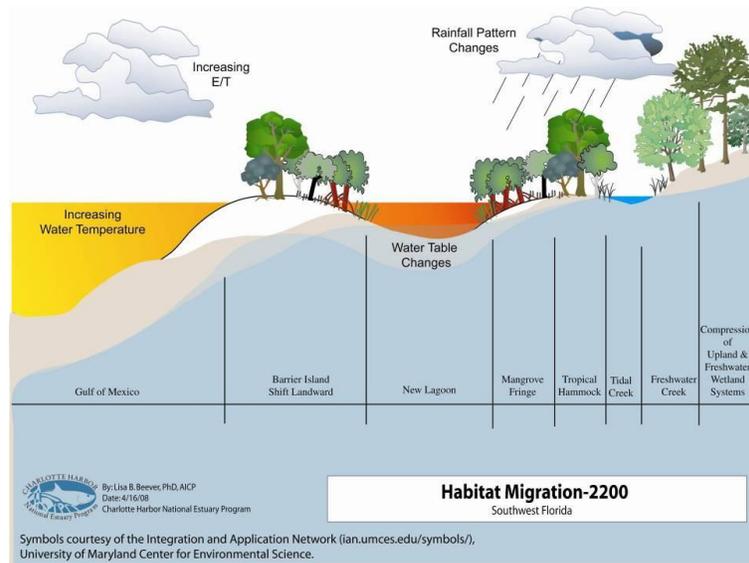


# Comprehensive Southwest Florida/Charlotte Harbor Climate Change Vulnerability Assessment

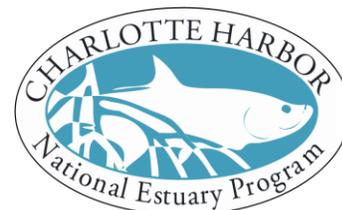


## Southwest Florida Regional Planning Council Charlotte Harbor National Estuary Program Technical Report 09-3 September 15, 2009

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The Charlotte Harbor National Estuary Program is a partnership of citizens, elected officials, resource managers and commercial and recreational resource users working to improve the water quality and ecological integrity of the greater Charlotte Harbor watershed. A cooperative decision-making process is used within the program to address diverse resource management concerns in the 4,400 square mile study area. Many of these partners also financially support the Program, which, in turn, affords the Program opportunities to fund projects such as this. The entities that have financially supported the program include the following:

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## Executive Summary

Southwest Florida is currently experiencing climate change. The natural setting of southwest Florida coupled with extensive overinvestment in the areas closest to the coast have placed the region at the forefront of geographic areas that are among the first to suffer the negative effects of a changing climate. More severe tropical storms and hurricanes with increased wind speeds and storm surges have already severely damaged both coastal and interior communities of southwest Florida. Significant losses of mature mangrove forest, water quality degradation, and barrier island geomorphic changes have already occurred. Longer, more severe dry season droughts coupled with shorter duration wet seasons consisting of higher volume precipitation have generated a pattern of drought and flood impacting both natural and man-made ecosystems. Even in the most probable, lowest impact future climate change scenario predictions, the future for southwest Florida will include increased climate instability; wetter wet seasons; drier dry seasons; more extreme hot and cold events; increased coastal erosion; continuous sea level rise; shifts in fauna and flora with reductions in temperate species and expansions of tropical invasive exotics; increasing occurrence of tropical diseases in plants, wildlife and humans; destabilization of aquatic food webs including increased harmful algae blooms; increasing strains upon and costs in infrastructure; and increased uncertainty concerning variable risk assessment with uncertain actuarial futures.

Maintaining the status quo in the management of estuarine ecosystems in the face of such likely changes would result in substantial losses of ecosystem services and economic values as climate change progresses. In the absence of effective avoidance, mitigation, minimization and adaptation, climate-related failures will result in greater difficulty in addressing the priority problems identified in the Charlotte Harbor National Estuary Program (CHNEP) Comprehensive Conservation and Management Plan (CCMP): hydrologic alteration, water quality degradation, fish and wildlife habitat loss, and stewardship gaps.

This study examines the current climate and ongoing climate change in southwest Florida along with five future scenarios of climate change into the year 2200. These scenarios include:

- 1) a condition that involves a future in which mitigative actions are undertaken to reduce the human influence on climate change (Stanton and Ackerman 2007),
- 2) a 90% probable future predicted by the Intergovernmental Panel on Climate Change (IPCC 2007b),
- 3) a 50% probable future predicted by IPCC,
- 4) a 5% probable future predicted by the IPCC, and
- 5) a “very worst” future in which no actions are taken to address climate change (Stanton and Ackerman 2007). This fifth scenario also corresponds with some of the other worst

case scenarios postulated by scientists who think the IPCC estimations are underestimated (USEPA CRE 2008).

This report also assesses significant potential climate changes in air and water and the effects of those changes on climate stability, sea level, hydrology, geomorphology, natural habitats and species, land use changes, economy, human health, human infrastructure, and variable risk projections, in southwest Florida. Among the consequences of climate change that threaten estuarine ecosystem services, the most serious involve interactions between climate-dependent processes and human responses to those climate changes.

Depending upon the method of prioritization utilized, some climate change effects will be experienced and can be compensated for in the relative near-term. Other effects with longer timelines will be more costly in habitat impact or human economic terms. There are a number of planning actions that, if undertaken now, could significantly reduce negative climate change effects and their costs in the future while providing positive environmental and financial benefits in the near term.

