreak between developed properties and the AL as well as improve view corridors, reduce the nuisance rodent population, and improve habitat diversity. The buffer should be cleared of trees and shrubs and subdivided into four 8-ft-wide strips. The inland-most strip should be disked annually to maintain a high proportion of exposed mineral soil and low herbaceous vegetation. The three remaining 8-ft strips should be rotationally disked such that only one strip is disked each year and each strip is disked once every three years. Disking should occur in late winter/early spring.

A portion of the Bayonne Unit within the buffer is currently being maintained by adjacent landowners as lawn, specifically, between stations 22 and 24 (Fig 7.3). In these areas, lawns will suffice in place of the buffer, as long as the 32-ft width is maintained.

FIGURE 7.2.

Examples of the three types of beach-access pathways in the AL:

(Upper) Natural
(Center) Elevated
(Lower) Emergency

The ALMP calls for wider pathways incorporating low-growing, herbaceous vegetation along the edges.

Natural beach-access pathways should be maintained with a minimum width of 15 ft.

Elevated pathways should maintain a minimum of 8 ft of bare sand or low-growing, herbaceous vegetation to either side.

Emergency pathways should be maintained with a minimum width of 50 ft.

FIGURE 7.3. Managed lawns by property owners along portions of the Bayonne Avenue unit provide a buffer zone and fire break between development and the natural vegetation of the AL.

7.3 Rodents

As discussed in Section 3.5, landowners adjacent to the AL have observed an increase in the rat population in recent years. The dense thickets of shrub vegetation and root systems that are created by existing pruning practices increase suitable habitat and protection for Norway and black rats. The most effective means of reducing the rat population is to reduce habitat availability. The management recommendations for the Sand Dunes and Bayonne units detailed herein will significantly reduce suitable habitat and increase exposure, making it easier for predators to control the population. Additionally, the creation of the buffer will further separate the adjacent properties from habitat within the AL area that would support Norway and black rats.

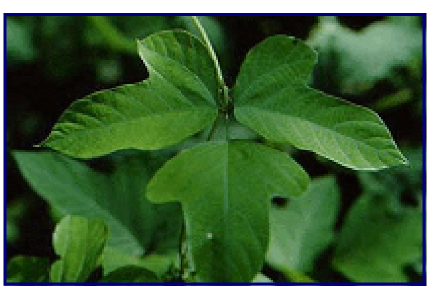
7.4 Invasive Species

Vegetation surveys of the AL identified a number of invasive exotic species occurring within the area, including Chinese tallow, wisteria, Chinese privet and others (Fig 7.4). These species impair ecological function and diminish the natural beauty of the AL. Every effort should be made to eradicate these species from the landscape. Appendix 5 contains a detailed description of invasive species and recommended methods of control.


ALLIGATOR WEED

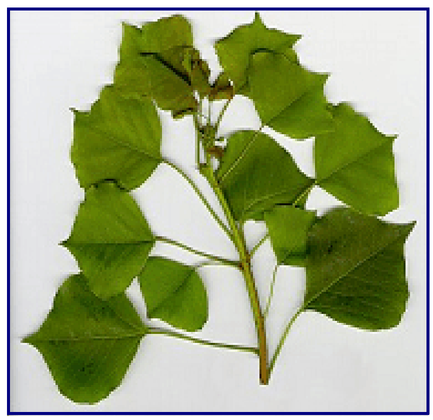

CHINESE PRIVET


COMMON REED


KUDZU


KUDZU PATCH


SESBANIA


CHINESE TALLOW


WISTERIA

FIGURE 7.4. Examples of invasive species in the AL which are recommended for eradication under the ALMP.

7.5 Wetland Protection and Regulatory Authorities

The greatest threats to wetlands within the AL would exist during land clearing and vegetation control within planning units #2 and #4. The use of mechanized land-clearing equipment will disturb wetland vegetation and soils, and requires a permit from USACE. Prior to any mechanized land clearing, the wetlands within the AL should be delineated by a qualified wetland consultant and verified by USACE, followed by a permit from USACE. No permit is required for hand clearing vegetation; however, care should be taken to minimize disturbance (heavy foot traffic) to wetland soils and vegetation by performing these activities when the wetlands are as dry as possible. Herbicides in and around wetlands should be used with caution, as chemicals may travel farther than anticipated when mixed with standing water. Ideally, boardwalks should be constructed where footpaths cross wetlands. If this is not possible, then footpaths should cross wetlands at their narrow points to minimize impact.

Some management practices recommended in the ALMP may be subject to federal or state regulation depending on the type and location of activity. Several agencies have jurisdiction within portions of the AL.

SCDHEC–OCRM – The Office of Ocean and Coastal Resource Management (OCRM), a division of SC Department of Health and Environmental Control (SCDHEC) is responsible for the management and protection of South Carolina beaches and oceanfront. OCRM designates a baseline and setback line for the entire South Carolina coast (see Figure 1.5 for the baseline and setback line of the accreted area). All construction and land-clearing seaward of the setback line may require a permit from OCRM. Additionally, OCRM requires a permit for construction or mechanized land-clearing within wetlands. (See Appendix 4 for wetland definition.)

USACE and EPA – The US Army Corps of Engineers along with the Environmental Protection Agency (EPA) has regulatory authority over wetlands in the United States, granted by Section 404 of the Clean Water Act. If wetlands are impacted through the deposition of fill material or by mechanical land-clearing, federal law requires a permit from USACE before the activity may begin. The permitting process can be lengthy, requiring 6 months to 1 year depending on the circumstances. Appendix 4 provides additional information regarding wetland identification and the permitting process.

USFWS and NMFS – The Endangered Species Act charges the US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) with the protection of federally threatened and endangered species. Threatened or endangered species that are most likely to occur within the AL include piping plovers, loggerhead sea turtles, and seabeach amaranth. See Section 1.4 of this document for more detail on the Endangered Species Act and for a complete list of threatened or endangered species known to occur in Charleston County that may also occur within the accreted area. Appendix 3 contains detailed information on threatened and endangered species known to occur in Charleston County.

The town of Sullivan's Island should consult USFWS and NMFS before beginning any activity within the AL to avoid any adverse impact to threatened or endangered species that may occur. Additionally, all federal permits require consultation with USFWS, NMFS, and SCDNR, including permits issued by USACE and EPA.

7.6 Planning Units

The four planning units and private tracts of the Sullivan's Island AL encompass 135.6 acres landward of the ocean-side shrub line, of which 35.8 acres (26.4 percent) are situated within the Fort Moultrie unit and 63.9 acres (47.1 percent) are situated within the Bayonne Avenue unit. Unit #2 (Sand Dunes Club) and Unit #3B (Sullivan's Island Elementary School) contain most of the remaining area of the AL (26.6 acres, 19.6 percent). Remaining Unit #3A (station 19) and Unit #3C (Pettigrew) encompass 4.1 acres (3 percent). The lighthouse tract (private) separates Units #2 and #3A, and encompasses 1.3 acres (1 percent) of the AL. Six lots with special deeds to mean high water between stations 22 and 22½ (private) separate Units #3C and #4, and encompass 3.9 acres (3 percent) of the AL. The private lands are **not** part of the ALMP.

Following are summary management strategies and target land cover for each planning unit. The basic strategies are principally either passive natural succession (eg – planning unit #1) or a mix of vegetation manipulation intensities (eg – planning unit #4). In the case of passive natural succession, the expectation is that maritime forest vegetation will ultimately dominate the landscape. As with any forest, some management is advantageous so as to improve the health and diversity of tree species. Such activities as pruning and thinning are accepted and proven management tools for healthy forests. For units where the recommended strategy involves more intensive vegetation manipulation, including conversion of some existing shrubland to grassland, natural examples (Fig 7.5) provide guidance regarding the desired character of the landscape under the ALMP. The examples in Figure 7.5 are taken from nearby barrier islands.

FIGURE 7.5.

Example aerial photographs of mixed maritime grassland and shrubland on nearby, South Carolina barrier islands which serve as a guide for the desired character of the Sullivan's Island AL under the ALMP.

The portion encircled on each image is an example of a naturally occurring vegetation complex similar to the desired outcome for the Sand Dunes and Bayonne units of the AL.

Dark green vegetation is similar in composition to the maritime shrubland found on Sullivan's Island.

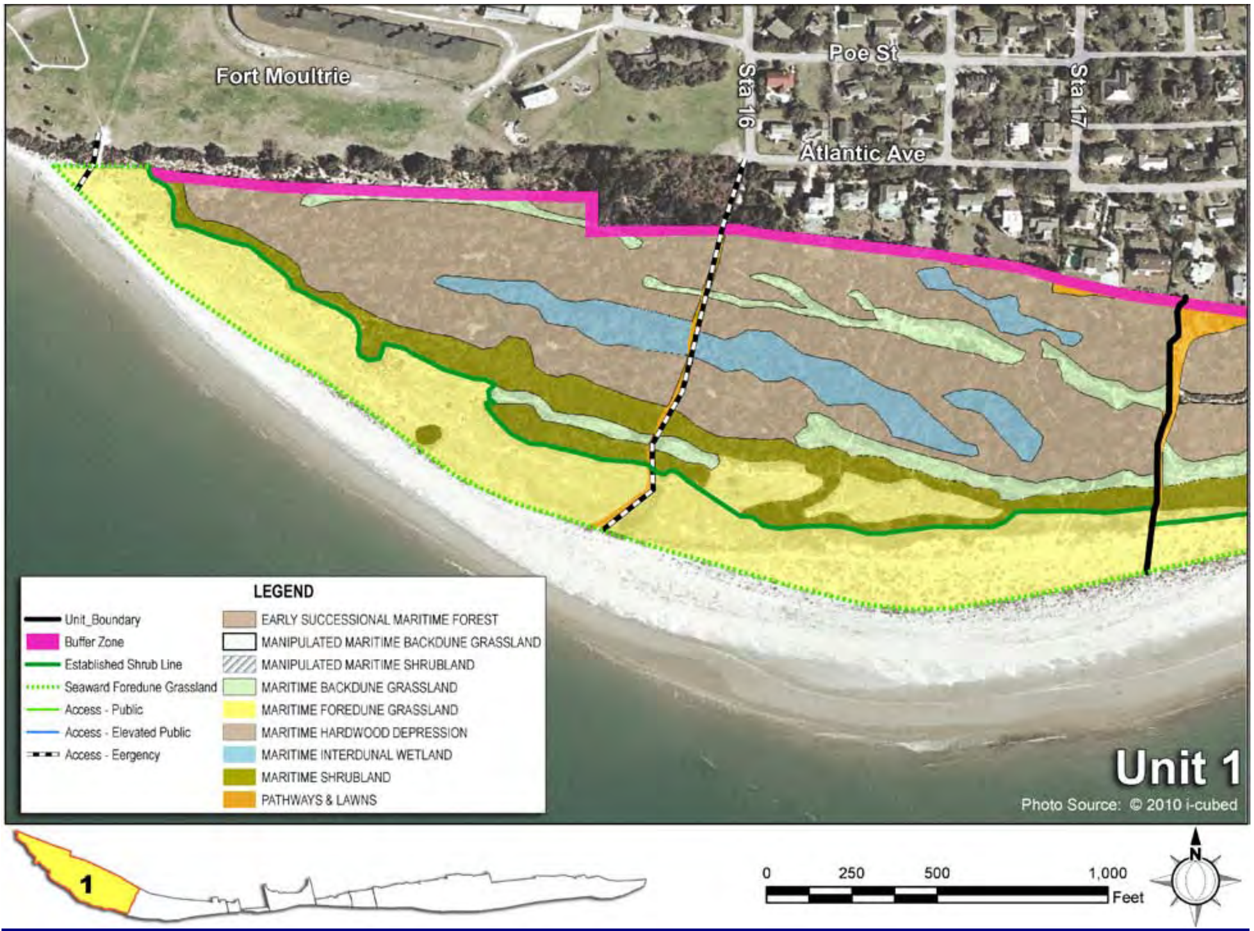
Gray-brown vegetation is similar in composition to the maritime foredune grassland found on Sullivan's Island.

(Upper)
Capers Island (southern end)

(Center)
Bulls Island (central portion)

(Lower)
Dewees Island (southern end).

Planning Unit #1 – Fort Moultrie

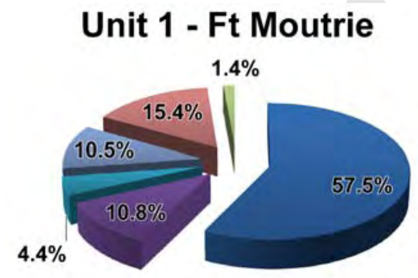


Location – The Fort Moultrie planning unit extends from the westernmost tip of the property, located southwest of Fort Moultrie, to the private pathway maintained by the adjoining residence identified as 1715 Atlantic Avenue.

Preferred Strategy – Being the oldest and least disturbed portion of the AL, the Fort Moultrie unit supports the most developed vegetation communities (see Section 3.3). Building upon the natural character of this unit, active management of the vegetation should be minimized to allow natural successional processes to drive the development of vegetation over time. Vegetation manipulation of the unit should be limited to exotic species' control and beach-access pathway maintenance. Please refer to Appendix 5 for information on exotic species management.

As detailed in Section 5.4, the most dramatic changes that are likely to occur within the Fort Moultrie unit due to natural successional processes will occur within the early successional maritime forest. While this portion of the AL is the oldest, the maritime forest that exists on the inland portion of the unit is fairly young. Change within the maritime forest will be slow, measured in tens if not hundreds of years.

Current Land Cover	
Early Successional Maritime Forest	57.5%
Maritime Backdune Grassland	10.8%
Maritime Foredune Grassland	4.4%
Maritime Interdunal Wetland	10.5%
Maritime Shrubland	15.4%
Pathways and Lawns	1.4%



Target Land Cover

None

Natural Succession

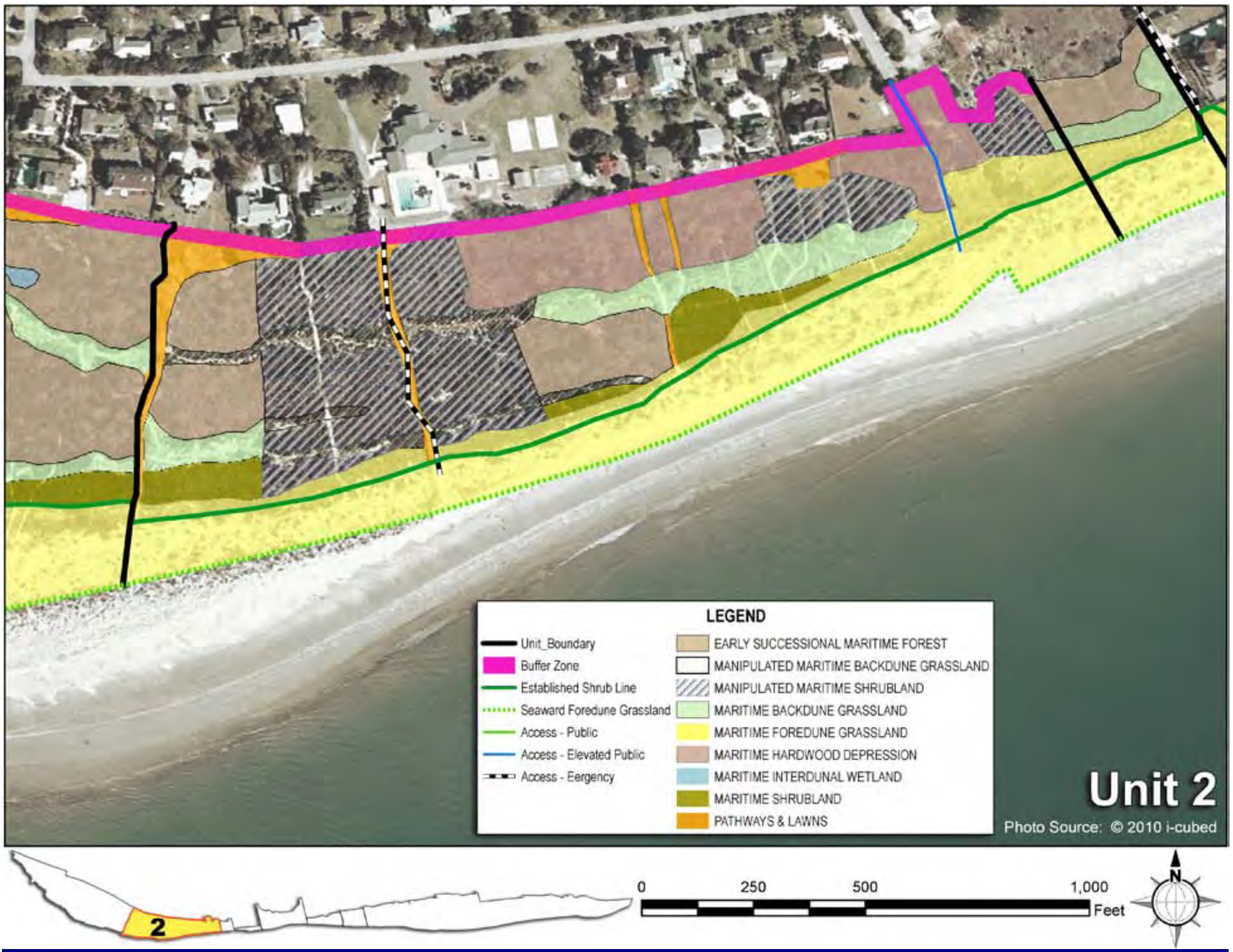
Rationale – As discussed in Section 5.6, if left alone, it is likely that the AL within the Fort Moultrie unit will remain stable with some continued accretion over the next 40 years, though the rate of accretion is dependent on rates of sand deposition, erosion, and sea-level rise. Continued accretion will result in the seaward vegetation moving outward with the shoreline. The bands of seaward vegetation, including maritime grasslands and shrublands, will move outward but will remain roughly the same size and configuration as they are today. As the coastline moves seaward, the protected inland vegetation community (maritime forest) will overtake areas previously supporting grasslands and shrublands as these communities move seaward and will increase in size relative to the other communities occurring within the Fort Moultrie unit (see Section 5.6).

The passive approach to management that is recommended for the Fort Moultrie unit precludes the use of land-cover targets, because land cover will be driven by natural processes (accretion, wind, salt spray, etc). Vegetation communities should be left alone to evolve with time and the changing shoreline.

Beach Access – The Fort Moultrie unit contains two emergency access pathways.

Other – Should the Town desire to build a nature center within the accreted area, it would be appropriate to do so within the Fort Moultrie unit. A logical location for this site would be on the west side of the entrance to the emergency access pathway at the end of station 16. There is a large patch of exotic wisteria that could be cleared in this area.

Planning Unit #2 – Sand Dunes Club



Location

The Sand Dunes Club unit extends from the private pathway maintained by the private residence identified as 1715 Atlantic Avenue to the western border of the lighthouse property owned by the US Coast Guard, which is located at 1815 I'on Avenue.

Preferred Strategy

The management strategy for the Sand Dunes Club unit should consist of a mix of vegetation manipulation intensities with the end result being conversion to and maintenance of a maritime grassland vegetation community punctuated by scattered maritime shrubland hammocks within the existing manipulated maritime shrubland and manipulated maritime backdune grassland communities. Converted maritime grassland communities should have a species composition similar to that of the naturally occurring maritime foredune grassland and maritime backdune grassland communities (see Section 3.3). Shrub hammocks should contain vegetation composition similar to naturally occurring maritime shrubland. The western and eastern portions of the Sand Dunes Club unit should serve as a transitional zone between the natural vegetation of the Fort Moultrie and School units and the maintained grassland community within the bulk of the Sand Dunes Club unit. The objective for this transition area is to avoid the appearance of an abrupt wall of vegetation between the planning units. To maintain vegetation community diversity, the existing maritime hardwood depression vegetation community should be conserved to the extent possible.

A cost-effective method for achieving the above-stated management objectives is to employ the use of hand labor. Trees/shrubs that are to be to retained should be marked with paint or flagging tape, and unwanted shrub vegetation should be removed by hand. Shrubs should be cut at ground level and removed. The stumps should be treated with herbicide (Roundup® or a similar glyphosate-based product) to prevent resprouting. Vegetative debris should be removed from the site. The use of a portable chipper may reduce hauling expense.

Mechanized equipment (such as Gyro-Tracs©, Hydro-axes, or similar) (Fig 7.6) are equipped with chipping heads designed to quickly clear unwanted vegetation. While the use of this equipment will be faster and possibly less expensive, the noisy, invasive nature of the equipment may disturb some neighboring residents as well as the public. Additionally, this method would result in a layer of wood chips and other debris scattered across the ground. This debris may inhibit the migration of grassland vegetation into the area, which requires contact with mineral soil to take root. This problem may be mitigated by following the chipping with a light disking of the entire area to expose mineral soil. Stumps should still be treated with herbicide to prevent resprouting.




FIGURE 7.6. Mechanical equipment such as Gyro-Tracs®, Hydro-axes, and similar equipment would facilitate clearing of unwanted vegetation in the AL at possibly lower cost, but they are noisy and invasive.

Ideally, the maritime grassland community surrounding the shrub hammocks will develop naturally. A local seed source exists within the adjacent maritime foredune grassland and maritime backdune grassland communities. Prevailing winds, birds, and other animals will transport seeds into the area. The forces which drive the community composition of the natural grassland communities (ie – wind, salt spray, burial, heat, moisture, etc) should act on the newly opened areas, resulting in a similar grassland community. However, succession and vegetation community development is a dynamic process and is influenced by many factors.

Because this portion of the Sand Dunes Club unit is farther from the shoreline than the majority of the grassland communities, natural forces that drive the development of those grassland communities will be slightly different, which may result in a completely different community than the one desired. Additionally, vegetation from the adjacent inland properties will be supplying a completely different seed source (ie – lawns and gardens) than the maritime grassland. This will likely influence vegetation development to some degree as well.

Due to the complexity of predicting the vegetation that will result naturally within the managed portions of the Sand Dunes Club unit, it is best to adapt management as conditions evolve. Periodic disturbance may be necessary to keep the development of a shrub community in check. Examples of periodic disturbance include disking, herbicide application, and fire. Unwanted species may migrate from adjacent lawns and gardens. If so, herbicide may be employed to combat the spread of these species. Vegetation manipulation should include exotic species control and beach-access pathway maintenance as well. Please refer to Appendix 5 for information on exotic species management. Note the extent to which the Sand Dunes Club unit falls seaward of the OCRM setback line (see Fig 1.5). Permits may be required from OCRM to clear vegetation seaward of the setback line. Mechanized clearing within wetlands will require permits from USACE and OCRM.

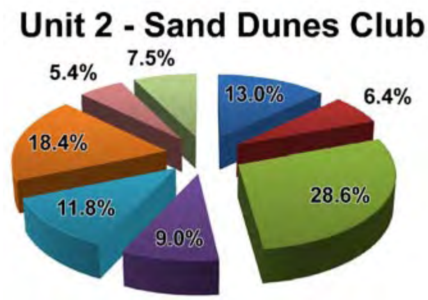
Current Land Cover

Early Successional Maritime Forest	13.0%
Manipulated Maritime Backdune Grassland	6.4%
Manipulated Maritime Shrubland	28.6%
Maritime Backdune Grassland	9.0%
Maritime Foredune Grassland	11.8%
Maritime Hardwood Depression	18.4%
Maritime Shrubland	5.4%
Pathways and Lawns	7.5%

Target Land Cover

Maritime Foredune and Backdune Grassland – 50%

Maritime Shrubland – 50%



Rationale

The Sand Dunes Club unit should consist of maritime grassland punctuated by scattered maritime shrubland islands. Approximately 50 percent of the total land cover within the Sand Dunes Club unit should be composed of maritime shrubland community, surrounded by a natural mix of maritime foredune and maritime backdune grasslands. The proportion of shrubland to grassland should increase with distance from the sea and with proximity to the Fort Moultrie and School units. Shrubland islands may vary in size and shape from single shrubs/trees to ¼ acre contiguous hammocks of random shape and may be designed such that views of the ocean are maintained from inland observation points. Ocean views may be increased by placing shrubland islands within low dune swales. Over time, larger shrubland islands may begin to develop vegetation community characteristics similar to maritime forest. This development will result in greater habitat diversity, and dispersion and should not be discouraged. Naturally occurring examples of this mix of vegetation communities can be found on neighboring Dewees Island, Capers Island, and Bulls Island.

As discussed in Section 5.6, it is likely that land within the Sand Dunes Club unit will continue to accrete over the next 40 years, though this is dependent on rates of sand deposition, erosion, and sea-level rise. Continued accretion will result in seaward expansion of vegetation. The proportion of shrubland to grassland should be maintained with this expansion. Existing maritime hardwood depression communities within the Sand Dunes Club unit should be preserved to maximize habitat diversity.

Beach Access

The Sand Dunes Club unit contains two emergency access pathways and two elevated access pathways.

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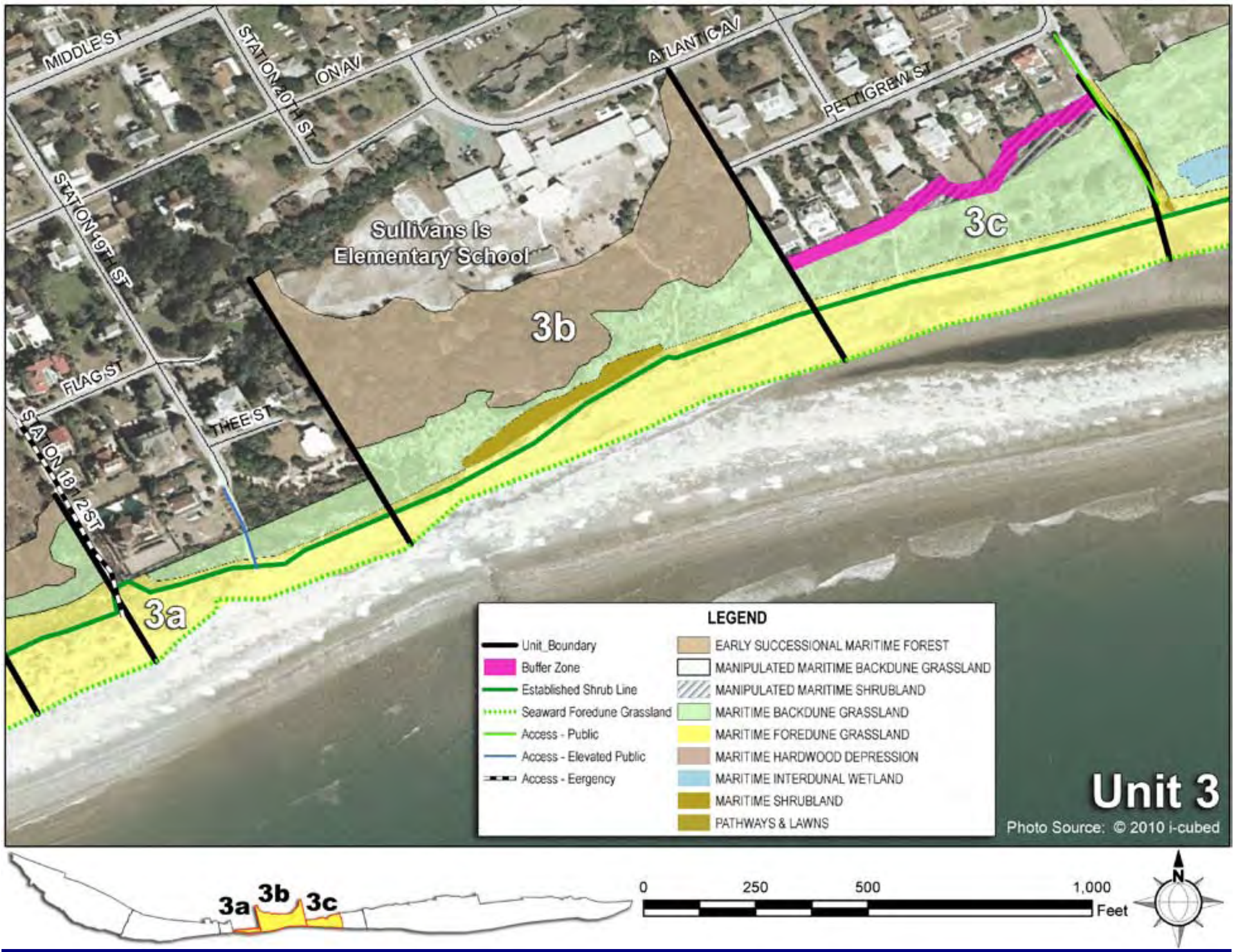
Planning Unit #3 – Sullivan’s Island Elementary School



Location

The School unit comprises the AL owned by the Sullivan’s Island Elementary School located at 2015 I'on Avenue.

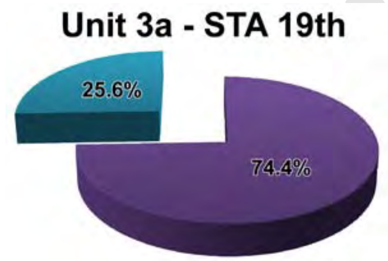
Preferred Strategy

The recommended management strategy for the School unit is to conserve the existing vegetation and allow natural successional processes to drive the development of vegetation over time. Vegetation manipulation of the unit should be limited to exotic species control and beach-access pathway maintenance. Please refer to Appendix 5 for information on exotic species management.

As detailed in Section 5.4, the most dramatic changes that are likely to occur within the School unit will be within the early successional maritime forest. The maritime forest that exists on the inland portion of the unit is fairly young. However, change will be slow, measured in tens if not hundreds of years.

Current Land Cover

Maritime Backdune Grassland	74.4%
Maritime Foredune Grassland	25.6%



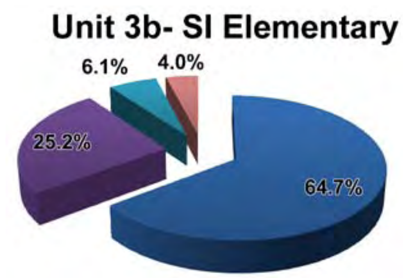
Target Land Cover

None

Natural Succession

Current Land Cover

Early Successional Maritime Forest	64.7%
Maritime Backdune Grassland	25.2%
Maritime Foredune Grassland	6.1%
Maritime Shrubland	4.0%



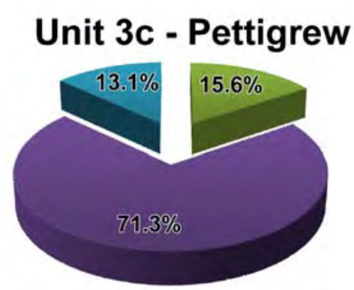
Target Land Cover

None

Natural Succession

Current Land Cover

Manipulated Maritime Shrubland	15.6%
Maritime Backdune Grassland	71.3%
Maritime Foredune Grassland	13.1%



Target Land Cover

None

Natural Succession

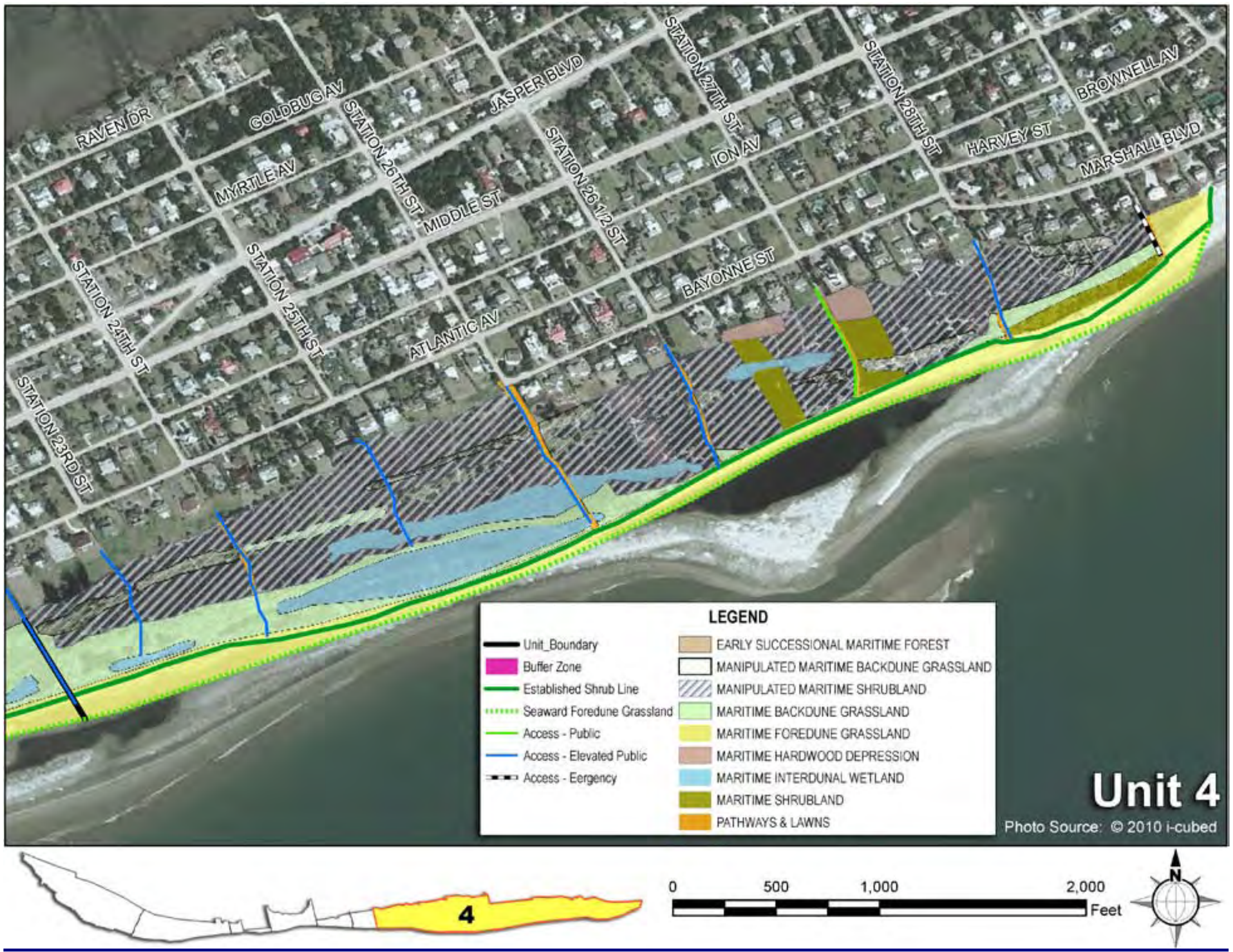
Rationale

As discussed in Section 5.6, it is likely that the AL within the School unit will remain fairly stable with some continued accretion over the next 40 years, though this is dependent on rates of sand deposition, erosion, and sea-level rise. Continued accretion will result in an increase in maritime forest cover relative to the other communities occurring within the School unit (see Section 5.6). The passive approach to management of this unit precludes the use of land cover targets. Vegetation communities should be left alone to evolve with time and the changing shoreline.

Beach Access

The School unit contains no public-access pathways.

Planning Unit #4 – Bayonne Avenue



Location

The Bayonne Avenue unit extends from the elevated, public-access pathway at station 22½ to the easternmost point of the AL at station 29.

Preferred Strategy

The management strategy for the Bayonne Avenue unit should consist of a mix of vegetation manipulation intensities. The management goal for this unit is conversion to and maintenance of a maritime grassland vegetation community punctuated by scattered maritime shrubland hammocks within the existing manipulated maritime shrubland and manipulated maritime backdune grassland communities. Maritime grassland communities should have a species composition similar to that of the naturally occurring maritime foredune grassland and maritime backdune grassland communities (see Section 3.3). Shrub hammocks should contain vegetation composition similar to naturally occurring maritime shrubland (see Section 3.3). The western portion of the Bayonne Avenue unit should serve as a transitional zone between the natural vegetation of the School unit and the maintained grassland community within the bulk of the Bayonne Avenue unit. To maintain vegetation community diversity, the maritime hardwood depression vegetation community should be conserved to the extent possible.

A cost-effective method for achieving the above-stated management objectives is to employ the use of hand labor. Trees/shrubs that are to be to retained should be marked with paint or flagging tape, and unwanted shrub vegetation should be removed by hand. Shrubs should be cut at ground level and removed. The stumps should be treated with herbicide (Round-up® or a similar glyphosate-based product) to prevent resprouting. Vegetative debris should be removed from the site. The use of a portable chipper may reduce hauling expense.

Mechanized equipment (such as Gyro-Tracs©, Hydro-axes, or similar) are equipped with chipping heads designed to quickly clear unwanted vegetation. While the use of this equipment will be faster and possibly less expensive, the noisy, invasive nature of the equipment may disturb some neighboring residents as well as the public. Additionally, this method would result in a layer of wood chips and other debris scattered across the ground. This debris may inhibit the migration of grassland vegetation into the area, which require contact with mineral soil to take root. This problem may be mitigated by following the chipping with a light disking of the entire area to expose mineral soil. Stumps should still be treated with herbicide to prevent resprouting.

Ideally, the maritime grassland community surrounding the shrub hammocks will develop naturally. A local seed source exists within the maritime foredune grassland and maritime back dune grassland communities. Prevailing winds, birds, and animals will transport seeds into the area. The forces which drive the community composition of the natural grassland communities (ie – wind, salt spray, burial, heat, moisture, etc) should act on the newly opened areas, resulting in a similar grassland community. However, succession and vegetation community development is a dynamic process and is influenced by many factors.

Because this portion of the Bayonne Avenue unit is farther from the shoreline than the majority of the grassland communities, natural forces that drive the development of those grassland communities will be slightly different and may result in a completely different community than the one desired. Additionally, vegetation from the adjacent inland properties will be supplying a completely different seed source (ie – lawns and gardens) than the maritime grassland. This will likely influence development to some degree as well.

Due to the complexity of predicting the vegetation that will result naturally within the managed portions of the Bayonne Avenue unit, it is best to adapt management as conditions evolve. Periodic disturbance may be necessary to keep the development of a shrub community in check. Examples of periodic disturbance include disking, herbicide application, and fire. Unwanted species may migrate from adjacent lawns and gardens. If so, herbicide may be employed to combat the spread of these species.

Vegetation manipulation should include exotic species control and beach-access pathway maintenance. Please refer to Appendix 5 for information on exotic species management. Note the extent to which the Bayonne Avenue unit falls below the OCRM setback line (see map). Permits may be required from OCRM to clear vegetation below the setback line. Mechanized clearing within wetlands will require permits from USACE and OCRM.

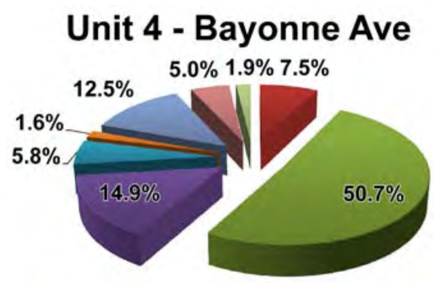
Current Land Cover

Manipulated Maritime Backdune Grassland	7.5%
Manipulated Maritime Shrubland	50.7%
Maritime Backdune Grassland	14.9%
Maritime Foredune Grassland	5.8%
Maritime Hardwood Depression	1.6%
Maritime Interdunal Wetland	12.5%
Maritime Shrubland	5.0%
Pathways and Lawns	1.9%

Target Land Cover

Maritime Foredune and Backdune Grassland – 50%

Maritime Shrubland – 50%



Rationale

The Bayonne Avenue unit should consist of maritime grassland punctuated by scattered, maritime shrubland islands. Approximately 50 percent of the total land cover within the Bayonne Avenue unit should be composed of maritime shrubland community, surrounded by a natural mix of maritime foredune and maritime back dune grasslands. The proportion of shrubland to grassland should increase with distance from the sea and with proximity to the School unit. Shrubland islands may vary in size and shape from single shrubs/trees to ¼-acre contiguous hammocks of random shape and may be designed such that views of the ocean are maintained from inland observation points. Ocean views may be increased by placing shrubland islands within low dune swales. Over time, larger shrubland islands may begin to develop vegetation community characteristics similar to maritime forest. This development will result in greater habitat diversity and dispersion and should not be discouraged. Naturally occurring examples of this mix of vegetation communities can be found on neighboring Dewees, Capers, and Bulls Islands.

As discussed in Section 5.6, it is likely that land within the Bayonne Avenue unit will continue to accrete over the next 40 years, though this is dependent on rates of sand deposition, erosion, and sea-level rise. Continued accretion will result in the expansion of vegetation seaward. Proportion of shrubland to grassland should be maintained with this expansion. Existing maritime hardwood depression communities within the Bayonne Avenue unit should be preserved to maximize habitat diversity.

Beach Access

The Bayonne Avenue unit contains one emergency access path, eight elevated access pathways, and two natural public-access pathways.

7.7 Implementation Strategies

The ALMP provides a strategy and target vegetation mixes for four defined areas of Sullivan's Island. The specific plan and layout for managed vegetation is expected to require time for implementation as funds allow. The specific localities for future shrubland and grassland within Unit #2 and Unit #4 should be planned carefully so as to achieve the goals and objectives of the community.

Small areas within each unit may be used as test plots so as to evaluate the cost and maintenance requirements for larger scale efforts over time. Progress toward the target land cover should be monitored by periodic vegetation surveys with the aid of controlled vertical photography.

Adaptive Management

Given the range of vegetation management techniques available and the large number of plant species native to barrier islands, some adaptive management should be an integral part of future implementation strategies. The ALMP considers future changes under the plan to be an ongoing process. Techniques that are cost effective and result in desired outcomes will likely become favored over some other techniques. As long as there is accreted land, vegetation can be transformed where necessary to achieve target land cover or left to evolve naturally through successional processes.

Criteria for Success

Management of the AL will be a constantly evolving process. As conditions and goals change, management must adapt. To accomplish the goals set forth in the ALMP, there must be measurable criteria that determine success. Because the primary objectives of this management plan involve the manipulation of vegetation, success criteria will primarily relate to aspects of the vegetative cover within the planning units. Success criteria for each planning unit are detailed as follows.

> ***Planning Unit #1 – Fort Moultrie*** – Because there is very little vegetation manipulation planned for this unit, minimal monitoring is necessary. The primary management need for this unit is the removal of exotic plant species. It is sufficient to perform annual pedestrian surveys of the unit to assess the degree to which exotic species have invaded the unit. Should occupation of the site become problematic, corrective action should be taken. Most likely, this will involve herbicide application. Refer to Appendix 5 for more details on exotic species control.

Planning Unit #2 – Sand Dunes Club – Management within this unit includes the clearing of shrub vegetation and the establishment of maritime grassland. There will be two success criteria for this unit.

1) Target Vegetation Community Coverage – The goal for this unit is to retain 50 percent the land dominated by maritime shrubland vegetation community and 50 percent of the land dominated by maritime grassland community. Using controlled aerial photography purchased every three years, the percentage of area dominated by grassland and shrubland may be measured. This may be best accomplished using GIS software. Should the coverage of either community deviate from 50 percent by more than 10 percent, then action should be taken to return the communities to a 50/50 mix. This monitoring should be performed every three years.

2) Vegetation Community Composition – The vegetation composition and density of the grassland and shrubland vegetation communities within this unit should mimic, to the extent possible, the grassland and shrubland communities that exist naturally within the AL. Quantitative comparison of species composition between existing natural vegetation communities and the communities managed within the Sand Dunes Club unit should be performed annually. To simplify this comparison, percent cover of native vegetation should be compared between sample plots taken within the managed areas and the naturally occurring areas. Within the grassland communities, sample plots should be 1-m by 1-m quadrats for herbaceous vegetation and 4-m by 4-m quadrats for woody shrub vegetation. Total percent cover of each species found within the quadrats should be measured and averaged across all quadrats. Every year, five herbaceous and five woody quadrats should be randomly located and surveyed within both the natural and managed grassland and shrubland communities (ie – total of 20 quadrats) within the Sand Dunes Club unit.

A list of the plant species occurring within the natural communities should be maintained year after year. The base list may be the list compiled during the initial ALMP study, but this list should be amended as new species are discovered. At least 90 percent of the percent cover within the managed communities should be composed of species found on this list. Additionally, total percent cover within the managed communities should be within 10 percent of the naturally occurring communities during the same year of monitoring.

Planning Unit #3 – School Unit – Because there is very little vegetation manipulation planned for this unit, minimal monitoring is necessary. The primary management need for this unit is the removal of exotic plant species. It is sufficient to perform annual pedestrian survey of the unit to assess the degree to which exotic species have invaded the unit. Should occupation of the site become problematic, action should be taken. Most likely, this will involve herbicide application. Refer to Appendix 5 for more details on exotic species control.

Planning Unit 4 – Bayonne Avenue Unit – Management within this unit includes the clearing of shrub vegetation and the establishment of maritime grassland. There will be two success criteria for this unit.

1) Target Vegetation Community Coverage – The goal for this unit is to retain 50 percent the land dominated by maritime shrubland vegetation community and 50 percent of the land dominated by maritime grassland community. Using controlled aerial photography purchased every three years, the percentage of area dominated by grassland and shrubland may be measured. This may be best accomplished using GIS software. Should the coverage of either community deviate from 50 percent by more than 10 percent, then action should be taken to return the communities to a 50/50 mix. This monitoring should be performed every three years.

2) Vegetation Community Composition – The vegetation composition and density of the grassland and shrubland vegetation communities within this unit should mimic, to the extent possible, the grassland and shrubland communities that exist naturally within the AL. Quantitative comparison of species composition between existing natural vegetation communities and the communities managed within the Bayonne Avenue unit should be performed annually. To simplify this comparison, percent cover of native vegetation should be compared between sample plots taken within the managed areas and the naturally occurring areas. Within the grassland communities, sample plots should be 1-m by 1-m quadrats for herbaceous vegetation and 4-m by 4-m quadrats for woody shrub vegetation. Total percent cover of each species found within the quadrats should be measured and averaged across all quadrats. Every year, five herbaceous and five woody quadrats should be randomly located and surveyed within both the natural and managed grassland and shrubland communities (ie – total of 20 quadrats) within the Bayonne Avenue unit.

> A list of the plant species occurring within the natural communities should be maintained year after year. The base list may be the list compiled during the initial ALMP study, but this list should be amended as new species are discovered. At least 90 percent of the percent cover within the managed communities should be composed of species found on this list. Additionally, total percent cover within the managed communities should be within 10 percent of the naturally occurring communities during the same year of monitoring.

Measures of success will include the following:

- The degree to which a particular planning unit has reached its target land cover and overall goals.
- The degree to which invasive species, unwanted undergrowth, and nuisance habitat have been reduced or eliminated.
- The degree to which favored species or species diversity have increased within the AL.
- The degree to which pathways and buffer areas have been modified so as to achieve the criteria specified in the ALMP.
- The degree to which unplanned fires have been avoided.

Management of vegetation as recommended in the ALMP entails pruning and removal of debris along with mixing of soil and organic matter to promote new growth. This produces temporary visual impacts which are an integral part of the management process. Therefore, the timing of work within the AL should be designed to coincide with natural growing seasons so that the landscape resumes a natural character as quickly as possible. A key criteria in the plan is to limit the size of shrub hammocks to ~¼ acre in planning units #2 and #4, and intersperse areas of grasslands so as to avoid large expanses of one species such as waxed myrtle. Should monitoring reveal a failure to achieve these criteria, corrective action should be taken.

It is expected that the ALMP will be updated as experience is gained and lessons are learned. Like the AL landscape, a plan such as this should go through a succession of stages until it accomplishes its goals for the benefit of the community.

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ACKNOWLEDGMENTS

TO FOLLOW

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Timothy W. Kana, PhD PG – **CSE** – Project Manager and Principal Liaison – Senior Coastal Scientist – Responsible for project direction, scoping, liaison with Town officials, plan development, synthesis of historical data, and participation in community forums – 30 years of experience.

John B. "Bart" Sabine – **Sabine & Waters** – Registered Forester and Senior Environmental Scientist – Responsible for directing forest and wetland habitat studies and classifying existing land cover and forest management plan, participation in community forums – 30 years of experience.

Christopher J. Mack, PE – **Dewberry** – Coastal Engineer, Assistant Project Manager, and Local Liaison – Responsible for hurricane surge simulation modeling, community liaison, and participation in community forums – 16 years of experience.

John B. Sabine III – **Sabine & Waters** – Staff Ecologist – Responsible for delineation of critical area, wetlands habitat, and protected species survey – 6 years of experience.

Elena Drei-Horgan, PhD, CFM – **Dewberry** – Coastal Engineer, National Expert, Lead Modeler – Specializes in numerical modeling of storm surge, waves, and coastal hazard analysis for flood insurance studies – 16 years of experience.

John J. "Trey" Hair III – **CSE** – Senior CADD/GIS Technician – Responsible for final map production, ground photography, and file exchange among team members – 10 years of experience.

Diana R. Sangster – **CSE** – Senior Editorial and Administrative Associate – Responsible for report production, editing, and contract administration – 30 years of experience.

Kenneth J. Smoak – **Sabine & Waters** – Senior Ecologist – Responsible for preparing summary of wetland and forest ecology of the area and assisting with plans for forestry enhancement and conservation – 20 years of experience.

Matthew T. Zielke – **Sabine & Waters** – GIS Specialist – Responsible for preparing GIS-based habitat, wetlands and forest maps, and assisting with development of computer links for the draft plans – 7 years of experience.

Philip A. McKee – **CSE** – Senior Technical Associate – Responsible for ground truth topographic field data collection in the AL and adjacent beach zone via RTK-GPS (Trimble Model R8 GNSS) – 15 years of experience.

APPENDIX 1

Proposed Principles for Management of the Town's Accreted Land

Approved by Council on 15 December 2009

PROPOSED PRINCIPLES FOR MANAGEMENT OF THE TOWN'S ACCRETED LAND

December 15, 2009 version

1. The Town of Sullivan's Island owns the accreted land that is protected by the deed restrictions with the Lowcountry Open Land Trust. Every Town resident and property owner has a stake in the property, regardless of the location of that individual's residence or property.
2. The accreted land is protected for its aesthetic, scientific, educational, **and ecological** and safety value for all residents, as noted in the deed restrictions placed on this land with the Lowcountry Open Land Trust **and within the Town of Sullivan's Island Codes and Ordinances. It must be recognized that this land was placed in trust for the benefit of all Sullivan's Island residents.**
3. As its owner, the Town has responsibilities to be a *good steward* of the land and a *good neighbor* to the owners of properties that abut its land.

The Management Plan must benefit the long term maritime eco- system and its impact on wildlife and vegetation. The Town also recognizes that scenic views and breezes inside and outside the accreted land are valuable natural resources.

4. Steward responsibilities
    a. As its owner, the Town has responsibility for management of the land.
        i. Responsibility for designing and implementing a management plan rests with the Town.
        ii. Management plans should be based on their impact on the land as an environmental, educational and recreational resource.
        iii. The Management Plan must recognize this land is part of a bio-diverse ecological process and must consider the natural succession of vegetation in this setting. Additionally, the accreted land provides a line of defense over which hazards of storm waves can be diminished and therefore provides an important shore protection function.
        iv. Responsibility for funding the management of the land rests with the Town and management decisions must be independent of the sources of **funding**.
    b. Management or modification of the accreted land should be at the sole direction and discretion of the Town after soliciting input from all Town citizens and property owners and appropriately credentialed experts in relevant fields.

c. Since there is much diversity in the accreted land from one area to another **which can change over time**, defined zones or management units should be identified based upon their characteristics, and a long-term plan developed for each of them. As an example, the land from Station 16 westward and in front of Fort Moultrie, and that in front of the Town-owned school property, should be allowed to evolve naturally, with minimal intervention except for purposes of public safety, education, and control of invasive species.
d. Current laws governing the accreted land should remain in effect until the Town has **adopted, funded, and begun implementation of** the management plan to a substantial extent.

5. Neighbor responsibilities
   a. The Town should do what it can to respect the neighbors to the accreted land while meeting its stewardship responsibilities.
   b. The Town's management plan **may** include a transition or edge band that abuts privately held properties that would be managed differently from, and more aggressively than, the (usually much deeper) seaward balance of the accreted land.
      i. The transition/edge band should be managed to further the following objectives **where appropriate**:
         1. Provision of a buffer from unwanted wildlife
         2. Minimization of potential fire hazard
         3. Enhancement of public safety
         4. Enhancement of breezes
         5. Enhancement of possible sight lines to the property seaward of the band
      ii. Achievement of these objectives in the transition/edge band will be accomplished via different means depending on the characteristics of the accreted land including and seaward of the band. As examples:
         1. Where the band has characteristics of a developing maritime forest, the undergrowth might be cleared and smaller bushes and trees that compete with more significant trees might be removed.
         2. Where the seaward property is primarily myrtle fields, or currently cleared **within the Town's ordinances, or** partially cleared spaces, the band may be cleared or cut to provide an open field habitat, possibly with seeding of other grasses

and/or wildflowers, with periodic mowing **under the guidance of a landscape professional.**

3. Trees that are vanguard members of a maritime forest should be spared. Trees may be pruned when it is to benefit the health of the tree.
4. Harmful, non-native, invasive species of vines, bushes, shrubs or trees should be removed.

c. Public beach paths should be maintained based on the nature of the land they traverse, whether they are used for emergency access vehicles, and existing characteristics of the paths.

APPENDIX 2

Town of Sullivans Island
Deed Restrictions for
Certain Accreted Lands
Dated 12 February 1991

(as attached to the RFQ for the ALMP study)

STATE OF SOUTH CAROLINA)
) TITLE TO REAL ESTATE
COUNTY OF CHARLESTON)

WHEREAS, the Lowcountry Open Land Trust (the "Grantor") is a nonprofit corporation whose purpose is to preserve and conserve natural areas; and

WHEREAS, the Grantor is the owner in fee simple of certain real property (hereinafter referred to as the "Property" which has aesthetic, scientific, educational, and ecological value in its present state as a natural area which has not been subject to development or exploitation, which property is described more on the attached Exhibit A;

WHEREAS, the parties desire to place restrictions upon the Property for the purposes of, inter alia retaining land or water areas predominantly in their natural, scenic, open or wooded condition or as suitable habitat for fish, plants, or wildlife; and

WHEREAS, "natural, scientific, educational, aesthetic, scenic and recreational resource," as used herein shall, without limiting the generality of the terms, mean the condition of the Property at the time of this grant, evidenced by:

A) The appropriate survey maps from the United States Geological Survey, showing the property line and other contiguous or nearby protected areas;

B) An aerial photograph of the Property at an appropriate scale taken as close as possible to the date hereof; and

C) On-site photographs taken at appropriate locations on the Property;

and other documentation, which documentation shall be sufficient to establish the condition of the Property as of the date hereof which documentation shall be maintained in duplicate by both the Grantor and the Grantee hereof and made available to interested members of the public upon reasonable request for purposes of enforcing the restrictions contained herein.

KNOW ALL MEN BY THESE PRESENTS THAT the Lowcountry Open land Trust, a non-profit corporation, organized and existing under the laws of the State of South Carolina (the "Grantor"), in the state aforesaid in consideration of the sum of Ten and 00/100 ($10.00) Dollars, and other valuable consideration, to it in hand paid at and before the sealing of these presents by the Town of Sullivan's Island, South Carolina (the "Town"/"Grantee"), in the State aforesaid the receipt whereof is hereby acknowledged, have granted, bargained, sold and released and by these Presents do grant, bargain, sell and release unto the said the Town of Sullivan's Island, South Carolina, its successors and assigns, the following described property:

Attachment A
Deed Restrictions

FOR DESCRIPTION OF PROPERTY SEE EXHIBIT A ATTACHED HERETO AND INCORPORATED HEREIN BY REFERENCE (THE "PROPERTY").

This conveyance is made subject to the following terms, conditions, restrictions, and covenants (hereinafter the "Restrictions"):

1. Except as otherwise provided or permitted in Paragraphs 2 and 3 hereof, the Property shall remain in its natural state, no changes shall be made to its topography or vegetation and no structures or improvements shall be erected on the Property.

2. Notwithstanding the provisions of Paragraphs 1 and 3 and subject to the limitations of Paragraph 4, the Town Council is given the unrestricted authority to trim and control the growth of vegetation for the purposes of mosquito control, scenic enhancement, public and emergency access to the Atlantic Ocean and providing views of the ocean and beaches to its citizens.

3. Notwithstanding the provisions of Paragraph 1 hereof, and subject to the limitations of this Paragraph 3 and of Paragraphs 2 and 4, the Town Council of Sullivan's Island (the "Council") shall have the right to improve, change, modify or alter the Property only if such actions are to further or effect one or more of the following enumerated public objectives or policies ("Public Policies"):

a) Drainage
b) Mosquito control
c) Public walkways and emergency access to the Atlantic Ocean
d) Beach renourishment
e) Erosion control
f) Vegetation management
g) Educational programs
h) Public safety
i) Public health; and
j) Scenic enhancement

Prior to taking any action affecting the Property to further or effect a Public Policy ("Public Action"), the Council shall make specific written findings of fact;

1) that the proposed Public Action is proposed solely for the purpose of furthering or effecting one or more of the enumerated Public Policies,

2) that the proposed Public Action is necessary for the health, safety or general welfare of the Town,

3) that the benefits of the proposed Public Action outweigh the damage done to the aesthetic, ecological, scientific, or educational value of the Property in its natural state, and

4) that in making its findings of fact, the Council has given due and reasonable consideration to

i) the cumulative effect of the proposed Public Action and past Public Actions on the natural state of the Property,

ii) the alternative methods, if any, of furthering or effecting the proposed Public Policy which do not impact adversely on the natural state of the Property, and

iii) the probable results of not taking the proposed Public Action.

The above described written findings of fact must be made prior to each individual Public Action relating to the Property and shall be specific to the circumstances of the proposed Public Action and not merely conclusive in nature. In no event shall any Public Action violate the provisions of Paragraph 4 hereof.

4. In all events, the following activities, improvements and structures shall be prohibited on the Property:

a) any building or structure with a roof

b) Asphalt pavement, concrete pavement or pavement of a non-porous material

c) electrical power lines, wires, conduit, stations or pads

d) sewer lines, pipes or lift stations

e) water lines, pipes or lift stations

f) commercial activities in any way related to the buying or selling of things, goods or services.

Notwithstanding the provisions of Paragraph 4(c), (d) and (e) the Council may allow utility easements for electrical, sewer and water lines to cross through the Property, provided no utility services are provided as a result to any improvements on the Property.

5. These Restrictions may be enforced by the Town, any property owner within the Town, or by any voter registered within the Town. Such persons may seek any appropriate remedy for any violation, including, but not limited to, injunctive relief to force a termination of the violation or to permit restoration of the area damaged by an prohibited activity. The forbearance to

enforce the terms and provisions thereof in the event of a breach shall not be deemed a waiver of any rights granted hereunder. The Town shall not be liable to any person for any violation of these Restrictions by any person other than itself.

6. During the term of these restrictions, the Town shall cause to remain in effect an ordinance of the Town making it a violation of law for any person to violate the provisions of these Restrictions, as such Restrictions may be modified pursuant to Paragraph 8 hereof. The Town may enact ordinances and regulations affecting the Property which are more restrictive than these Restrictions or which are not inconsistent with these Restrictions.

7. If any provision of these Restrictions shall be invalid or for any reason become unenforceable, no other provision shall thereby be affected or impaired.

8. These Restrictions may be modified or repealed only upon an affirmative vote of both (a) seventy-five (75%) percent of the registered voters of the Town who vote in the referendum held pursuant to the terms hereof, and (b) one hundred (100%) percent of the members of Town Council. For purposes of these Restrictions, a registered voter in the Town shall mean any voter eligible to vote in Town elections who is registered 30 days prior to the referendum held pursuant to the terms hereof. At least 45 days prior to any referendum held pursuant to the terms hereof, the Council shall adapt reasonable regulations concerning the manner of voting hereunder. Nothing herein shall prohibit the Council from adopting regulations which allow voting by ballot on a designated day or days or by circulation of written petitions over a period of time.

9. These Restrictions shall remain in full force and effect for a period of 50 years and shall be automatically renewed and continued in effect for additional periods of 50 years each until such time as these Restrictions are repealed in accordance with the provisions of Paragraph 8 hereof. The terms of this Paragraph may be modified in accordance with the provisions of Paragraph 8 hereof.

GRANTEE'S ADDRESS: Town of Sullivan's Island
Town Hall
P. O. Box 427
Sullivan's Island, SC 29482

TOGETHER with all and singular, the Rights, Members, Hereditaments and Appurtenances to the said Premises belonging, or in anywise incident or appertaining.

TO HAVE AND TO HOLD, all and singular, the said Premises before mentioned unto the said Town of Sullivan's Island, South Carolina, its Successors and Assigns forever.

AND it does hereby bind itself and its Successors, to warrant and forever defend, all and singular the said Premises unto the said Town of Sullivan's Island, South Carolina, its Successors and Assigns, against it and its Successors, lawfully claiming, or to claim the same or any part thereof.

WITNESS its Hand and Seal, this 12 day of February, in the year of our Lord one thousand nine hundred and ninety-one and the two hundred and fifteenth year of the sovereignty and Independence of the Untied States of America.

SIGNED, SEALED AND DELIVERED
IN THE PRESENCE OF:

[signature]

[signature]

LOWCOUNTRY OPEN LAND TRUST

By: [signature]
Its:

By: Susan A. Kidd
Its:

STATE OF SOUTH CAROLINA)

CHARLESTON COUNTY)

PERSONALLY appeared before me the undersigned witness and made oath that (s)he saw the within named LOWCOUNTRY OPEN LAND TRUST by its authorized officer(s), sign, seal and as its act and deed, deliver the within written Deed, and that (s)he with the other witness named above witnessed the execution thereof.

SWORN to before me this 12
day of February A.D. 1991

[signature] (SEAL)
Notary Public for South Carolina
My commission expires: 4-2-96

[signature]
(Signature of Witness)

Attachment A
Deed Restrictions

EXHIBIT A

All those lots, parcels and pieces of property located within the Town of Sullivan's Island, County of Charleston, State of South Carolina, being more specifically described as follows:

Parcel 1

All that real property not previously conveyed by the Board of Township Commissioners, Town Council of Sullivan's Island, the State of South Carolina or their predecessors in title, located and situated within the boundaries created by Star of the West Street, Middle Street, Station 12 Street, and the mean high water mark of the waters of the Atlantic Ocean and Charleston harbor. Said property is also shown as Parcel #1 on the below described plat attached hereto and marked Exhibit B.

Parcel 2

All that real property not previously conveyed by the Board of Township Commissioners, Town Council of Sullivan's Island, the State of South Carolina or their predecessors in title, located and situated within the boundaries created by Palmetto Street, Poe Avenue, Station 16 Street, and the mean high water mark of the waters of the Atlantic Ocean. Said property is also shown as Parcel #2 on the below described plat attached hereto and marked Exhibit B.

SPECIFICALLY SAVING AND EXCEPTING all that land now owned by the United States Government.

SPECIFICALLY SAVING AND EXCEPTING all those lots, parcels and pieces of land know as Tract A and Tract B on a plat by William Porcher, dated April 21, 1989, entitled "Plat Showing Battery Logan Owned by Sullivan's Island Board of Township Commissioners, Being Subdivided into Tract A and Tract B, Sullivan's Island, Charleston County, South Carolina" being duly recorded in the R.M.C. Office for Charleston County on the 24th day of May, 1989, in Plat Book BW, at Page 28.

Parcel 3

All that real property not previously conveyed by the Board of Township Commissioners, Town Council of Sullivan's Island, the State of South Carolina or their predecessors in title, located and situated within the boundaries created by Station 16 Street, Atlantic Avenue, Station 18 Street and the mean high water mark of the waters of the Atlantic Ocean. Said property is also shown as Parcel #3 on the below described plat attached hereto and marked Exhibit B.

Parcel 4

All that real property not previously conveyed by the Board of

Attachment A
Deed Restrictions

Township Commissioners, Town Council of Sullivan's Island, the State of South Carolina or their predecessors in title, located and situated within the boundaries created by Station 18 Street, I'on Street, Station 18-1/2 Street and the mean high water mark of the waters of the Atlantic Ocean. Said property is also shown as Parcel #4 on the below described plat attached hereto and marked Exhibit B.

SPECIFICALLY SAVING AND EXCEPTING Lots M, N, M2, N2, and property presently owned by the United States Coast Guard, along with West Atlantic Avenue as shown on plat entitled "Town of Sullivan's Island, Charleston County, South Carolina", dated May 18, 1964, attached hereto and incorporated herein as Exhibit B.

Parcel 5

All that real property not previously conveyed by the Board of Township Commissioners, Town Council of Sullivan's island, the State of South Carolina or their predecessors in title, located and situated within the boundaries created by Station 18-1/2 Street, Thee Street, the western boundary of the lands now leased by Charleston County School District No. 2 and the mean high water mark of the waters of the Atlantic Ocean. Said property is also shown as Parcel #5 on the below described plat attached hereto and marked Exhibit B.

Parcel 6

All that real property not previously conveyed by the Board of Township Commissioners, Town Council of Sullivan's Island, the State of South Carolina or their predecessors in title, located and situated seaward beyond the boundaries of all that real property leased under School District No. 2 of Charleston County, State of South Carolina as more specifically shown by Grant of Lease dated the 23rd day of April, 1954, and recorded in the R.M.C. Office for Charleston County in Book N58, at Page 150. Said property is also shown as Parcel #6 on the below described plat attached hereto and marked Exhibit B.

Parcel 7

All that real property not previously conveyed by the Board of Township Commissioners, Town Council of Sullivan's Island, the State of South Carolina or their predecessors in title, located and situated within the boundaries created by the eastern boundaries of the lands now leased by Charleston County School District No. 2, Pettigrew Street, Station 22 Street and the mean high water mark of the waters of the Atlantic Ocean. Said property is also shown as Parcel #7 on the below described plat attached hereto and marked Exhibit B.

Parcel 8

All that real property not previously conveyed by the Board of Township Commissioners, Town Council of Sullivan's Island, the State of South Carolina or their predecessors in title, located and situated within the boundaries created by Station 22 Street, East Atlantic Avenue and Station 22-1/2 Street and the mean high water mark of the waters of the Atlantic Ocean. Said property is also shown as Parcel #8 on the below described plat attached hereto and marked Exhibit B.

Parcel 9

All that real property not previously conveyed by the Board of Township Commissioners, Town Council of Sullivan's Island, the State of South Carolina or their predecessors in title, located and situated within the boundaries created by Station 22-1/2 Street, Bayonne Street, Station 28 Street and the mean high water mark of the waters of the Atlantic Ocean. Said property is also shown as Parcel #9 on the below described plat attached hereto and marked Exhibit B.

Parcel 10

All that real property not previously conveyed by the Board of Township Commissions, Town Council of Sullivan's Island, the State of South Carolina or their predecessors in title, located and situated within the boundaries created by Station 28 Street, Marshall Boulevard, Station 32 Street and the mean high water mark of the waters of the Atlantic Ocean. Said property is also shown as parcel #10 on the below described plat attached hereto and marked Exhibit B.

Parcel 11

All that real property not previously conveyed by the Board of Township Commissioners, Town Council of Sullivan's Island, the State of South Carolina or their predecessors in title, located and situated and lying seaward of those lots known and described as Lots 1 through 5, Block 16 and Lots 1 through 7. Block 17, as more specifically shown on the below described plat which is marked Exhibit B. Said property is also shown as Parcel #11 on the below described plat attached hereto and marked Exhibit B.

The above tracts of land are more specifically shown and delineated as the colored portion of a plat entitled "Sullivan's Island, Charleston County, South Carolina", dated May 18, 1964, which is attached hereto and incorporated herein by reference and marked Exhibit B.

Attachment A
Deed Restrictions

Being the same property conveyed to the Grantor herein by Deed of even date from the Town of Sullivan's Island which is recorded in the RMC Office for Charleston County prior to the recording of this deed but simultaneously herewith in Book ______________, at Page ______________.

Grantees address: P. O. Box 1293
456 King Street
Charleston, SC 29402

APPENDIX 3

Protected Species under the Federal Endangered Species Act of 1973

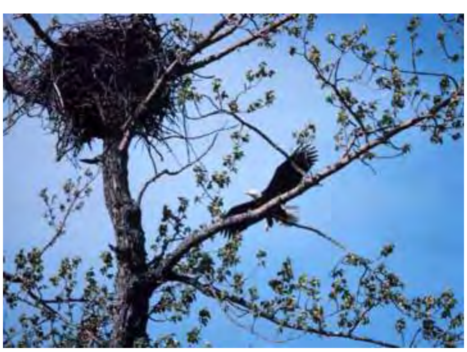
(those that may occur in the AL study area)

APPENDIX 3. PROTECTED SPECIES

Bald Eagle

The bald eagle (*Haliaeetus leucocephalus*) was listed as threatened throughout the conterminous (lower 48) United States until June 28, 2007. On June 29, 2007 the bald eagle was no longer listed, but is still protected under the Bald and Golden Eagle Protection Act. The bald eagle is primarily associated with coasts, rivers and lakes, usually nesting near bodies of water where it feeds. An opportunistic predator, the bald eagle feeds primarily on fish but also takes a variety of birds, mammals and turtles (both live and as carrion) when fish are not readily available. The breeding season of bald eagles varies with latitude. Nesting in the Southeast occurs in three primary areas: peninsular Florida, coastal South Carolina and coastal Louisiana, with sporadic breeding in the rest of the southeastern states. Otherwise, bald eagles occur throughout the Southeast as migrating or over-wintering birds (USFWS 1989).

In the Southeast, the bald eagle nesting period is usually from October 1 to May 15. Egg laying begins as early as late October and peaks in late December. The female does most of the nest construction, but the male assists. The typical nest is constructed of large sticks with softer materials such as dead weeds, cornstalks, grasses, and sod added as nest lining. Bald eagle nests are very large, up to six feet in width and weighing hundreds of pounds. In the Southeast, nests are constructed in dominant or codominant pines or bald cypress trees. Individual pairs return to their same territories year after year, and often territories are inherited by subsequent generations. Eagles are most vulnerable to disturbance early in the nesting period, i.e. during courtship, nest building, egg laying, incubation and brooding (usually the first twelve weeks of the nesting cycle). Disturbance during this critical period may lead to nest abandonment and/or chilled or overheated eggs or young. Human activity near a nest later in the nesting cycle may cause premature fledging thereby lessening the chance of survival. Although bald eagle nests are federally protected, a nest in and of itself (from a biological perspective) is relatively inconsequential to a given pair of eagles. It is the nest site that originally attracted the pair that is of critical importance. It is not uncommon for nests to be blown from trees by storms, after which the resident pairs typically re-nest on the same sites, often in the same trees.



Therefore in the instances where nests, and even nest trees, are lost, management guidelines should continue to apply in their absence for a period extending through at least two complete breeding seasons subsequent to the loss. Bald eagles use alternate nests in different years. Although all nests used by a given pair are situated in the same general vicinity, several nests go unused for several consecutive years and thereby may appear abandoned. Even a solitary nest can go unused for several years, often due to the death of one member of the resident pair, and then be reoccupied by either the original pair or one member of the original pair with a new mate. Even in instances where both members of a pair have died, the site would likely be taken over by another pair if no habitat degradation occurs. For these reasons, management guidelines should apply to apparently "abandoned" nests for a period extending at least through five consecutive breeding seasons of non-use (USFWS 1989).

Management Zones

A. Primary Zone: This is the most critical area and must be maintained to promote acceptable conditions for eagles.

1. Size: Except under unusual circumstances, the primary zone should encompass an area extending from 750 to 1500 feet outward from the nest tree. The precise radius distance between these two extremes would be dependent upon the proximal and spatial configuration of the critical elements (nest tree (s), feeding area, roost trees, etc.) within a particular nesting area, or other compelling factors.

2. Recommended Restrictions:

a. Close proximity of the following activities to bald eagle nests are likely to have detrimental impacts on eagle nesting and, therefore, should not occur within the primary management zone at any time:

(1) Residential, commercial or industrial development, tree cutting, logging, construction and mining: and
(2) Use of chemicals toxic to wildlife.

b. The following activities would likely be detrimental while eagles are present and, therefore, should be restricted in the primary zone during the nesting period, but not necessarily during the non-nesting season:

(1) Unauthorized human entry; and
(2) Helicopter or fixed-wing aircraft operation within 500 feet vertical distance or 1,000 feet horizontal distance from a nest.

B. Secondary Zone: Restrictions in this zone are needed to minimize disturbance that might compromise the integrity of the primary zone and to protect important areas outside the primary zone. The secondary zone should be arranged so as to be contiguous with feeding areas and provide a protected access between nests and the feeding area. In some cases, that would involve extending a corridor from the primary zone to a particular feeding area, with that corridor requiring the same restrictions as the secondary zone.

1. Size: The secondary zone should encompass an area extending outward from the boundary of the primary zone, a distance of 750 feet to one mile. The precise distance will be dependent upon site-specific circumstances.

2. Recommended Restriction:

a. Certain activities within the secondary zone are likely to be detrimental to bald eagles and in most cases should be restricted. These activities include, but are not necessarily limited to:

(1) Development of new commercial and industrial sites;
(2) Construction of multi-story buildings and high density housing developments between the nest and the eagles' feeding area;
(3) Construction of new roads, trails, and canals which would tend to facilitate access to the nest; and
(4) Use of chemicals toxic to wildlife, such as herbicides or pesticides.

b. Other activities may take place in the secondary zone, but only during the non-nesting period. Even intermittent use or activities of short duration during nesting are likely to constitute disturbance. Examples are logging, land clearing, construction, seismographic activities employing explosives, mining, oil well drilling, and low-level aircraft operations. Minor activities such as hiking, bird watching, fishing, camping, picnicking, hunting, and recreational off-road vehicle use may be permitted in the secondary zone at any time.

Feeding

These guidelines are designed to enhance the quality of bald eagle feeding areas and eliminate or minimize human disturbance.

A. The use of toxic chemicals in watersheds and rivers where bald eagles feed should be prohibited.

B. Alteration of natural shorelines where bald eagles feed should be prevented or limited. Degraded shorelines should be rehabilitated where possible.

C. Water quality in eagle feeding areas should be monitored and remedial steps taken when needed.

Roosting

These guidelines are designed to help preserve present roosting sites and provide future habitat for roosts within and adjacent to nesting territories.

- Within the primary management zone, no trees, living or dead should be removed.
- Within the secondary management zone, as many large trees as possible living or dead, should be retained as roost and perch trees. Characteristically, these should be the large trees in the stand. Trees with open crowns and stout lateral limbs are preferable.

The major factor leading to the decline of the bald eagle was lowered reproductive success following the introduction of the pesticide DDT in 1947. DDT residues caused eggshell thinning which led to broken eggs. Use of DDT was suspended in 1972, and by the late 1970's eagle populations began to show signs of recovery. Currently, the most significant factor to affect the recovery of the bald eagle in the Southeast is habitat destruction and disturbance by humans. Additional threats are illegal shooting, electrocution, impact injuries, and lead poisoning (USFWS 1989).

Wood Stork

The wood stork (*Mycteria americana*) is a large wading bird approximately 127 centimeters tall, with a wingspan of 1 to 1.5 meters. This species is highly colonial, usually nesting in large rookeries and feeding in flocks. The plumage is generally white, with black primary and secondary wing feathers and a short black tail. The head displays a prominent bill that is slightly decurved, thick at the base and black.

Wood storks are typically associated with freshwater and brackish wetlands. Most nesting colonies in the Southeast are located in woody vegetation, such as bald cypress, over standing water, or on islands surrounded by open water. Foraging habitat may include freshwater marshes, flooded pastures and flooded ditches (USFWS 1992). Foraging sites are often in areas of fish concentrations due to either local reproduction or drying.

Kirtland's Warbler

Kirtland's warbler (*Dendroica kirtlandii*) is a small neotropical songbird measuring approximately six inches which travels along the North and South Carolina coasts during its migration to the Bahamas. Wintering dates are from September through April. These rare birds are seen and heard by only a handful of humans, mostly biologists. The male's blue-gray back is streaked with black, with a black eye mask and "broken" eye ring make the bird distinctly recognizable. He is pale yellow below with dark streaks alongside his breast. The female is duller and lacks the mask. This warbler constantly bobs its tail.

Entering and leaving the U.S. along coasts of North and South Carolina during its migration, the earliest arrivals (young of the year) may reach the Bahamas in August, but some (adults) remain in the nesting range into late September. Many may not pause in migration until at or near destination (Mayfield 1988).

The diet of the warbler includes many different insect species at various developmental stages, including caterpillars, butterflies, moths, flies, grasshoppers, as well as ripe blueberries, when in season.

Least Tern

At nine (9) inches in length, the Least Tern (*Sterna antillarum*) is the smallest North American tern. During the breeding season wings and back are grey, with white forehead and black head and nape of neck. The tail is forked and the bill is yellow during the breeding season, but fades to black during the winter (Peterson and Peterson 2002).

The least tern's breeding range includes much of the eastern seaboard.

Nesting in South Carolina occurs around mid-May, in colonies on beaches and sandbars (Sidle and Harrison 1990). Least terns are monogamous (one breeding partner at a time), and produce one brood of 1-3 eggs per year. The oceanfront beach is a harsh environment and the least tern has developed techniques for protecting its young, such as shaking water on their eggs to cool them and defecating on intruders (including humans!) into the colony (Sidle and Harrison 1990). Least terns will often be seen hovering over water, searching for prey, such as aquatic invertebrates and small fish (Sidle and Harrison 1990).

Wilson's Plover

Wilson's Plover (*Charadrius wilsonia*) is a small banded plover that occupies sandy beaches and tidal mudflats along the southern Atlantic and Gulf Coasts. The plover is distinguished from other plovers by its heavy black bill and single complete black band cross its white breast (Corbat and Bergstrom 2000).

Wilson's Plovers breed in South Carolina, along open sand or shell beaches. The species is monogamous and nests in colonies or in isolated pairs. Nests are simple depressions in the sand, often next to a piece of driftwood, bunch of grass, or some other beach debris. Parents care for offspring until fledging (learn to fly).

The estimated breeding population of Wilson's Plovers is approximately 6,000 and is quite susceptible to major catastrophe such as hurricanes (Corbat and Bergstrom 2000). Human activity during the breeding season also poses a threat to the species by flushing incubating adults from the nest, leaving the eggs exposed to over heating and predation. Coastal development is reducing breeding and non-breeding habitat (Corbat and Bergstrom 2000).

Piping Plover

The piping plover (*Charadrius melodus*) is a shorebird measuring 18 centimeters in length at maturity. The piping plover is the only pale-backed plover on the East Coast and Great Lakes. This plover's back is the color of dry sand. It has a black ring around the neck, yellow to yellow-orange legs, and has a black band across the forehead over the eyes (USFWS 1992).

The piping plover breeds on sandy beaches, sandbars, and similar habitats along the Atlantic coast from North Carolina to Newfoundland, and west to the Dakotas. It occurs along sparsely vegetated areas that are slightly raised in elevation. Breeding areas are generally near a feeding area such as a dune pond or tidal slough. These birds are primarily coastal during the winter and prefer areas with expansive sand or mud flats in close proximity to a sandy beach (USFWS 1992).

Rafinsque's Big-eared Bat

Rafinesque's big-eared bat (*Plecotus rafinesquii*) is a medium sized bat with long pointed ears. Total length of the Rafinesque's big-eared bat averages 80 to 110 millimeters. Actual weight is 7.9 to 13.6 grams, with females being larger than males. There are 2 prominent lumps on the face. The color of the pelage of this species is very diagnostic and serves to distinguish this bat from similar species. The bases of the ventral hairs are black or blackish, and the tips are white or whitish, with substantial contrast between the two (Jones 1977).

Rafinesque's big-eared bat occurs from southern Virginia, west to central Indiana, south and west to southeastern Oklahoma and east to Texas, and south along the Atlantic coast to Florida. Roosting sites utilized most frequently by the species include partially lighted, abandoned and unoccupied buildings or other manmade structures. These bats also roost in caves, trees, and other natural places. Colonies of Rafinesque's big-eared bat range in size from, several animals to as many as 100. The bats emerge from the roost after dark, and return to the roost prior to dawn, with very little foraging during twilight hours. Within a roosting area, the bats appear to move frequently in both summer and winter (Jones 1977).

Kemp's Ridley Sea Turtle

The Kemp's Ridley (*Lepidochelys kempii*) is the smallest and most endangered of the eastern sea turtles. At maturity the shell may reach 71 centimeters in length. The shell is typically very broad. The carapace is gray, gray-brown, or olive. The plastron (bottom of shell) is generally white or yellowish. The head is large with two pairs of prefrontal scales (Collins 1959).

Kemp's Ridley is generally found worldwide, although there are only two known nesting locations, Padre Island, Texas and the Mexican coast between the San Rafael River and Rancho Nuevo. This sea turtle inhabits reefs and shallow coastal waters where it is generally carnivorous, feeding on crabs, snails, squid, and jellyfish (Coop. Ext. Serv./ Univ. Ga. 1992).

Leatherback Sea Turtle

The leatherback sea turtle (*Dermochelys coriacea*) is the largest living turtle, growing to two and one-half meters long and 550 kilograms. It is also the only sea turtle with a leathery shell. The carapace is black, leathery, and scaleless, with seven long ridges. The plastron is spotted white with five long ridges (Collins 1959). The leatherback lives in the open ocean as far out as the edge of the continental shelf. The species is truly pelagic, wandering thousands of miles between nesting beaches and ocean foraging areas. Nesting by the leatherback occurs regularly, but by no means abundantly, in Florida during the spring and early summer months (Ashton 1982).

Loggerhead Sea Turtle

The loggerhead sea turtle (*Caretta caretta*) is a marine sea turtle growing as long as 79 to 122 centimeters and weighing up to 136 kilograms. The carapace is reddish-brown, long and tapered, with five large plates on each side. The head is relatively large with two pairs of prefrontal scales (Collins 1959).

The loggerhead is found in warm parts of the Atlantic, Pacific and Indian Oceans, as well as the Mediterranean and Caribbean Seas. It is found hundreds of miles out to sea as well as inshore areas such as bays, lagoons, salt marshes, creeks, ship channels, canals and mouths of large rivers (USFWS 1995). It nests along the Atlantic and Gulf Coast beaches, with the greatest percentage of nesting occurring in Florida. Female loggerheads come on shore to undisturbed, quiet beaches in the early summer to lay eggs. Hatchlings and small juveniles are most often associated with floating mats of *sargassum* in pelagic habitats (Ashton 1982).

Green Sea Turtle

The green sea turtle (*Chelonia mydas*) is a large, herbivorous sea turtle with a heart-shaped shell, which is broader and flatter than most other sea turtles. The carapace (top of the shell) is broad, low, heart-shaped, smooth, and unkeeled, i.e., the plates do not overlap. The carapace is generally olive to dark brown with numerous black spots. The head has one pair of prefrontal scales, and a single mandibular scale (Collins 1959).

The green sea turtle occurs off shore near Atlantic coastal states during warmer months. Nesting along south Atlantic beaches is rare, with primary nesting occurring in the Caribbean and Florida. Juveniles first appear along Florida coastal waters at 1 to 3 years of age. Juveniles forage as herbivores in shallow coastal waters (Ashton 1982).

Shortnose Sturgeon

The shortnose sturgeon (*Acipenser brevirostrum*) is an anadromous fish approximately 41 to 91 centimeters long, inhabiting marine and tidal freshwater river systems along the Atlantic coast. The fish is brown to gray or black on the back, turning gold or yellow on the sides, and to white underneath (Coop. Ext. Ser/Univ. Ga. 1992). The blunt snout and 11 dorsal plates are distinctive characteristics of this sturgeon (Collins 1959).

During winter, this species occurs in saltwater bays and estuaries of medium to high salinity. During late winter to early spring the shortnose sturgeon moves upstream into freshwater swamps where it will spawn among flooded trees when water temperatures reach 10-15 degrees centigrade. During summer the adults will congregate in low salinity estuaries to feed on bottom dwelling invertebrates. Eggs and larvae may be susceptible to siltation effects.

Bachman's Warbler

Historical records indicate that the Bachman's warbler (*Vermivora bachmanii*) nests in low wet forested areas containing variable amounts of water, but usually some water that is permanent. These areas are described in general as being forested with sweet gum, oaks, hickories, black gum, and other hardwoods; and where there was an opening in the forest canopy, the ground being covered with dense thickets of cane, palmetto, blackberry, gallberry and other shrubs and vines (USFWS 1992).

Seabeach Amaranth

Seabeach amaranth (*Amaranthus pumilus*) is an annual plant found on Atlantic Ocean beaches. It is a herbaceous annual with fleshy and pinkish red to reddish stems in excess of 2 millimeters in diameter. The spinach green leaves are parallel to the sand surface with the stem upright, generally less that 10 centimeters above the ground (Bucher and Weakley 1990). Upon germinating, this plant initially forms a small, unbranched sprig, but soon begins to branch profusely into a clump. This clump often reaches a 0.3 meters in diameter and consists of 5 to 20 branches (USFWS 1992).

Seabeach amaranth occurs on barrier island beaches, where its primary habitat consists of overwash flats at accreting ends of islands and lower foredunes and upper strands of non-eroding beaches (USFWS 1992).

APPENDIX 4

Wetland Definitions
Based on Federal
Jurisdiction and Regulation

APPENDIX 4. WETLAND DEFINITION

The COE and the Environmental Protection Agency (EPA) define wetlands as:

> *Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.*

The COE investigates three characteristics of the area when making wetland determinations: vegetation, soils and hydrology. Unless the area has been altered or is a rare natural situation, wetland indicators of all three characteristics must be present during some portion of the growing season for an area to be classified as a wetland.

Nearly 5,000 plant types may occur in wetlands in the United States. These plants are known as hydrophytic vegetation. Some common examples are cattails, bulrushes, cordgrass, sphagnum moss, bald cypress, willows, mangroves, sedges, rushes and arrowheads. Other vegetation indicators of wetland include shallow root systems, swollen trunks or roots growing from the stem or trunk above the soil surface.

The second consideration in determining wetlands is the investigation of the soils. Soils with characteristics that indicate they developed in conditions where soil oxygen was limited due to saturation for long periods during the growing season are called hydric soils. There are over 2,000 hydric soils in the United States. The US Soil Conservation Service, now the Natural Resource Conservation Service (NRCS) maintains a list of hydric soils. This list can be used to give an indication as to whether wetlands may be present or not. If the soil type is not known there are a number of indicators that can be used as clues:

- Soil consists of predominately decomposed plant material.
- Soil has bluish or gray color below the surface, or the major color of the soil is dark and dull.
- Soil has the odor of rotten eggs.
- Soil is sandy and has dark stains of organic material in the upper layer of the soil. These streaks are decomposed plant material attached to soil particles. When soil from these streaks is rubbed between the fingers, a dark stain is left on the fingers.

Wetland hydrology refers to the presence of water at or above the soil surface for a sufficient period of the year to significantly influence the plant types and soils. The following indicators provide evidence that flooding or soil saturation is occurring:

- Standing or flowing water is observed during growing season.
- Soil is waterlogged during the growing season.
- Watermarks are present on trees.
- Drift lines, which are small piles of debris oriented in the direction of water movement, are present.
- Thin layers of sediments are deposited on leaves or other objects.

Wetland Impacts

If wetlands will be impacted in the course of a project, then a permit may be required before the activity begins. There are two basic types of permits. The individual permit is generally used for large projects and impacts of significant importance. A very thorough accounting of the impacts and benefits of the proposed project must be reviewed by the state and federal agencies and public meetings must be held for additional input before the COE can issue the permit. The applicant is usually responsible for providing all the supporting information, tests and studies to prove that the fill permit is necessary. Also, they must compensate for the impacts by providing mitigation. The COE is required to get comments from a wide variety of sources when considering the issuance of a permit. These include US Fish and Wildlife Service (USFWS) National Marine Fisheries (NMF), US Environmental Protection Agency (EPA), South Carolina Department of Health and Environmental Control (DHEC), South Carolina Department of Natural Resources (DNR) and the SC State Historical Preservation Office (SHPO), as well as the public. The permit process can be very daunting.

An individual permit can typically take six months to a year to process. Since this process is so involved and time consuming, a system of Nationwide Permits (NWPs) was instituted with changes to the CWA in 1982. The NWPs are designed to provide a fair and flexible framework that will reduce the regulatory burdens of the individual permit and still meet water quality objectives. The NWPs include specific project limitations, which ensure that impacts will be no more than minimal and the aquatic environment will be protected. The applicant is rewarded for meeting these limitations with a much shortened permit process, saving time and money.

Permit Exemptions

The CWA contains one other mechanism for impacting wetlands. Some activities are set aside and exempt from the restrictions of the CWA. Certain agricultural and forestry operations were granted these exemptions in Section 404(f) of the CWA. The forestry activities exempt from Section 404 regulation include normal silvicultural activities such as plowing, seeding or planting, cultivating, minor drainage and harvesting for the production of forest products. To be considered as exempt, the activities specified above must be part of an established silviculture operation.

Section 404(f) reads as follows:

1. Except as provided in paragraph (2) of this subsection, the discharge of dredge or fill material

    a) from normal farming, silviculture, and ranching activities such as plowing, seeding, cultivating, minor drainage, harvesting for the production of food, fiber and forest products, or upland soil and water conservation practices;

    b) for the purpose of maintenance, including emergency reconstruction of recently damaged parts of currently serviceable structures such as dikes, dams, levees, groins, riprap, breakwaters, causeways, and bridge abutments or approaches, and transportation structures;

    c) for the purpose of construction or maintenance of farm or stock ponds or irrigation ditches, or the maintenance of drainage ditches;

    d) for the purpose of construction of temporary sedimentation basins on a construction site which does not include placement of fill material into the navigable waters;

    e) for the purpose of construction or maintenance of farm roads or forest roads, or temporary roads for moving mining equipment, where such roads are constructed and maintained, in accordance with best management practices, to assure that flow and circulation patterns and chemical and biological characteristics of the navigable waters are not impaired, that the reach of the navigable waters is not reduced, and that any adverse effect on the aquatic environment will be otherwise minimized;

    f) resulting from any activity with respect to which a State has an approved program, under section 208(b)(4) which meets the requirements of subparagraphs (B) and (C) of such section, is not prohibited by or otherwise subject to regulation under this section or section 301(a) or 402 of the Act (except for effluent standards or prohibitions under section 307).

2. Any discharge of dredged or fill material into the navigable waters incidental to any activity having as its purpose to bring an area of the navigable waters into a use to which it was not previously subject, where the flow or circulation of navigable waters may be impaired or the reach of such waters be reduced, shall be required to have a permit under this section.

APPENDIX 5

Invasive Species

The following species are considered invasive and are either present in the AL study area or are commonly observed in the Southeast United States. This appendix describes each species and offers specific management guidelines for control or eradication of the species via biological, chemical, or other techniques.

APPENDIX 5. INVASIVE SPECIES

Chinese Tallow Tree

Chinese tallow tree or popcorn tree (*Sapium sebiferum*) was introduced in the late 1700s for vegetable tallow production from the waxy seed coating, possibly as an alternative to expensive whale blubber for lamp fuel and candle tallow. In the early 1900s, extensive plantations were established along the Gulf coastal plain in support of a soap-making industry based on the vegetable tallow derived from the tallow tree. The kernels also produce a drying oil, Stillingia oil, which can be used in machine oils, lighting fuels, and varnishes and paints. The oil is considered poisonous and has been proven toxic to cattle. The tree produces heavy seed crops, and oil in the seed averages 20 percent by weight. The species later became popular for its brilliant fall foliage and quick shade, and was planted extensively across the Gulf coastal plain in suburban housing developments (Louisiana Invasive Plant Species: *Tridica sebifera*: (L.) Small).

Observed in the AL area, associated with maritime forest and Carolina willow woodland.

Management

Mechanical Control: Cutting of horizontal shoots result in the immediate production of small independent plants, making this method impractical unless combined with herbicide use (see below).

Fire can hold the tallow at bay when tree density is low, but since tallow can suppress fuel species, fire can burn up to a stand but then go out from lack of fuel, leaving the tallow relatively unharmed. Fire control is still under research.

Biological Control: The plant apparently lacks serious biocontrols or pathogens in the United States, although a bagworm (*Eumeta* sp) from Japan appears to be a pest.

Chemical Control: Attempts at managing Chinese tallow suggest that herbicidal methods are the most effective option for control at this time.

Basal bark applications are made by applying herbicide directly to the bark around the circumference of the tree from ground level up to 15 inches above the ground. Hand-held equipment (paint brush) or backpack sprayer is usually used for this application. For trees that have stems less than 6 inches in basal diameter, apply up to a 5 percent triclopyr (Garlon 4) solution mixed with spray adjuvant oil. Trees exceeding 6 inches in basal diameter can be successfully controlled with a 15-20 percent triclopyr/oil solution. Old or rough bark requires more spray than smooth young bark (Jubinsky 2002).

To control resprouting of freshly cut stumps, a 20 percent solution of triclopyr will provide control. Spray the root collar area, sides of the stump, and the outer portion of the cut surface including the cambium until thoroughly wet. No more than one-half hour should elapse between cutting and applying herbicide (Jubinsky 2002).

The best time to initiate herbicidal control measures on Chinese tallow is during the spring months. During this time, either the cut stump or basal bark treatment is effective. During a normal weather year, trees begin producing seed in late August or early September. Use of the cut stump treatment during periods of the year when seeds are present is not recommended. During autumn months, restrict control measures to the basil bark method only (Jubinsky 2002).

Cattails

Cattails (*Typha latifolia*) are prolific plants that play an important role as a source of food and shelter for different marsh-dwelling animals. They can be found in damp soil or shallow water where sufficient nutrients are available. However, they can quickly dominate a wetland plant community. A 50:50 ratio of open water and vegetation is a frequent objective when managing cattail marshes in North America (Fredrickson and Reid 1987).

Observed in the AL area, associated with interdunal wetlands.

Management

Mechanical Control: The control of cattails by the manipulation of water level must be timed to the annual cycle of carbohydrate storage. Special leaf and stem cells called aerenchyma provide air passage from both living and dead leaves to the rhizomes. Removing dead leaves and submerging the shoots in early spring will strain the plant and eventually kill it. The depth of water necessary to kill the plants depends on temperature, the quantity of starch the plant stored the previous year, and the general vigor of the plants. Therefore, no minimum water depth can be prescribed, but generally, a water level maintained at 3-4 feet above the tops of existing spring shoots will retard growth. The use of water is most efficient if the water level is raised progressively, so that all plant parts remain submerged by no less than a few inches (Fredrickson and Reid 1987).

Cutting, crushing, shearing, and disking during the growing season can be used to impede starch storage. These treatments are effective if performed during a three-week window from one week before to one week after the pistillate spike is lime green and the staminate spike is dark green. However, the treatments are most effective during the 3-4 days when the spikes are so colored (Fredrickson and Reid 1987).

Deep disking can retard shoot formation and can damage the rhizomes, but the effect on plant survival is variable. The overall effect on the entire stand is minimal if water conditions are favorable for cattail survival. Control of water levels and of recruitment from the seed bank is necessary to prevent reestablishment of the cattails. Deep disking combined with continued drying and freezing in fall decreases plant survival. If the wetland can be kept sufficiently dry to repetitively disk in any two to three successive seasons, cattails can be eliminated or their stem densities severely reduced (Fredrickson and Reid 1987).

When the plants are dormant, cutting, crushing, shearing, or disking is extremely effective for severing the aerenchyma link between the rhizomes and the leaves. To reduce plant survival, however, these techniques must be combined with high water levels in spring to induce stress from anaerobic starch conversion (Fredrickson and Reid 1987).

Burning cattails is difficult during the growing season, except during extreme low-water conditions. Dry residual cattail litter provides enough fuel to carry a fire through growing plants. The fire usually does not kill the plants but can reduce starch storage. Fires in cattail marshes rarely are hot enough at ground level for heat penetration to impede rhizome function or shoot viability (Fredrickson and Reid 1987).

Most cattail marshes must be burned in winter or before significant growth has occurred in spring when fuels are dry enough to carry a fire. However, frozen or saturated soils can hamper the progress of the fire through cattail duff. When combined with high water levels in spring to smother the residual stalks, fire can be used to control cattails (Fredrickson and Reid 1987).

In wetlands with well-developed peat soils, fires during drought conditions can destroy the entire cattail plant including the rhizomes. Such fires actually burn the peat, and the ability to smother the fire by reflooding the marsh must exist before prescribing such fires. Peat fires can also eliminate the existing seed bank and, if sufficiently severe, lower the relative bottom of a marsh. Local concern with the effects of peat fires on air quality can be substantial (Fredrickson and Reid 1987).

Biological Control: There is currently no good choice to achieve biological control of cattails. Grass carp are often mentioned as a potential control method, but in reality, they prefer not to eat cattails (Lynch 2002).

Chemical Control: Herbicides, especially glyphosate, interrupt metabolic pathways and have been used successfully to kill cattails. Herbicides that are translocated to the rhizomes are most effective for cattail control. Application in mid to late summer when carbohydrates are stored enhances the effectiveness of translocated herbicides. Therefore, herbicides have little effect on seed production during the year of application. As with other techniques, the duration of the effect of herbicides depends on subsequent water-level control and recruitment from the seed bank (Fredrickson and Reid 1987).

Sesbania

Sesbania (*Sesbania exaltata*) is an erect annual herb of the legume family, which typically grows to a height of 3–10 ft. Sesbania prefers wet, highly disturbed habitats and sandy sites. It occurs in low sandy fields, sandbars of streams, alluvial ground along sloughs and borders of oxbow lakes, and along roadsides, railroads, in disturbed urban sites and agricultural areas. It may become a troublesome exotic species in wetland communities that are managed for waterfowl (Vegetation Management Guideline Sesbania 2001)

Observed in the AL area.

Management

Control of sesbania is best accomplished by creating conditions favorable for the germination of beneficial plants early in the growing season. Once established, beneficial plants can outcompete newly germinated sesbania. Therefore, control strategies should be performed early in the growing season. If early control is not possible, late disk-flood often prevents reestablishment of sesbania and creates conditions favorable for fall migrating shorebirds. This can be followed by an early drawdown during the subsequent growing season (Vegetation Management Guideline Sesbania 2001).

Mechanical Control: Spot treatment can best be accomplished by removal of the stems prior to the production of fruits. Follow-up will probably be necessary for several additional growing seasons if a seed bank is present or if reinfestation occurs (Vegetation Management Guideline Sesbania 2001).

Mowing should occur prior to seed set if possible. Mow as high as possible to preserve and promote growth of desirable plants in the understory.

Burning appears to stimulate germination.

Biological Control: An isolate of the fungal pathogen *Colletotrichum truncatum* was discovered on the Southern Weed Science Laboratory Experimental Research Farm and has been evaluated over the past several years for use as a bioherbicide against this weed. Various invert and vegetable oil emulsion formulations developed in this laboratory eliminated or greatly reduced free moisture requirements, and have consistently provided 85–95 percent control of weeds in field trials (Boyette et al 2003).

Chemical Control: Various herbicides have proved to be effective in controlling sesbania. One such method includes spraying 2,4-D with a boom sprayer at the rate of three/quarter pint per acre. The plants can also be wicked with Roundup or Rodeo (Vegetation Management Guideline Sesbania 2001).

Another chemical that has had success is propanil or Stam. The Stam 3+3 method (Stam is used twice at three quarts per acre) seems to work best. Blazer is another herbicide that works well against sesbania. Grandstand is a good, low-cost broad-leaf herbicide. It works best tank-mixed with about a quart of Stam (Kendig 2003).

Two herbicides registered for use will help manage broadleaf weeds and sedges. Research indicates that Permit has the potential to injure rice when applied pre-emergence. Therefore, Permit applications should be limited to post-emergence. The control of sesbania taller than 8 inches or after permanent flood has been inconsistent. (Williams et al 2001).

Regiment belongs to the sulfonylurea herbicide family, which includes Londax. Regiment is slow-acting and usually takes two to three weeks to kill weeds. However, Regiment stops weed growth within a few hours of application. Because of injury potential, Regiment application to rice before the three-leaf stage is not recommended. Another strength is its ability to control alligator weed when tank-mixed with Aim (Williams et al 2001).

Chinese Privet

Chinese Privet (*Ligustrum sinense*) was introduced from China in the 1800s. It is a semi-evergreen shrub growing to 30 ft in height. Leaves are opposite in two rows and at right angles to the stem. Panicles of white flowers open from April through June followed by ovoid drupes formed as pale green and ripening to dark purple, almost black in late fall. The trunks of these shrubs usually branch near the ground and have a smooth gray appearance. Privet is shade-tolerant and forms dense thickets in bottomlands and along boundary lines. Reproduction is by root sprouts as well as seed which are spread abundantly by birds and other animals. Very few plants can grow under the dense vegetation of these shrubs (Cook 2005).

Observed in the AL area, associated with the maritime forest.

Management

The most important aspect of controlling privet is managing sprouting that often occurs subsequent to initial control. Control methods that remove or damage aboveground stems, such as mechanical cutting or prescribed burning, will likely cause sprouting. Subsequent monitoring and repeated treatments may be necessary to eliminate sprouting stems.

Mechanical Control: Seedlings can be removed by hand-pulling. When hand-pulling seedlings, the entire root system must be extracted to prevent sprouting. Established seedlings become increasingly difficult to hand-pull because of a strong root system. Mowing or cutting can reduce the spread of privet by preventing seed production. Repeated cutting may eventually eradicate privet. Cutting close to ground level and applying herbicides to the cut stumps may control larger stems (see below). Cutting stems without accompanying herbicide treatment will likely promote growth from sprouting. Even with repeated follow-up cutting, mechanical control alone may be difficult.

Effectiveness of prescribed fire to control privet may vary. Fire can kill aboveground portions of Chinese privet. Due to the ability of privet to sprout following damage from fire, persistent annual burning will likely be required for local eradication (Miller 2005).

Biological Control: There are currently no biological controls for Chinese privet.

Chemical Control: Painting cut stumps with herbicides can often effectively control invasive privet. Areas where this method may be particularly desirable include sparse infestations of large stems, places where stems are concentrated, such as fence lines, or habitats where the presence of desirable native species precludes foliar application. Foliar spraying can also be effective, particularly for dense populations. Apply a glyphosate herbicide solution or Arsenal AC solution in water with a surfactant to thoroughly wet all leaves in August to December. For stems too tall for foliar sprays, apply Garlon 4 as a solution in commercially available basal oil, diesel fuel, or kerosene with a penetrant (check with herbicide distributor) to young bark as a basal spray. Alternatively, cut large stems and immediately treat stumps with Arsenal AC, or Velpar L as solutions in water with a surfactant. When safety to surrounding vegetation is a concern, immediately treat stumps and cut stems with a glyphosate herbicide or Garlon 3A as solutions in water with a surfactant (Miller 2005).

Autumn Olive

Autumn olive (*Eleagnus umbellata*) was introduced from China and Japan in 1830 and was widely planted for wildlife habitat improvement. This deciduous bush grows up to 20 ft in height, has silver undersides and produces red berries in the fall. Autumn olive prefers dryer sites and is a shade-tolerant species which forms dense stands that grow at the expense of other species (Miller 2004*).*

Observed in the AL area, adjacent to residences.

Management

The most effective control against autumn olive is early detection and detection by annually monitoring for small plants and hand-pulling to prevent seed production. Cutting and burning stimulate sprouting. Repeated cutting over several consecutive years will reduce plant vigor and may prevent spread. The combination of cutting and the use of herbicide are the most effect means of control.

Mechanical Control: Seedlings and small plants should be hand-pulled when the soil is moist. Be sure to remove the entire plant including the roots since new plants can sprout from the root fragments. It is difficult to pull the entire root system. Larger plants should be cut off from the main stem and treated with herbicide.

Biological Control: Currently, there are no known biological control methods (Rhoads and Block 2002).

Chemical Control: Apply Arsenal AC or Vanquish as solutions in water with a surfactant to thoroughly wet all leaves in April to October (can damage trees with roots in area). For stems too tall for foliar sprays, apply a solution of Garlon 4 in commercially available basal oil, diesel fuel, or kerosene with a penetrant (check with herbicide distributor) to young bark completely around the trunk up to 16 inches above the ground. Or, cut large stems and immediately treat stumps with a solution of a glyphosate herbicide (safe to surrounding trees) or Arsenal AC or Chopper (both will damage trees with roots in treated zone) in water with a surfactant (Miller 2002).

Multiflora Rose

Multiflora rose (*Rosa multiflora*) was introduced from Asia and planted as an ornamental, as living fences for livestock containment, and for wildlife habitat. Multiflora rose is a deciduous climbing, arching, and or trailing shrub that grows 10 ft tall. Distinguishing features are the clustered white flowers with yellow anthers, pinnately compound leaves, sharp thorns and red rose hips in the fall. This species spreads by root stems, sprouts, and seed dispersal by animals. Thickets of multiflora rose forms small and large infestations which often climb trees, exclude other desired plants, and hinder site management (Miller 2004).

Management

Young plants may be pulled by hand. Mature plants can be controlled through frequent, repeated cutting or mowing. Several contact and systemic herbicides are also effective in controlling multiflora rose. Follow-up treatments are likely to be needed. Two naturally occurring biological controls affect multiflora rose to some extent: a native fungal pathogen (rose-rosette disease) that is spread by a tiny native mite and a non-native seed-infesting wasp, the European rose chalcid. Native alternatives to Multiflora rose include common blackberry (*Rubus allegheniensis*), swamp rose (*Rosa palustris*), flowering raspberry (*Rubus odoratus*), and pasture rose (*Rosa carolina*) (USFWS 2004).

Mechanical Control: Mechanical and chemical methods are currently the most widely used methods for managing multiflora rose. Frequent, repeated cutting or mowing at the rate of three to six times a year per growing season for two to four years has proven effective at achieving mortality of multiflora rose. In high-quantity natural communities, cutting of individual stems plants is preferred to mowing to minimize site disturbance.

Biological Control: Biological control is not yet available for the management of multiflora rose. However, researchers are investigating several options, including a native viral pathogen (rose-rosette disease), which is spread by a very tiny mite and a seed-infesting wasp, the European rose chalcid. An important drawback to the rose-rosette fungus and the European rose chalcid is their potential impact to other rose species and cultivators.

Chemical Control: Various herbicides have been used successfully in controlling multiflora rose but, because of the long-lived stores of seeds in the soil, follow-up treatments are usually necessary. Application of systemic herbicides (eg – glyphospate) to freshly cut stumps may be the most effective methods, especially if conducted late in the growing season. Plant growth regulators may be used to control the spread of multiflora rose by preventing fruit set (Bergman 2007).

Japanese Honeysuckle

Japanese honeysuckle (*Lonicera japonica*) was introduced from Japan in the 1800s and planted as an ornamental and a deer browse. It is the most commonly occurring invasive plant in the southeastern United States. Japanese honeysuckle is a semi-evergreen woody vine with opposite branches and leaves. It is a high climbing vine that can trail up to 80 ft. The fragrant, stalked flowers are in bloom from April to August. Fruits and seeds are produced from June to March in the form of nearly spherical green berries, which turn black as they ripen (Miller 2005).

Observed in the AL area, associated with the maritime forest, Carolina willow woodland, and max-myrtle saturated shrubland.

Management

Japanese honeysuckle produces long vegetative runners that develop roots where stem and leaf junctions come in contact with moist soil. Underground stems help establish and spread the plant locally. Long-distance dispersal is by birds and other wildlife that readily consume the fruits. Several effective methods of control are available for Japanese honeysuckle, including chemical and nonchemical, depending on the extent of the infestation and available time and labor.

Mechanical Control: Repeated pulling of the entire vine and root system may be effective for small patches. Monitor frequently and remove any new plants. Cut and remove any twining vines to prevent them from girdling and killing shrubs and other plants. Mowing large patches may be useful if repeated regularly but is most effective when combined with herbicide application. Mow at twice a year, first in mid-July and again in mid-September. Burning removes aboveground vegetation but does not kill the underground rhizomes, which will continue to sprout.

Biological Control: No biological control agents are currently available for Japanese honeysuckle.

Chemical Control: In moderate cold climates, Japanese honeysuckle leaves continue to photosynthesize long after most other plants have lost their leaves. This allows for application of herbicides when many native species are dormant. However, for effective control with herbicides, healthy green leaves must be present at application time and temperatures must be sufficient for plant activity. Several systemic herbicides (eg – glyphosate and triclopyr) move through the plant to the roots when applied to the leaves or stems and have been used effectively on Japanese honeysuckle. Follow the label guidelines (Bravo 2006).

Kudzu

Kudzu (*Pueraria montana*) was introduced into the United States in 1876 at the Philadelphia Centennial Exposition, where it was promoted as a forage crop and an ornamental plant. It is a deciduous woody leguminous vine that grows 30–100 ft long. Distinguishing features include three-leaflet leaves, yellow-green stems with erect golden hairs, lavender pea-like flowers, and hairy flattened seedpods. Colonization is by vines rooting at nodes and by wind, animal, and water-dispersed seeds. Seed viability is generally low. Kudzu grows rapidly, forming dense mats of vegetation that overwhelm all other plant species including tall trees. Kudzu requires direct sunlight for rapid growth.

Management

With a large root system packed with starch and aggressive growth habit, eradication of kudzu requires persistent treatment. Several strategies can be employed to eradicate kudzu, including herbicides, prescribed burning, mowing, and livestock grazing. When selecting control strategy consider restraints, which may prevent broadcast applications of herbicides, use of tractors to spray, or mow, and the presence of desirable vegetation in the patch. Because kudzu can reach depths of four feet or greater, the thick mat of vines and leaves can hide gullies, ditches, logs, wells and other hazards. Carefully check the site after a prescribed burn, or in winter or early spring when the leaves have fallen to determine if obstacles to application exist.

Mechanical Control: Repeated mowing can weaken and ultimately control kudzu. Mowing is generally a good first step towards control, provided it can be done without risk to the tractor operator. Close mowing reduces the tangle of leaves and vines and treatment of re-growth is more easily accomplished. Thick mats of vines are often difficult to mow with light-duty rotary mowers. Flail mowers with horizontal blades cutting in a chopping action may operate more effectively.

Using kudzu as forage for cattle and other livestock was an early promotion with its introduction into the U.S. Kudzu hay has excellent nutritional value and is palatable to livestock. To control kudzu by grazing, it is necessary to adequately fence the entire patch and to provide sufficient additional grazing areas on which to rotate livestock as the kudzu is grazed down. Only by repeatedly grazing the re-growth over successive growing seasons will the root reserves of starch be depleted.

Prescribed fire can be used to consume vines and leaves to permit inspection of the site and to determine the size and density of the kudzu root crowns. Burning should occur in the winter or early spring. Using spring-burns limits exposure of bare soil to winter rains, minimizing soil erosion on steep slopes. Prescribed burning is useful in promoting seed germination prior to herbicide treatment (Moorhead and Johnson 2005).

Biological Control: Efforts are being organized by the U.S. Forest Service to begin a search for biological control agents for kudzu.

Chemical Control: Apply foliar sprays of Tordon 101 as a solution in water or Tordon K as a solution in water with a surfactant to wet foliage until run-off in July to October for successive years (Tordon herbicides are restricted-use pesticides). Spray foliage of climbing vines as high as possible. When using Tordon herbicides, rainfall must occur within six days after application for needed soil activation. The soil activity of Tordon herbicides can kill or damage plants having roots within the treated area. Other options provide partial control and may be useful in specific situations. Apply Escort in water to foliage from July to September. For areas where minimal injury to other plants is desired, apply Transline as a solution in water with a surfactant to thoroughly wet all leaves and stems in July to September. A glyphosate herbicide or Garlon 4 as solutions in water with a surfactant can be used during the growing season with repeated applications. Follow product application instructions (Miller 2002).

Wisteria (Chinese and Japanese)

Wisteria (*Wisteria sinensis* and *W. floribunda*) was introduced from Asia in the early 1800s as an ornamental. Both varieties of wisteria were used on porches across the south. The climbing woody vines can reach up to 70 ft long. They are deciduous vines with showy fragrant lavender pea-like flowers in the spring. The leaves are alternate and pinnately compound. Wisteria spreads by rooting at nodes and water-dispersal of seeds that form in large, velvety leguminous pods. Wisteria forms dense growth capable of killing trees and excluding other plant species.

Observed in the AL area, associated with the maritime forest.

Management

The only practical methods currently available for control of exotic wisterias are mechanical and chemical. Cut climbing or trailing vines as close to the root collar as possible. This technique, while labor intensive, is feasible for small populations, as a pretreatment for large impenetrable infestations, or for areas where herbicide use is not desirable. Wisteria will continue to re-sprout after cutting until its root stores are exhausted. For this reason, cutting should begin early in the growing season and, if possible, sprouts cut every few weeks until autumn. Cutting will stop the growth of existing vines and prevent seed production. However, cut vines left coiled around trunks may eventually girdle trees and shrubs as they continue to grow and increase in girth. For this reason, the vines should be removed entirely or at least cut periodically along their length.

Mechanical Control: Grubbing, removal of entire plants from the roots up, is appropriate for small initial populations or environmentally sensitive areas where herbicides cannot be used. Using a pulaski, weed wrench, or similar digging tool, remove the entire plant, including all roots and runners. Juvenile plants can be hand-pulled depending on soil conditions and root development. Any portions of the root system not removed may re-sprout. All plant parts (including mature fruit) should be bagged and disposed of in a trash dumpster to prevent re-establishment (Remaley 2006).

Biological Control: No biological control agents are currently available for wisteria.

Chemical Control: Apply Tordon 101, Tordon K, or Garlon 4 as solutions in water with a surfactant to thoroughly wet foliage until run-off in July to October for successive years (Tordon herbicides are Restricted Use Pesticides). Spray foliage of climbing vines as high as possible. When using Tordon herbicides, rainfall must occur within 6 days after application for needed soil activation. The soil activity of Tordon herbicides can kill or damage plants having roots within the treated area. Other options provide partial control and may be useful in specific situations. For areas where minimal injury to other plants is desired, apply Transline as a solution in water to thoroughly wet all leaves and stems in July to August. Apply a glyphosate herbicide as a solution in water with surfactant to wet all leaves in September to October with repeated applications (Miller 2002).

Common Reed

Common reed (*Phragmites australis*) is a tall grass that inhabits wet areas like brackish and freshwater marshes, riverbanks, lakeshores, ditches and dredge spoil areas. Native and introduced forms of Phragmites occur in the United States. Researchers believe that introduced European forms are the aggressive invasive that have replaced much of our native reed. Common reed threatens by displacing native plants and forming monocultures in otherwise biologically diverse natural wetlands. It spreads by seed and strong vegetative growth and is very difficult to control once established.

Management

Control of Phragmites is difficult, time-consuming, labor intensive and costly. Cutting, burning and chemical herbicides are all used to control it under various circumstances. Researchers have recently begun investigating the potential for biological control of this plant.

Mechanical Control: This type of control (e.g., repeated mowing) may be effective at slowing the spread of established stands but is unlikely to kill the plant. Excavation of sediments may also be effective at control but if small fragments of root are left in the soil, they may lead to reestablishment.

Prescribed burning after the plant has flowered, either alone or in combination with herbicide treatment, may also be effective. Burning after herbicide treatment also reduces standing dead stem and litter biomass, which may help to encourage germination of native plants in the following growing season. Plants should not be burned in the spring or summer before flowering as this may stimulate growth.

Biological Control: At this time no means of biological control are available in the United States for treating Phragmites infestations.

Chemical Control: Glyphosate-based herbicides (e.g., Rodeo®) are the most effective control method for established populations. S. C. Department of Natural Resources has also reported good success with Habitat®. If a population can be controlled soon after it has established chances of success are much higher because the below-ground rhizome network will not be as extensive. Herbicides are best applied in late summer/early fall after the plant has flowered either as a cut stump treatment or as a foliar spray. It is often necessary to do repeated treatments for several years to prevent any surviving rhizomes from re-sprouting. When applying herbicides in or around water or wetlands, be sure to use products labeled for that purpose to avoid harm to aquatic organisms. (Saltonstall 2008)

Tree of Heaven

Tree of heaven (*Ailanthus altissima*) was introduced from Europe as an ornamental. It is a rapid growing deciduous tree, which reaches 80 feet tall, and 6 feet in diameter and forms thickets and dense stands. It tolerates dense shade and flooding. Leaves are alternate and pinnately compound. The tree flowers April to June in long clusters, some measuring 20 inches, of greenish flowers. Persistent clusters of wing-shaped fruit can be seen on the female trees through the winter into February. Ailanthus spreads by root sprouts and wind and water born seed.

Management

Because of the high seed germination rate and the vegetative reproduction, ailanthus is difficult to irradicate and requires persistent monitoring and treatment to control this species. Most effective control is usually accomplished through the use of herbicides.

Mechanical Control: Cutting or pulling stem and vegetation will usually respond by resprouting multiple suckers from stumps and broken roots. Entire plants must be removed leaving no parts of the root or root fragments. If mechanical control is attempted targeting female trees decreases the reproduction rate. Choosing to remove the plants when soil is moist and early in the growing season may produce the best mechanical result.

Biological Control: Several fungal pathogens (*Verticillium dahliae* and *Fusarium oxysporum*) have been found in dying ailanthus. These may hold some potential for development of a biological control (Swearingen 2006).

Chemical Control: For larger trees the most effective method of control can be achieved through the careful use the of herbicides Garlon 3A or Arsenal AC with stem injection. Small trees, 6 inches or less can be treated with a basal spray of Garlon 4 or Pathfinder II at recommended dilution in a wide band around the circumference of the tree. For small trees and shrubs foliar spray can be applied July through October using Arsenal AC, Krenite S or Garlon 4 as the chemical company prescribes. Thorough wetting of the foliage is the most effective control in situations were application can be accomplished without unacceptable contact with nearby ornamental shrubs and trees (Swearingen 2006).

Alligator weed

Alligator weed (*Alternanthera philoxeroides*) is a perennial herb introduced from South America. It is one of the most difficult aquatic weeds to control. It grows in a wide range of soil and water conditions. It may be found free-floating, loosely attached, rooted, immersed, or in a dry field. It generally grows as a mat of interwoven plants. The leaves are glossy, lance-shaped, 2-5 inches long, and have a distinct midrib. The leaves are opposite and the flowers white.

Management

Mechanical Control: Successful mechanical/physical removal of this plant is extremely difficult since the plant is able to re-establish from very small pieces.

Biological Control: Biological control efforts using insect predators brought from the plant's native region have been successful in the south. Two insects that have been established are the flea beetle (*Agasicles hygrophhila*) and the stem-boring moth (*Vogtia malloi*).

Chemical Control: Alligator weed grows in different situations, each requiring particular herbicide controls. Various herbicides have proven to be successful. Glyphosate herbicides are recommended because they are biodegradable. However, glyphosate is a nonselective systemic herbicide that affects all green vegetation (Invasive Alien Plant Species of Virginia, Alligator weed). Brushoff is another herbicide suggested for terrestrial plants only (SQDNRM 2001).

Water Hyacinth

Water hyacinth (*Eichhornia crassipes*) is a member of the pickerelweed family (Pontedericeae). The plants vary in size from a few centimeters to over a meter in height. Water hyacinth can form dense mats that interfere with navigation, recreation, irrigation, and power generation. These mats competitively exclude native submersed and floating-leaved plants, create low oxygen conditions beneath the mats, impede water flow, and create good breeding conditions for mosquitoes (Ramey 2005).

Management

Mechanical Control: Mechanical controls such as harvesting have been used in such states as Florida for many years but are ineffective for large scale control, very expensive, and can't keep pace with the rapid plant growth in large water systems (Ramey 2005).

Biological Control: Scientists believe that the best bet for a long-term solution is to introduce one or more natural enemies as biological controls. In the 1970s, two South American weevils (*Neochetina bruchi* and *N. eichorniae*) and the water-hyacinth borer (*Sameodes albiguttalis*) were released in the United States. These and other organisms are being deployed in more than 20 other countries, including Australia, Cuba, Egypt, Honduras, Indonesia, Malaysia, Mexico, Panama, South Africa, Thailand, Vietnam, and Zimbabwe. There have been many successes, but results have been variable and the weed continues to cause problems (Cordo and Center 2000).

Chemical Control: The success of herbicidal control measures has varied in effectiveness. This method of control seems to work better in controlling small infestations accessible by land or boat. The herbicides most commonly used have been 2,4-D and Glyphosate. Many plants, both aquatic and terrestrial, are susceptible to the herbicides registered for water hyacinth control, so care must be taken when applying the chemical. Instructions on application methods should be read and understood before using the chemical (Dyason 1999).

American Lotus

American Lotus (*Nelumbo lutea*) can be found in muddy, shallow waters such as lake margins or in water as deep as six feet. Its leaves may be emergent above the water or floating on it. The flowers are yellow and extremely large (typically six inches wide). American lotus leaves are circular, and do not have a “cut”, as do water lily leaves.

Management

Mechanical Control: Repeated cutting of leaves has been effective in controlling American lotus. Cutting should begin before the first flower buds open in June. Care should be taken to remove the majority of the cut leaves to avoid depleting the water of oxygen as they decay (Missouri Department of Conservation 1999).

Exposing sediments to prolonged freezing and drying during the months of December, January, and February can be effective in controlling certain aquatic plants, if exposure lasts 2-4 weeks. Drain no more water than necessary to expose the unwanted plants and always leave at least eight feet of water in the deepest part of the pond to reduce the chance of a winter fish kill (Missouri Department of Conservation 1999).

Biological Control: Grass carp do not effectively control American lotus. The waxy coating (cuticle) and thick, fibrous stems of these plants make them difficult for grass carp to eat (Missouri Department of Conservation 1999).

Chemical Control: RODEO (Glyphosate) is labeled by its manufacturer, Monsanto, for use on American lotus. Refer to the product label for specific instructions. For best results apply herbicides in early spring and early summer, when plants are growing rapidly (Missouri Department of Conservation 1999).

APPENDIX 6

Mammal List

APPENDIX 6. MAMMALS

The following is a compilation of mammals that are found in the coastal plain of South Carolina, and other barrier islands along the eastern coast (adapted from Johnson et al 1974; Burt and Grossenheider 1980; McKenzie and Barclay 1980; Bellis 1995; Whitaker et al 2004). Many of these species may occur at Sullivans Island AL area, though it is unlikely that all of the following species occur at Sullivans Island.

Common Name	Scientific Name
Virginia opossum	*Didelphis virginiana*
Southern short-tailed shrew	*Blarina carolinensis*
Least shrew	*Cryptotis parva*
Eastern mole	*Scalopus aquaticus*
Eastern red bat	*Lasiurus borealis*
Northern yellow bat	*Lasiurus intermedius*
Seminole bat	*Lasiurus seminolus*
Eastern pipistrelle	*Pipistrellus subflavus*
Silver-haired bat	*Lasionycteris noctivagans*
Big brown bat	*Eptesicus fuscus*
Southern myotis	*Myotis austroriparius*
Eastern cottontail	*Sylvilagus floridanus*
Marsh rabbit	*Sylvilagus palustris*
Gray squirrel	*Sciurus carolinensis*
Southern flying squirrel	*Glaucomys volans*
Marsh rice rat	*Oryzomys palustris*
Cotton mouse	*Peromyscus gossypinus*
Hispid cotton rat	*Sigmodon hispidus*
Eastern woodrat	*Neotoma floridana*
Black rat	*Rattus rattus*
Norway rat	*Rattus norvegicus*
House mouse	*Mus musculus*
Gray fox	*Urocyon cinereoargenteus*
Domestic dog	*Canis familiaris*
Raccoon	*Procyon lotor*
Mink	*Mustela vison*
Bobcat	*Lynx rufus*
House Cat	*Felis domesticus*
White-tailed deer	*Odocoileus virginianus*

APPENDIX 7

Herp List

APPENDIX 7. HERPS

The following is a compilation of herpetofauna (reptiles and amphibians) that are found in the coastal plain of South Carolina, and other barrier islands along the eastern coast (adapted from Johnson and Hillestad 1974; McKenzie and Barclay 1980; Bellis 1995; Whitaker et al. 2004; Behler and King 2002). Many of these species may occur at Sullivan's Island Accreted Area, though it is unlikely that all of the following species occur there.

	Common Name	Scientific Name
Amphibians		
Salamanders	Greater siren	*Siren lacertina*
	Eastern newt	*Notophthalmus vinidescens*
	Two-toed amphiuma	*Amphiuma means*
Frogs and Toads	Pig frog	*Rana grylio*
	Southern leopard frog	*Rana sphenocephala*
	Eastern spadefoot	*Scaphiopus holbrooki*
	Eastern narrow-mouthed frog	*Gastrophryne carolinensis*
	Southern cricket frog	*Acris gryllus*
	Green treefrog	*Hyla cinerea*
	Pine woods treefrog	*Hyla femoralis*
	Squirrel treefrog	*Hyla squirella*
Reptiles		
Crocodilian	American alligator	*Alligator mississippiensis*
Turtles	Diamondback terrapin	*Malaclemys terrapin*
	Spotted turtle	*Clemmys guttata*
	Eastern mud turtle	*Kinosternon subrubrum*
	Loggerhead sea turtle	*Caretta caretta*
	Green sea turtle	*Chelonia mydas*
	Kemp's ridley sea turtle	*Lepidochelys kempii*
	Leatherback sea turtle	*Dermochelys coriacea*
Lizards	Green anole	*Anolis carolinensis*
	Island glass lizard	*Ophisaurus compressus*
	Eastern glass lizard	*Ophisaurus ventralis*
	Six lined racerunner	*Cnemidophorus sexlineatus*
	Southeastern five-lined skink	*Eumeces inexpectatus*
	Broad-headed skink	*Eumeces laticeps*
	Ground skink	*Scincella lateralis*
Snakes	Scarlet snake	*Cemophora coccinea*
	Racer	*Coluber constrictor*
	Corn snake	*Elaphe guttata*
	Rat snake	*Elaphe obsoleta*
	Common kingsnake	*Lampropeltis getula*
	Rough green snake	*Opheodrys aestivus*
	Common garter snake	*Thamnophis sirtali*
	Cottonmouth	*Agkistrodon piscivorus*
	Diamondback rattlesnake	*Crotalus adamanteus*

APPENDIX 8

Plant List

Species observed by the project team in the
AL study area in summer 2008

APPENDIX 8. PLANTS

Maritime Foredune Grassland

Shrub	Marsh-elder	*Iva frutescens*
Herbaceous	Sea-oats	*Uniola paniculata*
	Saltgrass	*Distchilis spicata*
	Camphorweed	*Heterotheca subaxillaris*
	Blackberry	*Rubus* sp.
	Sea side panicum	*Panicum amarum*
	Beach pea	*Strophostyles helvola*
	Fiddle-leaf morning-glory	*Ipomoea stolonifera*
	Dune sandbur	*Cenchrus tribuloides*
	Yucca	*Yucca* sp.
	Croton	*Croton glandulosus*
	Fire-wheel	*Gaillardia pulchella*
	Beach evening-primrose	*Onethera drummondii*
	Salt meadow saltgrass	*Spartina patens*

Maritime Backdune Grassland

Shrub	Earleaf green-brier	*Smilax auriculata*
	Saw green-brier	*Smilax bona-nox*
	Peppervine	*Ampelopsis arborea*
Herbaceous	Peppervine	*Ampelopsis arborea*
	Devil-joint	*Opuntia pusilla*
	Sea-oats	*Uniola paniculata*
	Camphorweed	*Heterotheca subaxillaris*
	Blackberry	*Rubus* sp.
	Seaside panicum	*Panicum amarum*
	Beach pea	*Strophostyles helvola*
	Seaside pennywort	*Hydrocotyle bonariensis*
	Dunes evening-primrose	*Onethera humifusa*
	Fire-wheel	*Gaillardia pulchella*
	Rumex	*Rumex* sp.
	Bushy bluestem	*Andropogon glomeratus*
	Earleaf green-brier	*Smilax auriculata*
	Virginia creeper	*Parthenocissus quinquefolia*
	Dogfennel	*Eupatorium capillifolium*
	Spiderwort	*Tradescantia virginiana*
	Poison ivy	*Rhus radicans*
	Indian-fig	*Opuntia ficus-indica*
	Croton	*Croton punctatus*

Manipulated Maritime Backdune Grassland

Shrub	Earleaf green-brier	*Smilax auriculata*
	Saw green-brier	*Smilax bona-nox*
	Peppervine	*Ampelopsis arborea*
	American wisteria	*Wisteria frutescens*
	Rattlebush	*Daubentonia punicea*
	Yucca	*Yucca* sp.
	Devil-joint	*Opuntia pusilla*

Herbaceous	Blackberry	*Rubus sp.*
	Earleaf green-brier	*Smilax auriculata*
	Saw green-brier	*Smilax bona-nox*
	Camphorweed	*Heterotheca subaxillaris*
	Fire-wheel	*Gaillardia pulchella*
	Spiderwort	*Tradescantia virginiana*
	Sea-oats	*Uniola paniculata*
	Peppervine	*Ampelopsis arborea*
	Devil-joint	*Opuntia pusilla*
	Rough buttonweed	*Diodea teres*
	Eastern plantain	*Plantago lanceolata*
	Saltgrass	*Distichlis spicata*
	Croton	*Croton punctatus*
	Seaside panicum	*Panicum amururan*
	Beach evening-primrose	*Onethera drummondii*

Lawns and Pathways

Herbaceous	Frog-fruits	*Phyla nodiflora*
	Beach evening-primrose	*Onethera drummondii*
	Rabbit-tobacco	*Graphalium* sp.
	Crabgrass	*Digitaria* sp.
	Rough buttonweed	*Diodea teres*
	Toadflax	*Linaria canadensis*
	Common ragweed	*Ambrosia artemisifolia*
	Bahia grass	*Paspalum notatum*
	Seaside pennywort	*Hydrocotyle bonariensis*
	Hoary plantain	*Plantago virginica*
	Flatsedge	*Cyperus* sp.
	Aloe	*Aloe vera*
	Rabbit-tobacco	*Graphalium* sp.

Maritime Interdunal Wetland

Shrub	Wax myrtle	*Morella cerifera*
	Groundsel tree	*Baccharis halmilifolia*
Herbaceous	Love grass	*Fimbristylis caroliniana*
	Frog-fruits	*Phyla nodiflora*
	Seaside pennywort	*Hydrocotyle bonariensis*
	Umbrella sedge	*Cyperus filicinus*
	Fingergrass	*Eustachys petraea*
	Common cattail	*Typha angustifolia*
	Saltmarsh bulrush	*Scirpus robustus*
	Saltgrass	*Distchlis spicata*
	Bushy bluestem	*Andropogon glomeratus*
	Arrow-leaf morning glory	*Ipomea saggittata*
	Aster	*Aster sp.*
	Soft rush	*Juncus effusus*
	Smartweed	*Polygonum* sp.
	Flatsedge	*Cyperus* sp.

Maritime Shrubland

Overstory	Wax myrtle	*Morella cerifera*
	Sugarberry	*Celtis laevigata*
	Chinese privet	*Ligustrum sinense*
	Chinese tallow	*Sapium sebiferum*
	Southern red cedar	*Juniperus silicicola*
	Carolina laurel cherry	*Prunus caroliniana*
	Red bay	*Persea borbonia*
	Hercules club	*Aralia spinosa*
Shrub	Wax myrtle	*Morella cerifera*
	Virginia creeper	*Parthenocissus quinquefolia*
	Peppervine	*Ampelopsis arborea*
	Poison ivy	*Rhus radicans*
	Alabama supple-jack	*Berchemia scandens*
	Arrow-leaf morning glory	*Ipomea saggittata*
	Groundsel tree	*Baccharis halimifolia*
	Sugarberry	*Celtis laevigata*
	Rattlebush	*Daubentonia punicea*
	Chinese tallow	*Sapium sebiferum*
	Southern red cedar	*Juniperus silicicola*
	Carolina laurel cherry	*Prunus caroliniana*
Herbaceous	Virginia creeper	*Parthenocissus quinquefolia*
	Blackberry	*Rubus sp.*
	Peppervine	*Ampelopsis arborea*
	Poison ivy	*Rhus radicans*
	Smartweed	*Polygonum sp.*
	Passion-flower	*Passiflora incarnata*
	Yucca	*Yucca sp.*
	Spiderwort	*Tradescantia virginiana*
	Seaside pennywort	*Hydrocotyle bonariensis*
	Saw green brier	*Smilax bona-nox*
	Fire-wheel	*Gaillardia pulchella*
	Beach evening-primrose	*Onethera drummondii*
	Common ragweed	*Ambrosia artemisifolia*

Manipulated Maritime Shrubland

Shrub	Groundsel tree	*Baccharis halmilifolia*
	Wax myrtle	*Morella cerifera*
	Chinese tallow	*Sapium sebiferum*
	Dog fennel	*Eupatorium capillifolium*
	Seashore mallow	*Kostelezkya virginica*
	Alabama supple-jack	*Berchemia scandens*
	Peppervine	*Ampelopsis arborea*
	Virginia creeper	*Parthenocissus quinquefolia*
	Poison ivy	*Rhus radicans*
	Blackberry	*Rubus sp*.
	Rattlebush	*Daubentonia punicea*
	Saw green-brier	*Smilax bona-nox*
	Passion-flower	*Passiflora incarnata*
	Earleaf greenbrier	*Smilax auriculata*
	Devil-joint	*Opuntia pusilla*

Herbaceous	American beauty berry	*Callicarpa americana*
	Virginia creeper	*Parthenocissus quinquefolia*
	Peppervine	*Ampelopsis arborea*
	Wood-sage	*Teucrium canadense*
	Poison ivy	*Rhus radicans*
	Alabama supple-jack	*Berchemia scandens*
	Dye bedstraw	*Galium tinctorium*
	Wood-sorrell	*Oxalis* sp.
	Smartweed	*Polygonum* sp.
	Blackberry	*Rubus* sp.
	Wild potato-vine	*Ipoemea pandurata*
	Hedge bindweed	*Calystegia sepium*
	Whitetop sedge	*Dichromena latifolia*
	Seashore mallow	*Kostelezkya virginica*
	Dogfennel	*Eupatorium capillifolium*
	Croton	*Croton punctatus*
	Camphorweed	*Heterotheca subaxillaris*
	Passion-flower	*Passiflora incarnata*
	Spiderwort	*Tradescantia virginiana*

Early Successional Maritime Forest

Overstory	Surgarberry	*Celtis laevigata*
	Wax mytrle	*Morella cerifera*
	Carolina laurel cherry	*Prunus caroliniana*
	Herculeus club	*Aralia spinosa*
	Pecan	*Carya illinoensis*
	Southern red cedar	*Juniperus silicicola*
Shrub	Wax myrtle	*Morella cerifera*
	Yaupon holly	*Ilex vomitoria*
	Carolina laurel cherry	*Prunus caroliniana*
	Southern red cedar	*Juniperus silicicola*
	Virginia creeper	*Parthenocissus quinquefolia*
	Poison ivy	*Rhus radicans*
	Japanese honeysuckle	*Lonicera japonica*
	Saw greenbrier	*Smilax bona-nox*
	Peppervine	*Ampelopsis arborea*
	Blackberry	*Rubus* sp.
	Earleaf greenbrier	*Smilax auriculata*
	Chinese privet	*Ligustrum sinense*
	Carolina willow	*Salix caroliniana*
Herbaceous	*Peppervine*	*Ampelopsis arborea*
	Poison ivy	*Rhus radicans*
	Spiderwort	*Tradescantia virginiana*
	Seaside pennywort	*Hydrocotyle bonariensis*
	Dogfennel	*Eupatorium capillifolium*
	Groundsel tree	*Baccharis halimifolia*
	Creeping cucumber	*Melothria pendula*
	Smartweed	*Polygonum* sp.
	Fireweed	*Erechtites hieracifolia*

Maritime Hardwood Depression

Overstory	Pecan	*Carya illinoensis*
	Sugarberry	*Celtis laevigata*
	Red mulberry	*Morus rubra*
	Wax myrtle	*Morella cerifera*
	Carolina willow	*Salix caroliniana*
	Chinese tallow	*Sapium sebiferum*
	Live oak	*Quercus virginiana*
	Cabbage palmetto	*Sabal palmetto*
Shrub	Wax myrtle	*Morella cerifera*
	Yaupon holly	*Ilex vomitoria*
	Carolina laurel cherry	*Prunus caroliniana*
	Oak	*Quercus sp.*
	Pecan	*Carya illinoensis*
	Roundleaf green-brier	*Smilax rotundifolia*
	Saw green-brier	*Smilax bona-nox*
	Sugarberry	*Celtis laevigata*
	Groundsel tree	*Baccharis halmifolia*
	Chinese tallow	*Sapium sebiferum*
	Red mulberry	*Morus rubra*
	American beauty berry	*Callicarpa americana*
	Peppervine	*Ampelopsis arborea*
	Hedge bindweed	*Calystegia sepium*
	Southern red cedar	*Juniperus silicicola*
	Rattlebush	*Daubentonia punicea*
	Virginia creeper	*Parthenocissus quinquefolia*
	Dogfennel	*Eupatorium capillifolium*
	Chinese privet	*Ligustrum sinense*
	American wisteria	*Wisteria frutescens*
	Seashore mallow	*Kostelezkya virginica*
Herbaceous	Sugarberry	*Celtis laevigata*
	Carolina laurel cherry	*Prunus caroliniana*
	Roundleaf green-brier	*Smilax rotundifolia*
	Virginia creeper	*Parthenocissus quinquefolia*
	Blackberry	*Rubus* sp.
	Poison ivy	*Rhus radicans*
	Spiderwort	*Tradescantia virginiana*
	Hedge bindweed	*Calystegia sepium*
	Seaside pennywort	*Hydrocotyle bonariensis*
	Fireweed	*Erechtites hieracifolia*
	Vetch	*Vicia* sp.
	Golden rod	*Solidago* sp.
	St. John's wort	*Triadenum* sp.
	Creeping cucumber	*Melothria pendula*
	Arrow-leaf morning-glory	*Ipomea sagittata*
	Japanese honeysuckle	*Lonicera japonica*
	Passion-flower	*Passiflora incarnata*
	Smartweed	*Polygonum* sp.

APPENDIX 9

Bird List

Species observed in the AL study area between
May and October 2008 by Sabine & Waters and
Mr. Jeff Mollenhauer (Audubon South Carolina)

APPENDIX 9. BIRDS

Beach	Manipulated Areas	Maritime Forest	Dune Grassland
Black Tern	American Redstart	American Redstart	Blue Jay
Brown Pelican	Barn Swallow	Barn Swallow	Blue-gray Gnatcatcher
Caspian Tern	Blue Jay	Blue Jay	Boat-tailed Grackle
Forster's Tern	Boat-tailed Grackle	Blue-gray Gnatcatcher	Bololink
Great Black-backed Gull	Brown Thrasher	Boat-tailed Grackle	Chimney Swift
Green Heron	Brown-headed Cowbird	Brown Pelican	Common Grackle
Herring Gull	Carolina Wren	Brown Thrasher	Common Ground-Dove
House Sparrow	Chimney Swift	Brown-headed Cowbird	Common Yellow-throat
Laughing Gull	Common Ground-Dove	Carolina Wren	Eurasian Collared Dove
Least Tern	Common Yellow-throat	Chimney Swift	House Finch
Merlin	Copper's Hawk	Common Ground-Dove	Laughing Gull
Osprey	Eurasian Collared Dove	Common Yellow-throat	Mourning Dove
Purple Martin	European Starling	Crow spp.	Northern Cardinal
Red Knot	Gray Catbird	Double-crested Cormorant	Prairie Warbler
Ring-billed Gull	Great-crested Flycatcher	Downy Woodpecker	Red-belllied Woodpecker
Royal Tern	House Finch	Eurasian Collared Dove	Royal Tern
Ruddy Turnstone	Laughing Gull	European Starling	
Sanderling	Mourning Dove	Gray Catbird	
Sandwich Tern	Northern Cardinal	Great-crested Flycatcher	
Semipalmated Sandpiper	Northern Mockingbird	Green Heron	
Willet	Northern Parula	House Finch	
Wilson's Plover	Painted Bunting	Laughing Gull	
	Rock Dove	Merlin	
	Royal Tern	Mourning Dove	
	Yellow-billed Cuckoo	Northern Cardinal	
		Northern Flicker	
		Northern Mockingbird	
		Orchard Oriole	
		Osprey	
		Painted Bunting	
		Prairie Warbler	
		Purple Martin	
		Red-eyed Vireo	
		Royal Tern	
		Short-billed Dowitcher	
		White-eyed Vireo	
		Yellow-billed Cuckoo	

APPENDIX 10

Historical Shoreline and Beach Volume Changes 1941–2006

APPENDIX TABLE A10. [page 1 of 3] Shoreline position data for four reaches by transect along Sullivan's Island 1941–2008. Distances are measured from the survey control line (Middle Street) to the seaward vegetation line (upper portion of the table) and the wet-dry sand contact line (approximate mean high water). The lower half of the table presents rates of change in feet and equivalent sand volume in cubic yards as explained in the text.

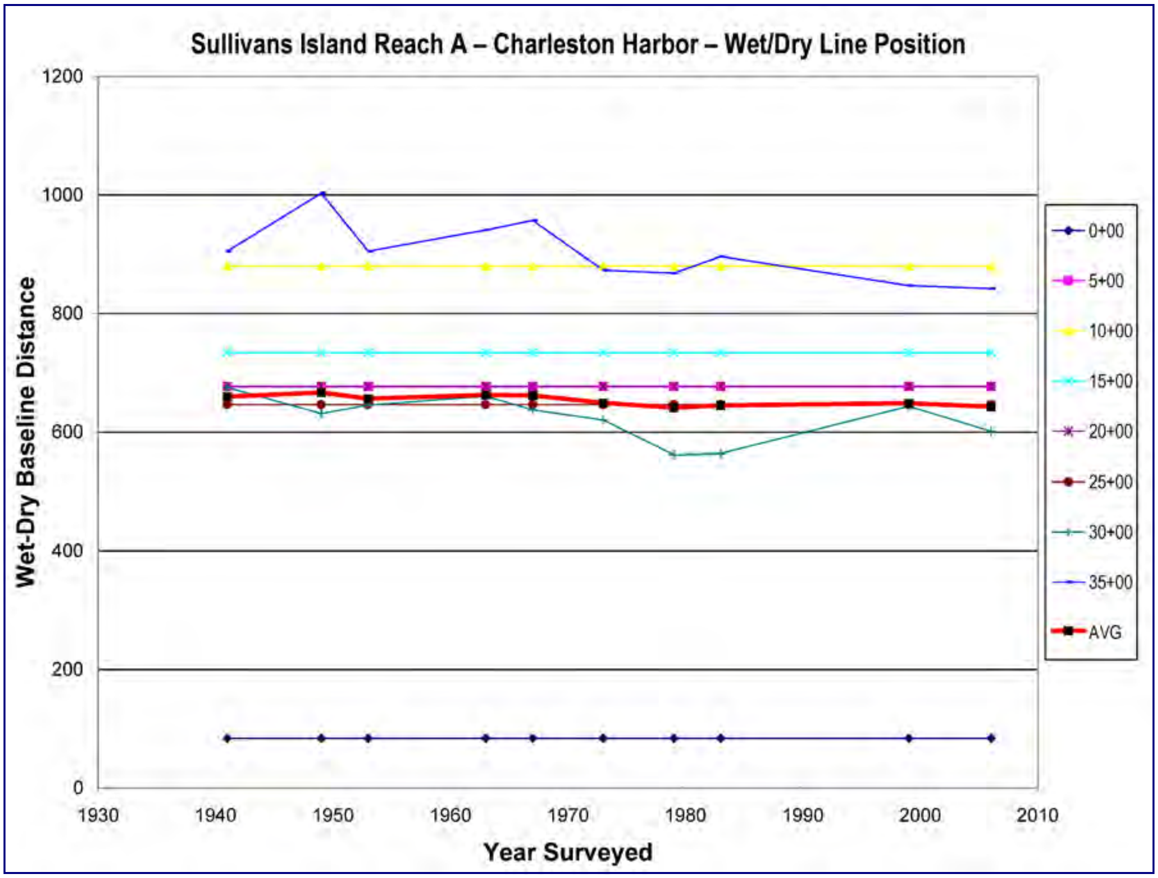
Shoreline	Year	REACH A – CHARLESTON HARBOR								REACH D – BREACH INLET										
Distance shown from BL		**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**158**	**160**	**165**	**168**	**170**	**175**	**178**	**180**	**185**	**188**	**190**
Edge of Vegetation	**1941**	84	676	880	734	677	646	560	843	1136	1411	1517	1361	1188	981	830	731	381	21	
Edge of Vegetation	**1949**	84	676	880	734	677	646	528	850	1338	1402	1538	1420	1289	1029	880	826	522	182	
Edge of Vegetation	**1953**	84	676	880	734	677	646	547	834	1320	1387	1509	1451	1333	1062	888	817	548	227	
Edge of Vegetation	**1963**	84	676	880	734	677	646	544	852	1478	1442	1266	1212	1174	978	845	676	358	176	47
Edge of Vegetation	**1967**	84	676	880	734	677	646	562	849	1377	1348	1281	1239	1166	958	826	595	212	46	57
Edge of Vegetation	**1973**	84	676	880	734	677	646	535	803	1356	1323	1293	1205	1184	977	829	560	194	63	2
Edge of Vegetation	**1979**	84	676	880	734	677	646	524	854	1361	1390	1393	1296	1208	989	877	625	232	80	76
Edge of Vegetation	**1983**	84	676	880	734	677	646	564	896	1423	1440	1415	1298	1245	1002	872	637	205	71	57
Edge of Vegetation	**1999**	84	676	880	734	677	646	529	832	1328	1309	1237	1217	1228	967	851	520	164	42	66
Edge of Vegetation	**2006**	84	676	880	734	677	646	549	819	1277	1303	1242	1209	1209	986	837	504	180	51	78
Edge of Vegetation	**2008**	84	676	880	734	677	646	575	820											
Change 1941-2008		0	0	0	0	0	0	15	-23	141	-108	-275	-152	21	5	7	-227	-201	30	
Avg Change (1941-2008) - 68 years		0	0	0	0	0	0	0.2	-0.3	2.1	-1.6	-4.1	-2.3	0.3	0.1	0.1	-3.4	-3.0	0.4	
Equiv unit vol change (1 ft = ~0.6 cy/ft)		0	0	0	0	0	0	9	-13.8	84.6	-64.8	-165	-91.2	12.6	3	4.2	-136.2	-120.6	18	
Shoreline	**Year**	**Reach A**								**Reach D**										
	Year	**0+00**	**5+00**	**10+00**	**15+00**	**20+00**	**25+00**	**30+00**	**35+00**	**158+00**	**160+00**	**165+00**	**168+00**	**170+00**	**175+00**	**178+00**	**180+00**	**185+00**	**188+00**	**190+00**
Wet - Dry Beach	**1941**	84	676	880	734	677	646	675	905	1628	1716	1782	1727	1663	1322	1015	857	534	235	-
Wet - Dry Beach	**1949**	84	676	880	734	677	646	631	1003	1484	1532	1576	1543	1507	1339	1307	1209	769	413	102
Wet - Dry Beach	**1953**	84	676	880	734	677	646	645	905	1520	1601	1576	1642	1548	1468	1229	1140	732	477	244
Wet - Dry Beach	**1963**	84	676	880	734	677	646	660	941	1866	1862	1601	1376	1187	1024	925	848	377	206	91
Wet - Dry Beach	**1967**	84	676	880	734	677	646	637	957	1423	1394	1372	1316	1262	1101	988	787	272	110	-
Wet - Dry Beach	**1973**	84	676	880	734	677	646	620	873	1429	1442	1423	1310	1251	1029	874	586	212	115	75
Wet - Dry Beach	**1979**	84	676	880	734	677	646	562	868	1410	1635	1522	1433	1362	1129	968	837	293	119	81
Wet - Dry Beach	**1983**	84	676	880	734	677	646	564	896	1655	1625	1539	1478	1409	1146	986	838	285	96	83
Wet - Dry Beach	**1999**	84	676	880	734	677	646	643	847	1424	1394	1367	1293	1268	1031	888	573	234	94	81
Wet - Dry Beach	**2006**	84	676	880	734	677	646	601	842	1344	1366	1382	1287	1275	1000	891	581	239	115	98
Change 1941-2008		0	0	0	0	0	0	-74	-63	-204	-322	-415	-434	-395	-291	-127	-284	-300	-141	
Avg Change (1941-2008) - 67 years		0	0	0	0	0	0	-1.1	-1.0	-3.1	-4.9	-6.3	-6.6	-6.0	-4.4	-1.9	-4.3	-4.5	-2.1	
Equiv unit vol change (1 ft = ~0.6 cy/ft)		0	0	0	0	0	0	-44.4	-37.8	-122.4	-193.2	-249	-260.4	-237	-174.6	-76.2	-170.4	-180	-84.6	
Distance shown from BL		**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**158**	**160**	**165**	**168**	**170**	**175**	**178**	**180**	**185**	**188**	**190**
Equiv unit vol change (1 ft = ~0.6 cy/ft) @veg		0	0	0	0	0	0	9	-13.8	84.6	-64.8	-165	-91.2	12.6	3	4.2	-136.2	-120.6	18	
Equiv unit vol change (1 ft = ~0.6 cy/ft) @wet/dry		0	0	0	0	0	0	-44.4	-37.8	-122.4	-193.2	-249	-260.4	-237	-174.6	-76.2	-170.4	-180	-84.6	
Average unit vol (@ veg vs @ wet/dry line)		*0*	*0*	*0*	*0*	*0*	*0*	*-17 7*	*-25 8*	*-18 9*	*-129*	*-207*	*-175 8*	*-112 2*	*85 8*	*-36*	*-153 3*	*-150 3*	*-33 3*	
Net Volume Change (cy) to next		0	0	0	0	0	(8,850)	(21,750)	(6,030)	(29,580)	(168,000)	(114,840)	(57,600)	(99,000)	(36,540)	(37,860)	(151,800)	(55,080)	(6,660)	
Cumulative volume Change (cy) per reach		0	0	0	0	0	(8,850)	(30,600)	(36,630)	(29,580)	(197,580)	(312,420)	(370,020)	(469,020)	(505,560)	(543,420)	(695,220)	(750,300)	(756,960)	
Average Annual Volume Change (cy/yr) by reach			0	0	0	0	(132)	(457)	**(547)**	(441)	(2,949)	(4,663)	(5,523)	(7,000)	(7,546)	(8,111)	(10,376)	(11,199)	**(11,298)**	
Change 1941-1983 (@Veg Line)		0	0	0	0	0	0	4	53	287	29	-102	-63	57	21	42	-94	-176	50	
Avg Change (1941-1983) - 42 years		0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.3	6.8	0.7	(2.4)	(1.5)	1.4	0.5	1.0	(2.2)	(4.2)	1.2	
Equiv unit vol change (1 ft = ~0.6 cy/ft)		0	0	0	0	0	0	2.4	31.8	172.2	17.4	-61.2	-37.8	34.2	12.6	25.2	-56.4	-105.6	30	
Net Volume Change (cy) to next		0	0	0	0	0	1,200	17,100	22,320	37,920	(21,900)	(29,700)	(720)	23,400	11,340	(6,240)	(81,000)	(22,680)	6,000	
Cumulative volume Change (cy) per reach		0	0	0	0	0	1,200	18,300	40,620	37,920	16,020	(13,680)	(14,400)	9,000	20,340	14,100	(66,900)	(89,580)	(83,580)	
Average Annual Volume Change (cy/yr) by reach			0	0	0	0	29	436	**967**	903	381	(326)	(343)	214	484	336	(1,593)	(2,133)	**(1,990)**	
Change 1983-2008 (@Veg Line)		0	0	0	0	0	0	11	-76	-146	-137	-173	-89	-36	-16	-35	-133	-25	-20	
Avg Change (1983-2008) - 25 years		0.0	0.0	0.0	0.0	0.0	0.0	0.4	(3.0)	(5.8)	(5.5)	(6.9)	(3.6)	(1.4)	(0.6)	(1.4)	(5.3)	(1.0)	(0.8)	
Equiv unit vol change (1 ft = ~0.6 cy/ft)		0	0	0	0	0	0	6.6	-45.6	-87.6	-82.2	-103.8	-53.4	-21.6	-9.6	-21	-79.8	-15	-12	
Net Volume Change (cy) to next		0	0	0	0	0	3,300	(19,500)	(26,280)	(33,960)	(93,000)	(47,160)	(15,000)	(15,600)	(9,180)	(20,160)	(47,400)	(8,100)	(2,400)	
Cumulative volume Change (cy) per reach		0	0	0	0	0	3,300	(16,200)	(42,480)	(33,960)	(126,960)	(174,120)	(189,120)	(204,720)	(213,900)	(234,060)	(281,460)	(289,560)	(291,960)	
Average Annual Volume Change (cy/yr) by reach			0	0	0	0	132	(648)	**(1,699)**	(1,358)	(5,078)	(6,965)	(7,565)	(8,189)	(8,556)	(9,362)	(11,258)	(11,582)	**(11,678)**	
Change 1941-2008 (@Veg Line)		0	0	0	0	0	0	15	-23	141	-108	-275	-152	21	5	7	-227	-201	30	
Avg Change (1941-2008) - 67 years		0.0	0.0	0.0	0.0	0.0	0.0	0.2	(0.3)	2.1	(1.6)	(4.1)	(2.3)	0.3	0.1	0.1	(3.4)	(3.0)	0.4	
Equiv unit vol change (1 ft = ~0.6 cy/ft)		0	0	0	0	0	0	9	-13.8	84.6	-64.8	-165	-91.2	12.6	3	4.2	-136.2	-120.6	18	
Net Volume Change (cy) to next		0	0	0	0	0	4,500	(2,400)	(3,960)	3,960	(114,900)	(76,860)	(15,720)	7,800	2,160	(26,400)	(128,400)	(30,780)	3,600	
Cumulative volume Change (cy) per reach		0	0	0	0	0	4,500	2,100	(1,860)	3,960	(110,940)	(187,800)	(203,520)	(195,720)	(193,560)	(219,960)	(348,360)	(379,140)	(375,540)	
Average Annual Volume Change (cy/yr) by reach			0	0	0	0	67	31	**(28)**	59	(1,656)	(2,803)	(3,038)	(2,921)	(2,889)	(3,283)	(5,199)	(5,659)	**(5,605)**	

APPENDIX TABLE A10. [page 2 of 3] Shoreline position data for four reaches by transect along Sullivan's Island 1941–2008. Distances are measured from the survey control line (Middle Street) to the seaward vegetation line (upper portion of the table) and the wet-dry sand contact line (approximate mean high water). The lower half of the table presents rates of change in feet and equivalent sand volume in cubic yards as explained in the text.

Shoreline	Year	REACH B – WEST STUDY AREA														
Distance shown from BL		**38**	**40**	**45**	**48**	**50**	**55**	**58**	**60**	**65**	**68**	**70**	**75**	**78**	**80**	**85**
Edge of Vegetation	**1941**	938	913	905	888	882	901	954	994	1044	1064	1039	911	852	917	1112
Edge of Vegetation	**1949**	939	946	939	900	875	863	868	879	1027	1027	1110	904	873	885	1087
Edge of Vegetation	**1953**	932	943	897	861	836	828	884	904	1069	1075	998	927	983	1083	1198
Edge of Vegetation	**1963**	934	1017	1007	983	1008	1096	1197	1272	1542	1514	1358	1241	1184	1220	1272
Edge of Vegetation	**1967**	948	1064	1203	1202	1203	1429	1557	1653	1599	1547	1506	1362	1199	1222	1268
Edge of Vegetation	**1973**	891	1049	1151	1404	1511	1548	1630	1691	1785	1717	1656	1506	1274	1279	1240
Edge of Vegetation	**1979**	969	1093	1434	1585	1676	1793	1797	1874	1866	1833	1815	1598	1328	1368	1333
Edge of Vegetation	**1983**	1009	1175	1505	1551	1713	1855	1885	1945	1943	1919	1878	1665	1395	1434	1379
Edge of Vegetation	**1999**	928	1078	1471	1642	1721	1859	1810	1773	1726	1660	1595	1339	1108	1120	1153
Edge of Vegetation	**2006**	948	1097	1427	1591	1683	1896	1960	1956	1837	1720	1609	1448	1230	1205	1160
Edge of Vegetation	**2008**	939	1097	1485	1643	1728	1968	2060	2027	1921	1789	1686	1452	1242	1230	1232
Change 1941-2008		1	184	580	755	846	1067	1106	1033	877	725	647	541	390	313	120
Avg Change (1941-2008) - 68 years		0.0	2.7	8.5	11.1	12.4	15.7	16.3	15.2	12.9	10.7	9.5	8.0	5.7	4.6	1.8
Equiv unit vol change (1 ft = ~0.6 cy/ft)		0.6	110.4	348	453	507.6	640.2	663.6	619.8	526.2	435	388.2	324.6	234	187.8	72
Shoreline	**Year**	**Reach B**														
	Year	**38+00**	**40+00**	**45+00**	**48+00**	**50+00**	**55+00**	**58+00**	**60+00**	**65+00**	**68+00**	**70+00**	**75+00**	**78+00**	**80+00**	**85+00**
Wet - Dry Beach	**1941**	1012	1051	1051	1039	1035	1061	1101	1130	1147	1139	1116	989	1013	1103	1387
Wet - Dry Beach	**1949**	1082	1113	1035	994	972	954	1018	1076	1198	1227	1236	1236	1204	1236	1418
Wet - Dry Beach	**1953**	1062	1075	966	956	941	939	1021	1114	1411	1473	1481	1447	1290	1328	1462
Wet - Dry Beach	**1963**	1080	1199	1256	1251	1250	1291	1439	2260	1830	1708	1636	1444	1269	1296	1541
Wet - Dry Beach	**1967**	1122	1226	1349	1427	1502	1712	1756	1768	1779	1770	1751	1618	1351	1347	1352
Wet - Dry Beach	**1973**	1038	1171	1488	1645	1735	1877	1921	1964	1913	1937	1777	1606	1463	1471	1335
Wet - Dry Beach	**1979**	1049	1202	1509	1674	1779	1972	1955	1958	2014	1957	1903	1684	1449	1457	1475
Wet - Dry Beach	**1983**	1088	1264	1573	1730	1829	2004	2018	2022	2051	2034	1991	1775	1468	1491	1496
Wet - Dry Beach	**1999**	1017	1192	1612	1809	1918	1922	1859	1864	1838	1772	1713	1542	1382	1359	1309
Wet - Dry Beach	**2006**	1030	1191	1527	1705	1816	2054	2113	2124	2061	1937	1843	1605	1345	1321	1284
Change 1941-2008		18	140	476	666	781	993	1012	994	914	798	727	616	332	218	-103
Avg Change (1941-2008) - 67 years		0.3	2.1	7.2	10.1	11.8	15.0	15.3	15.1	13.8	12.1	11.0	9.3	5.0	3.3	-1.6
Equiv unit vol change (1 ft = ~0.6 cy/ft)		10.8	84	285.6	399.6	468.6	595.8	607.2	596.4	548.4	478.8	436.2	369.6	199.2	130.8	-61.8
Distance shown from BL		**38**	**40**	**45**	**48**	**50**	**55**	**58**	**60**	**65**	**68**	**70**	**75**	**78**	**80**	**85**
Equiv unit vol change (1 ft = ~0.6 cy/ft) @veg		0.6	110.4	348	453	507.6	640.2	663.6	619.8	526.2	435	388.2	324.6	234	187.8	72
Equiv unit vol change (1 ft = ~0.6 cy/ft) @wet/dry		10.8	84	285.6	399.6	468.6	595.8	607.2	596.4	548.4	478.8	436.2	369.6	199.2	130.8	-61.8
Average unit vol (@ veg vs @ wet/dry line)		*5 7*	*97 2*	*316 8*	*426 3*	*488 1*	*618*	*635 4*	*608 1*	*537 3*	*456 9*	*412 2*	*347 1*	*216 6*	*159 3*	*5 1*
Net Volume Change (cy) to next		20,580	207,000	222,930	182,880	553,050	376,020	248,700	572,700	298,260	173,820	379,650	169,110	75,180	82,200	12,240
Cumulative volume Change (cy) per reach		20,580	227,580	450,510	633,390	1,186,440	1,562,460	1,811,160	2,383,860	2,682,120	2,855,940	3,235,590	3,404,700	3,479,880	3,562,080	3,574,320
Average Annual Volume Change (cy/yr) by reach		307	3,397	6,724	9,454	17,708	23,320	27,032	35,580	40,032	42,626	48,292	50,816	51,939	53,165	**53,348**
Change 1941-1983 (@Veg Line)		71	262	600	663	831	954	931	951	899	855	839	754	543	517	267
Avg Change (1941-1983) - 42 years		1.7	6.2	14.3	15.8	19.8	22.7	22.2	22.6	21.4	20.4	20.0	18.0	12.9	12.3	6.4
Equiv unit vol change (1 ft = ~0.6 cy/ft)		42.6	157.2	360	397.8	498.6	572.4	558.6	570.6	539.4	513	503.4	452.4	325.8	310.2	160.2
Net Volume Change (cy) to next		39,960	258,600	227,340	179,280	535,500	339,300	225,840	555,000	315,720	203,280	477,900	233,460	127,200	235,200	88,020
Cumulative volume Change (cy) per reach		39,960	298,560	525,900	705,180	1,240,680	1,579,980	1,805,820	2,360,820	2,676,540	2,879,820	3,357,720	3,591,180	3,718,380	3,953,580	4,041,600
Average Annual Volume Change (cy/yr) by reach		951	7,109	12,521	16,790	29,540	37,619	42,996	56,210	63,727	68,567	79,946	85,504	88,533	94,133	**96,229**
Change 1983-2008 (@Veg Line)		-70	-78	-20	92	15	113	175	82	-22	-130	-192	-213	-153	-204	-147
Avg Change (1983-2008) - 25 years		(2.8)	(3.1)	(0.8)	3.7	0.6	4.5	7.0	3.3	(0.9)	(5.2)	(7.7)	(8.5)	(6.1)	(8.2)	(5.9)
Equiv unit vol change (1 ft = ~0.6 cy/ft)		-42	-46.8	-12	55.2	9	67.8	105	49.2	-13.2	-78	-115.2	-127.8	-91.8	-122.4	-88.2
Net Volume Change (cy) to next		(17,760)	(29,400)	12,960	12,840	38,400	51,840	30,840	18,000	(27,360)	(38,640)	(121,500)	(65,880)	(42,840)	(105,300)	(44,460)
Cumulative volume Change (cy) per reach		(17,760)	(47,160)	(34,200)	(21,360)	17,040	68,880	99,720	117,720	90,360	51,720	(69,780)	(135,660)	(178,500)	(283,800)	(328,260)
Average Annual Volume Change (cy/yr) by reach		(710)	(1,886)	(1,368)	(854)	682	2,755	3,989	4,709	3,614	2,069	(2,791)	(5,426)	(7,140)	(11,352)	**(13,130)**
Change 1941-2008 (@Veg Line)		1	184	580	755	846	1067	1106	1033	877	725	647	541	390	313	120
Avg Change (1941-2008) - 67 years		0.0	2.7	8.7	11.3	12.6	15.9	16.5	15.4	13.1	10.8	9.7	8.1	5.8	4.7	1.8
Equiv unit vol change (1 ft = ~0.6 cy/ft)		0.6	110.4	348	453	507.6	640.2	663.6	619.8	526.2	435	388.2	324.6	234	187.8	72
Net Volume Change (cy) to next		22,200	229,200	240,300	192,120	573,900	391,140	256,680	573,000	288,360	164,640	356,400	167,580	84,360	129,900	43,560
Cumulative volume Change (cy) per reach		22,200	251,400	491,700	683,820	1,257,720	1,648,860	1,905,540	2,478,540	2,766,900	2,931,540	3,287,940	3,455,520	3,539,880	3,669,780	3,713,340
Average Annual Volume Change (cy/yr) by reach		331	3,752	7,339	10,206	18,772	24,610	28,441	36,993	41,297	43,754	49,074	51,575	52,834	54,773	**55,423**

APPENDIX TABLE A10. [page 3 of 3] Shoreline position data for four reaches by transect along Sullivan's Island 1941–2008. Distances are measured from the survey control line (Middle Street) to the seaward vegetation line (upper portion of the table) and the wet-dry sand contact line (approximate mean high water). The lower half of the table presents rates of change in feet and equivalent sand volume in cubic yards as explained in the text.

Shoreline	Year	REACH C – EAST STUDY AREA																				
Distance shown from BL		**88**	**90**	**95**	**98**	**100**	**105**	**108**	**110**	**115**	**118**	**120**	**125**	**128**	**130**	**135**	**138**	**140**	**145**	**148**	**150**	**155**
Edge of Vegetation	**1941**	1121	1086	981	912	864	660	677	686	711	713	733	817	860	862	868	879	925	980	1074	1134	1132
Edge of Vegetation	**1949**	1158	1078	1106	1069	1049	925	900	866	825	794	803	805	832	865	912	884	963	1019	1018	1096	1131
Edge of Vegetation	**1953**	1208	1189	1129	1080	994	1073	1065	1038	952	936	961	858	904	887	871	894	931	1011	1005	1100	1113
Edge of Vegetation	**1963**	1270	1263	1231	1206	1195	1164	1126	1092	1010	983	937	880	852	849	908	919	932	1000	1059	1158	1319
Edge of Vegetation	**1967**	1242	1208	1167	1170	1160	1143	1111	1092	1000	947	917	885	852	862	892	906	912	1061	1142	1178	1289
Edge of Vegetation	**1973**	1202	1157	1083	1037	985	904	862	840	808	811	736	825	844	831	972	1090	1175	1373	1385	1356	1249
Edge of Vegetation	**1979**	1292	1256	1167	1104	1073	972	941	1073	972	986	933	979	942	970	990	1063	1105	1306	1408	1423	1321
Edge of Vegetation	**1983**	1343	1296	1185	1120	1092	972	934	908	917	984	963	957	901	938	1061	1081	1141	1336	1439	1406	1314
Edge of Vegetation	**1999**	1115	1088	1043	1055	1076	1137	1164	1193	1278	1329	1368	1460	1502	1502	1722	1689	1652	1653	1562	1511	1497
Edge of Vegetation	**2006**	1127	1104	1121	1181	1219	1282	1313	1331	1406	1447	1512	1543	1529	1541	1518	1491	1478	1489	1512	1524	1444
Edge of Vegetation	**2008**	1243	1244	1243	1296	1319	1320	1392	1424	1467	1532	1540	1591	1574	1582	1548	1527	1521	1558	1573	1584	
Change 1941-2008		122	158	262	384	455	660	715	738	756	819	807	774	714	720	680	648	596	578	499	450	312
Avg Change (1941-2008) - 68 years		1.8	2.3	3.9	5.6	6.7	9.7	10.5	10.9	11.1	12.0	11.9	11.4	10.5	10.6	10.0	9.5	8.8	8.5	7.3	6.6	4.7
Equiv unit vol change (1 ft = ~0.6 cy/ft)		73.2	94.8	157.2	230.4	273	396	429	442.8	453.6	491.4	484.2	464.4	428.4	432	408	388.8	357.6	346.8	299.4	270	187.2
Shoreline	**Year**	**Reach C**																				
	Year	**88+00**	**90+00**	**95+00**	**98+00**	**100+00**	**105+00**	**108+00**	**110+00**	**115+00**	**118+00**	**120+00**	**125+00**	**128+00**	**130+00**	**135+00**	**138+00**	**140+00**	**145+00**	**148+00**	**150+00**	**155+00**
Wet - Dry Beach	**1941**	1265	1205	1201	1177	1130	973	888	861	950	1041	1095	1191	1212	1213	1212	1193	1195	1216	1245	1270	1350
Wet - Dry Beach	**1949**	1408	1406	1406	1305	1231	1169	1175	1180	1176	1157	1143	1122	1115	1102	1067	1052	1052	1108	1182	1227	1310
Wet - Dry Beach	**1953**	1546	1578	1563	1568	1545	1486	1450	1425	1368	1334	1314	1265	1236	1218	1174	1150	1140	1132	1148	1169	1270
Wet - Dry Beach	**1963**	1350	1315	1269	1248	1235	1204	1186	1172	1125	1065	1011	931	931	937	971	1011	1046	1154	1231	1297	1688
Wet - Dry Beach	**1967**	1319	1289	1226	1205	1196	1172	1146	1121	1037	993	970	967	983	997	1046	1121	1132	1265	1347	1471	1880
Wet - Dry Beach	**1973**	1247	1198	1118	1064	1024	946	913	896	865	858	862	933	1041	1125	1132	1198	1245	1483	1461	1440	1379
Wet - Dry Beach	**1979**	1471	1431	1286	1233	1213	1181	1160	1213	1181	1090	1145	1107	1079	1083	1113	1165	1221	1426	1653	1725	1362
Wet - Dry Beach	**1983**	1474	1437	1321	1255	1225	1173	1148	1135	1104	1090	1079	1059	1053	1056	1102	1174	1242	1480	1674	1753	1746
Wet - Dry Beach	**1999**	1276	1253	1220	1247	1282	1385	1451	1477	1501	1512	1523	1545	1565	1588	1811	1841	1857	1865	1892	1904	1802
Wet - Dry Beach	**2006**	1262	1284	1360	1443	1534	1483	1528	1545	1575	1597	1614	1646	1652	1647	1605	1584	1583	1644	1676	1694	1652
Change 1941-2008		-3	79	159	266	404	510	640	684	625	556	519	455	440	434	393	391	388	428	431	424	302
Avg Change (1941-2008) - 67 years		0.0	1.2	2.4	4.0	6.1	7.7	9.7	10.4	9.5	8.4	7.9	6.9	6.7	6.6	6.0	5.9	5.9	6.5	6.5	6.4	4.6
Equiv unit vol change (1 ft = ~0.6 cy/ft)		-1.8	47.4	95.4	159.6	242.4	306	384	410.4	375	333.6	311.4	273	264	260.4	235.8	234.6	232.8	256.8	258.6	254.4	181.2
Distance shown from BL		**88**	**90**	**95**	**98**	**100**	**105**	**108**	**110**	**115**	**118**	**120**	**125**	**128**	**130**	**135**	**138**	**140**	**145**	**148**	**150**	**155**
Equiv unit vol change (1 ft = ~0.6 cy/ft) @veg		73.2	94.8	157.2	230.4	273	396	429	442.8	453.6	491.4	484.2	464.4	428.4	432	408	388.8	357.6	346.8	299.4	270	187.2
Equiv unit vol change (1 ft = ~0.6 cy/ft) @wet/dry		-1.8	47.4	95.4	159.6	242.4	306	384	410.4	375	333.6	311.4	273	264	260.4	235.8	234.6	232.8	256.8	258.6	254.4	181.2
Average unit vol (@ veg vs @ wet/dry line)		*35 7*	*71 1*	*126 3*	*195*	*257 7*	*351*	*406 5*	*426 6*	*414 3*	*412 5*	*397 8*	*368 7*	*346 2*	*346 2*	*321 9*	*311 7*	*295 2*	*301 8*	*279*	*262 2*	*184 2*
Net Volume Change (cy) to next		21,360	98,700	96,390	90,540	304,350	227,250	166,620	420,450	248,040	162,060	383,250	214,470	138,480	334,050	190,080	121,380	298,500	174,240	108,240	223,200	49,590
Cumulative volume Change (cy) per reach		21,360	120,060	216,450	306,990	611,340	838,590	1,005,210	1,425,660	1,673,700	1,835,760	2,219,010	2,433,480	2,571,960	2,906,010	3,096,090	3,217,470	3,515,970	3,690,210	3,798,450	4,021,650	4,071,240
Average Annual Volume Change (cy/yr) by reach		319	1,792	3,231	4,582	9,124	12,516	15,003	21,279	24,981	27,399	33,120	36,321	38,387	43,373	46,210	48,022	52,477	55,078	56,693	60,025	**60,765**
Change 1941-1983 (@Veg Line)		222	210	204	208	228	312	257	222	206	271	230	140	41	76	193	202	216	356	365	272	182
Avg Change (1941-1983) - 42 years		5.3	5.0	4.9	5.0	5.4	7.4	6.1	5.3	4.9	6.5	5.5	3.3	1.0	1.8	4.6	4.8	5.1	8.5	8.7	6.5	4.3
Equiv unit vol change (1 ft = ~0.6 cy/ft)		133.2	126	122.4	124.8	136.8	187.2	154.2	133.2	123.6	162.6	138	84	24.6	45.6	115.8	121.2	129.6	213.6	219	163.2	109.2
Net Volume Change (cy) to next		51,840	124,200	74,160	52,320	162,000	102,420	57,480	128,400	85,860	60,120	111,000	32,580	14,040	80,700	71,100	50,160	171,600	129,780	76,440	136,200	84,420
Cumulative volume Change (cy) per reach		51,840	176,040	250,200	302,520	464,520	566,940	624,420	752,820	838,680	898,800	1,009,800	1,042,380	1,056,420	1,137,120	1,208,220	1,258,380	1,429,980	1,559,760	1,636,200	1,772,400	1,856,820
Average Annual Volume Change (cy/yr) by reach		1,234	4,191	5,957	7,203	11,060	13,499	14,867	17,924	19,969	21,400	24,043	24,819	25,153	27,074	28,767	29,961	34,047	37,137	38,957	42,200	**44,210**
Change 1983-2008 (@Veg Line)		-100	-52	58	176	227	348	458	516	550	548	577	634	673	644	487	446	380	222	134	178	130
Avg Change (1983-2008) - 25 years		(4.0)	(2.1)	2.3	7.0	9.1	13.9	18.3	20.6	22.0	21.9	23.1	25.4	26.9	25.8	19.5	17.8	15.2	8.9	5.4	7.1	5.2
Equiv unit vol change (1 ft = ~0.6 cy/ft)		-60	-31.2	34.8	105.6	136.2	208.8	274.8	309.6	330	328.8	346.2	380.4	403.8	386.4	292.2	267.6	228	133.2	80.4	106.8	78
Net Volume Change (cy) to next		(18,240)	1,800	42,120	48,360	172,500	145,080	116,880	319,800	197,640	135,000	363,300	235,260	158,040	339,300	167,940	99,120	180,600	64,080	37,440	92,400	(2,880)
Cumulative volume Change (cy) per reach		(18,240)	(16,440)	25,680	74,040	246,540	391,620	508,500	828,300	1,025,940	1,160,940	1,524,240	1,759,500	1,917,540	2,256,840	2,424,780	2,523,900	2,704,500	2,768,580	2,806,020	2,898,420	2,895,540
Average Annual Volume Change (cy/yr) by reach		(730)	(658)	1,027	2,962	9,862	15,665	20,340	33,132	41,038	46,438	60,970	70,380	76,702	90,274	96,991	100,956	108,180	110,743	112,241	115,937	**115,822**
Change 1941-2008 (@Veg Line)		122	158	262	384	455	660	715	738	756	819	807	774	714	720	680	648	596	578	499	450	312
Avg Change (1941-2008) - 67 years		1.8	2.4	3.9	5.7	6.8	9.9	10.7	11.0	11.3	12.2	12.0	11.6	10.7	10.7	10.1	9.7	8.9	8.6	7.4	6.7	4.7
Equiv unit vol change (1 ft = ~0.6 cy/ft)		73.2	94.8	157.2	230.4	273	396	429	442.8	453.6	491.4	484.2	464.4	428.4	432	408	388.8	357.6	346.8	299.4	270	187.2
Net Volume Change (cy) to next		33,600	126,000	116,280	100,680	334,500	247,500	174,360	448,200	283,500	195,120	474,300	267,840	172,080	420,000	239,040	149,280	352,200	193,860	113,880	228,600	81,540
Cumulative volume Change (cy) per reach		33,600	159,600	275,880	376,560	711,060	958,560	1,132,920	1,581,120	1,864,620	2,059,740	2,534,040	2,801,880	2,973,960	3,393,960	3,633,000	3,782,280	4,134,480	4,328,340	4,442,220	4,670,820	4,752,360
Average Annual Volume Change (cy/yr) by reach		501	2,382	4,118	5,620	10,613	14,307	16,909	23,599	27,830	30,742	37,821	41,819	44,387	50,656	54,224	56,452	61,709	64,602	66,302	69,714	**70,931**



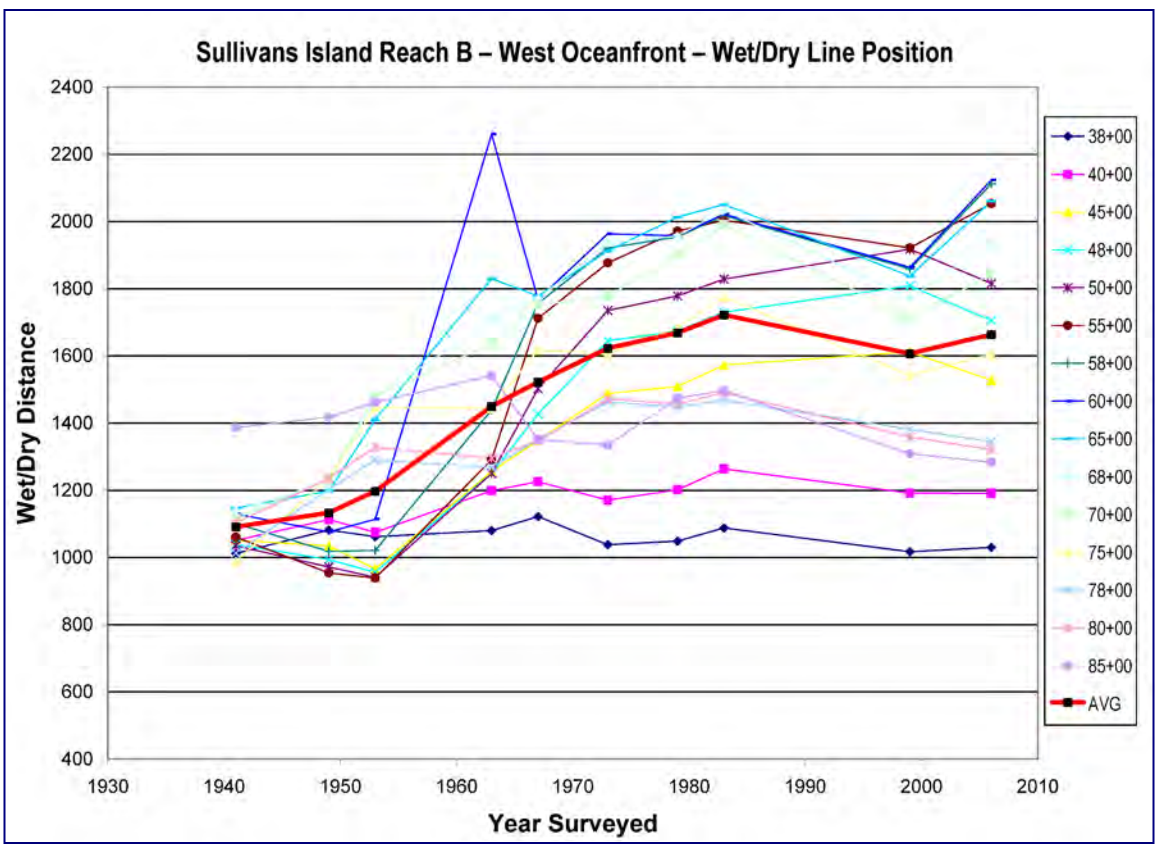
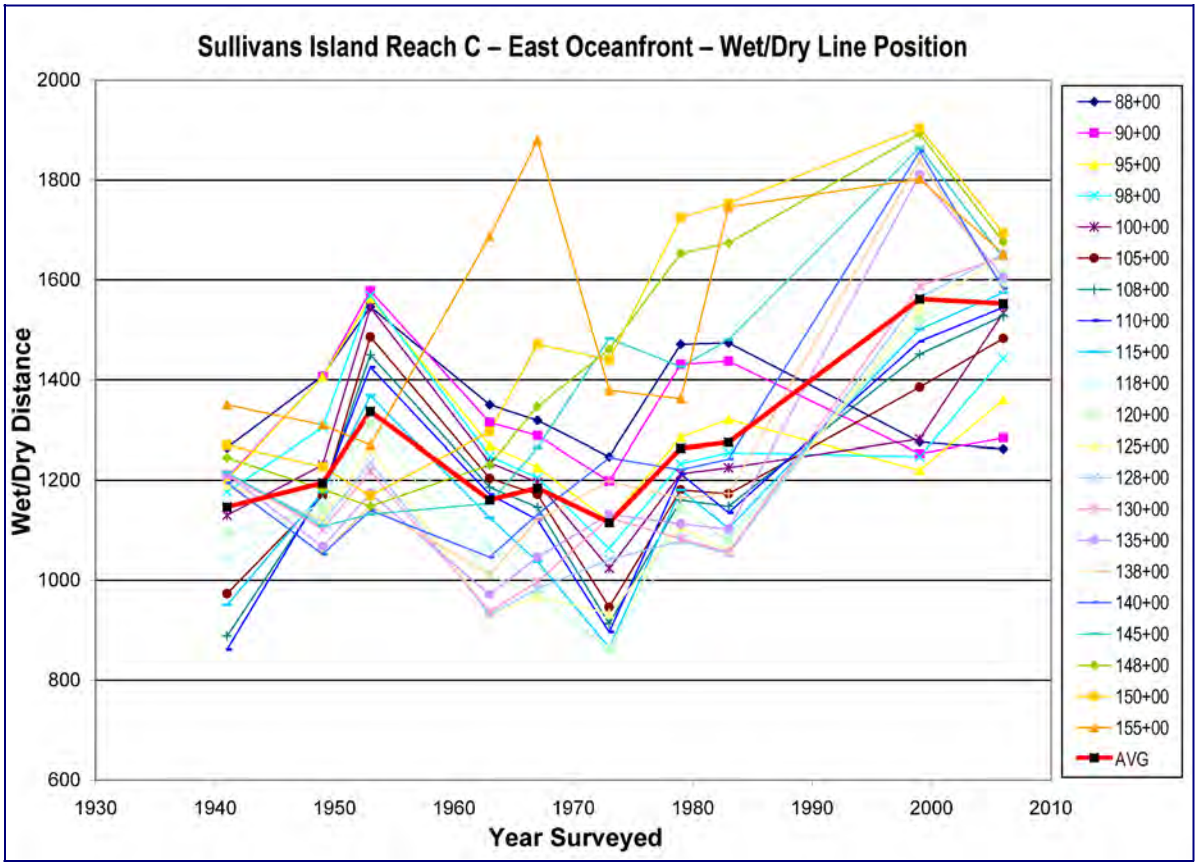


FIGURE A10-1. Trends in the approximate mean high waterline (wet-sand/dry-sand line on aerial photographs) position by reach for 1941 to 2008 based on the data in Appendix Table A10.



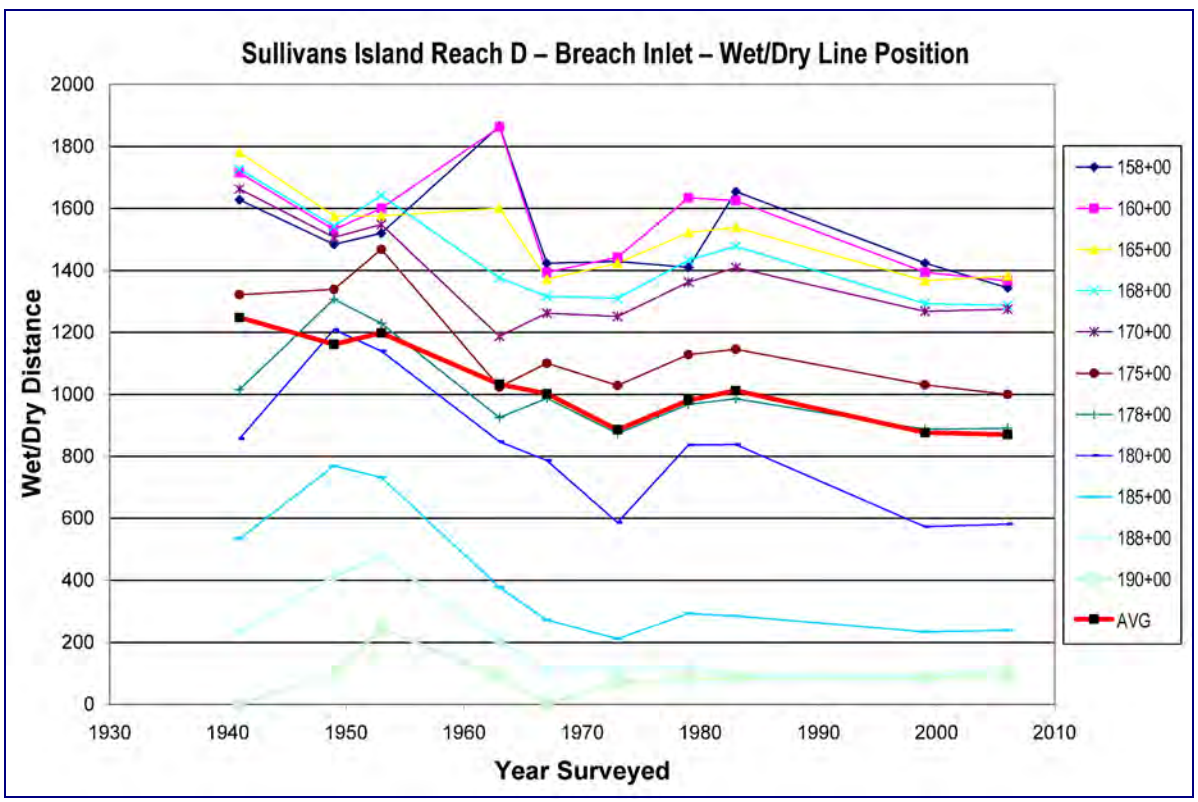


FIGURE A10-2. Trends in the approximate mean high waterline (wet-sand/dry-sand line on aerial photographs) position by reach for 1941 to 2008 based on the data in Appendix Table A10.

APPENDIX 11

Samples of Possible Funding Sources

APPENDIX 11. A SAMPLE OF POSSIBLE FUNDING SOURCES (prepared by Sabine & Waters)

Grant	Granting Agency	Deadline	Max Award	Website	Contact	Requirements	Purpose
Neotropical Migratory Bird Conservation Fund	USFWS	11/01/2008	$250,000	www.fws.gov	703-358-1784	3:1 nonfederal fund match	Long-term conservation of neotropical migratory birds and their habitats
North American Wetlands Conservation Act	USFWS	March 7, August 1	$75,000	http://www.acjv.org/funding.htm	703-358-1784	50% nonfederal fund match	Long-term protection, restoration, and/or enhancement of wetlands and associated upland habitats for the benefit of all wetlands-associated migratory birds
Sea Grant	NOAA	closed	$70,000		843-727-2078	50% nonfederal fund match	Education and extension activities that address major issues associated with marine and coastal resources
Environmental Education Grant Program	EPA	Mid-November	$50,000		202-564-0451	25% nonfederal fund match	Support environmental education projects that promote environmental stewardship
The Gaylord and Dorothy Donnelly Foundation	The Gaylord and Dorothy Donnelly Foundation	12/01/08, 03/16/09, 07/31/09		www.gddf.org	John Sands (jsands@gddf.org) 312-977-2700, 843-651-3793		Support land stewardship by limiting urban sprawl, preserving threatened landscapes, promoting sustainable land uses [We foster the conservation and stewardship of land in a natural condition, providing current and future generations a link with their heritage.]
South Carolina Conservation Bank	South Carolina Conservation Bank	March 31, July 31	bargain sale value of land	http://sccbank.sc.gov/	Marvin N. Davant DavantM @dnr.sc.gov	Property is put into conservation easement	Protect significant natural resource areas and wildlife habitats – protect water quality – maintain the state's forest lands – protect farmlands, especially family farms – protect and enhance the state's natural beauty – protect and enhance significant historical and archaeological sites – enhance public access for outdoor recreation and preserve traditional uses such as hunting, fishing, and other types of outdoor recreation – encourage cooperation and innovative partnerships among landowners, state agencies, municipalities, and non-profit organizations.
Charleston County Rural & Urban Grants Program	Charleston County		varies with their funding	www.smallchangeforbigchange.org	843-559-0572 843-202-7204		Promote rural land conservation, wetlands protection, parkland acquisition, greenway and trail acquisition, and limited minor improvements.
Acres for America	NFWF and Walmart Stores, Inc.	April		www.nfwf.org	404 679-7099	land acquisition 1:1 match	Conservation projects that result in the preservation of key tracts of land for fish, wildlife, and plants

Grant	Granting Agency	Deadline	Max Award	Website	Contact	Requirements	Purpose
Wildlife Forever	Wildlife Forever	January & July	$10,000	http://www.wildlifeforever.org/grants/overview.aspx.	763-253-0222	1:1 Fund match	Enhance wildlife and fish populations through acquisition, research, and management – conserve and enhance wildlife and aquatic habitat – promote wildlife and fish habitat and quality
The Coastal Program	USFWS			www.fws.gov/coastal/	Craig Aubrey 843-747-4707 X301	1:1 Fund match	Protection, restoration, and enhancement of fish and wildlife habitat in the nation's coastal areas
Native Plant Conservation Initiative	NFWF & Plant Conservation Alliance	Not available in 2008		www.nps.gov	Ellen.Gabel @nfwf.org	10 year commitment	Provide nonprofit organizations and government agencies funds to protect, enhance, and/or restore native plant communities on public and private lands
National Fish and Wildlife Foundation Keystone Initiative Grants	NFWF	April, November	$50,000 – $300,000	nfwf.org	(202) 857-0166 Mike Slattery	2:1 Nonfederal fund match	Bird conservation, fish conservation, marine and coastal conservation, and wildlife and habitat conservation
Pulling Together Initiative	NFWF, USFWS, BLM, USFS, USDA Animal and Plant Health Inspection Service (APHIS), and NRCS	Not available in 2008	$45,000	http://www.nfwf.org/AM/Template.cfm?Section=Grants	Ellen.Gabel @nfwf.org	1:1 nonfederal fund match	Benefit efforts by nonprofit organizations and government agencies to manage invasive and noxious plant species
Five Star Restoration Challenge Grant Program	NACo, NFWF, Wildlife Habitat Council, EPA, Southern Company, & Pacisic Gas and Electric	February	$14,500	http://www.nfwf.org/AM/Template.cfm?Section=Grants	Amanda.Bassow @nfwf.org	1:1 nonfederal fund match	Support community-based wetland, riparian, and coastal habitat restoration projects that build diverse partnerships and foster local natural resource stewardship through education, outreach and, training activities
The Laura Jane Musser Fund - Environmental Stewardship Program	The Laura Jane Musser Fund	February	$35,000	www.musserfund.org	Mary Karen Lynn-Klimenko 612-825-2024 Ljmusserfund @earthling.net		Assist public or not-for-profit entities to initiate or implement projects in rural areas to undertake consensus-based activities in environmental stewardship or dispute resolution
NOAA's OCRM – Coastal and Estuarine Land Conservation Program	NOAA	Varies	Varies	http://coastalmanagement.noaa.gov	Website	Varies	Partner with federal agencies and state and local governments to provide federal funding and technical assistance to better manage our nation's coastal resources
Southern Company Power of Flight	Southern Company & NFWF	April	$30,000 - $100,000	http://www.nfwf.org	Suzanne Sessine suzanne.sessine @nfwf.org	1:01	Projects of interest include: habitat restoration and management – environmental education involving birds, particularly in urban areas – applied research with direct implications for management and conservation – and nature tourism development