There are crucial areas where adaptation planning and implementation will be needed in order to avoid, minimize and mitigate the anticipated effects to the natural and man-altered areas of southwest Florida. Some effects, such as air temperature and water temperature increases, will be experienced throughout the region. Others, such as sea level rise and habitat shifts, will occur in specific geographic and clinal locations. In the course of the project 246 climate change management adaptations were identified (Beever et al. 2009) that could be utilized to address the various vulnerabilities identified for the region. Future adaptation plans will identify the management measures best suited for each geographic location.

Monitoring of the effects and results of climate changes will be necessary to assess when and where adaptive management needs to be and should be applied. A critical goal of this monitoring is to establish and follow indicators that signal approach toward an ecosystem threshold that, once passed, puts the system into an alternative state from which conversion back is difficult to impossible. The likely effects of climate change, particularly tropical storms, drought and sea level rise, on southwest Florida ecosystems and infrastructure development are too great for policymakers, property owners, and the public-at-large to stand by and wait for greater evidence before considering strategies for adaptation. It is essential to plan and act now to avoid, mitigate, minimize, and adapt to the negative effects of climate change, and to examine the possibilities of providing benefits to human and natural systems by adapting to the changing planet.

## Introduction

The **Charlotte Harbor National Estuary Program** (CHNEP, [www.chnep.org](http://www.chnep.org)) and the **Southwest Florida Regional Planning Council** (SWFRPC, [www.swfrpc.org](http://www.swfrpc.org)) have completed significant fundamental work to address sea level rise and other climate change issues to date (Beever 2009 in Fletcher 2009).

In the late 1980's the SWFRPC completed hurricane storm surge modeling and maps that have been used by the region and local governments to guide land use decisions, infrastructure investments, and conservation lands acquisition. This early work and resulting decisions have increased resiliency associated with sea level rise.

In 2003 the SWFRPC collaborated with local scientists and EPA's Office of Atmospheric Programs, Climate Change Division, on the "Land Use Impacts and Solutions to Sea Level Rise in Southwest Florida" project. The project resulted in sea level rise projections by probability and year, along with maps that represent the near worst case scenario.

On November 19, 2007, the Charlotte Harbor National Estuary Program Policy Committee added a climate change adaptation component to its Comprehensive Conservation and Management Plan (CCMP), later adopted on March 24, 2008. This set the stage for the Environmental Protection Agency (USEPA) Region 4 to fund CHNEP and, its host agency, the Southwest Florida Regional Planning Council to conduct an analysis of the effects that climate change stressors may have on ecosystems and human infrastructure within the region surrounding Charlotte Harbor and Lemon Bay. Stressors delineated in the USEPA Climate Ready Estuaries (CRE) draft "Synthesis of Adaptations Options for Coastal Areas," were considered for use in the analysis. The goal of the analysis was to identify projected impacts and potential adaptation options for implementation within that portion of the CHNEP study area that is in the region served by the Southwest Florida Regional Planning Council. Follow-on projects may be appropriate to more fully examine options for minimizing the social and environmental costs of anticipated effects.

Public participation was actively sought throughout the project; the progress and outputs of the project will be communicated to local governments, stakeholder groups and the public at large for use in developing coastal and land use planning, and avoidance, minimization, mitigation and adaptation of climate change impacts throughout the CHNEP study area.

Throughout 2008 the SWFRPC and CHNEP prepared this Vulnerability Assessment for the counties shared by the two agencies. A database with climate effects and adaptation options forms the core of the assessment. The work was funded by EPA Region 4. As one of 6 Climate-Ready Estuary pilot programs, CHNEP and SWFRPC are partnering with the City of Punta Gorda to develop a city-specific Adaptation Plan, which will implement recently adopted city

comprehensive plan policies related to climate change. The City of Punta Gorda suffered the impacts of Hurricane Charley in 2004.

In 2009, the SWFRPC adopted "Climate Prosperity" as part of its Comprehensive Economic Development Strategy to promote energy efficiencies for green savings, to encourage and support green business opportunities, and to develop green talent in the workforce. The Council has formed an Energy & Climate Committee to develop plans for implementing the strategy throughout the region.

This project directly supports USEPA Strategic Plan Goal 1 (Clean Air and Climate Change) and Goal 4 (Healthy Communities and Ecosystems). Sub-objective 4.4.2 of the USEPA Strategic Plan supports research that contributes to the overall health of people, communities and ecosystems, with a focus on global climate change. In addition, this project will assist the USEPA's Office of Atmospheric Programs (OAP), Climate Change Division (CCD) in achieving its objective to support application of tools to assess vulnerabilities to sea level rise and integration of information on climate science, impacts and adaptation, particularly in coastal communities.

This project is consistent with the USEPA's Climate Ready Estuaries Initiative and represents the CHNEP's commitment to active participation in the USEPA proposed Pilot Program. The CHNEP is an USEPA-designated "Climate Ready Estuary." This allows coastal leaders to implement climate adaptation within their communities and market their needs and actions to public and private interests.

This project implements the CHNEP Comprehensive Conservation and Management Plan Quantifiable Objective SG-2, specifically addressing Priority Action SG-Q.

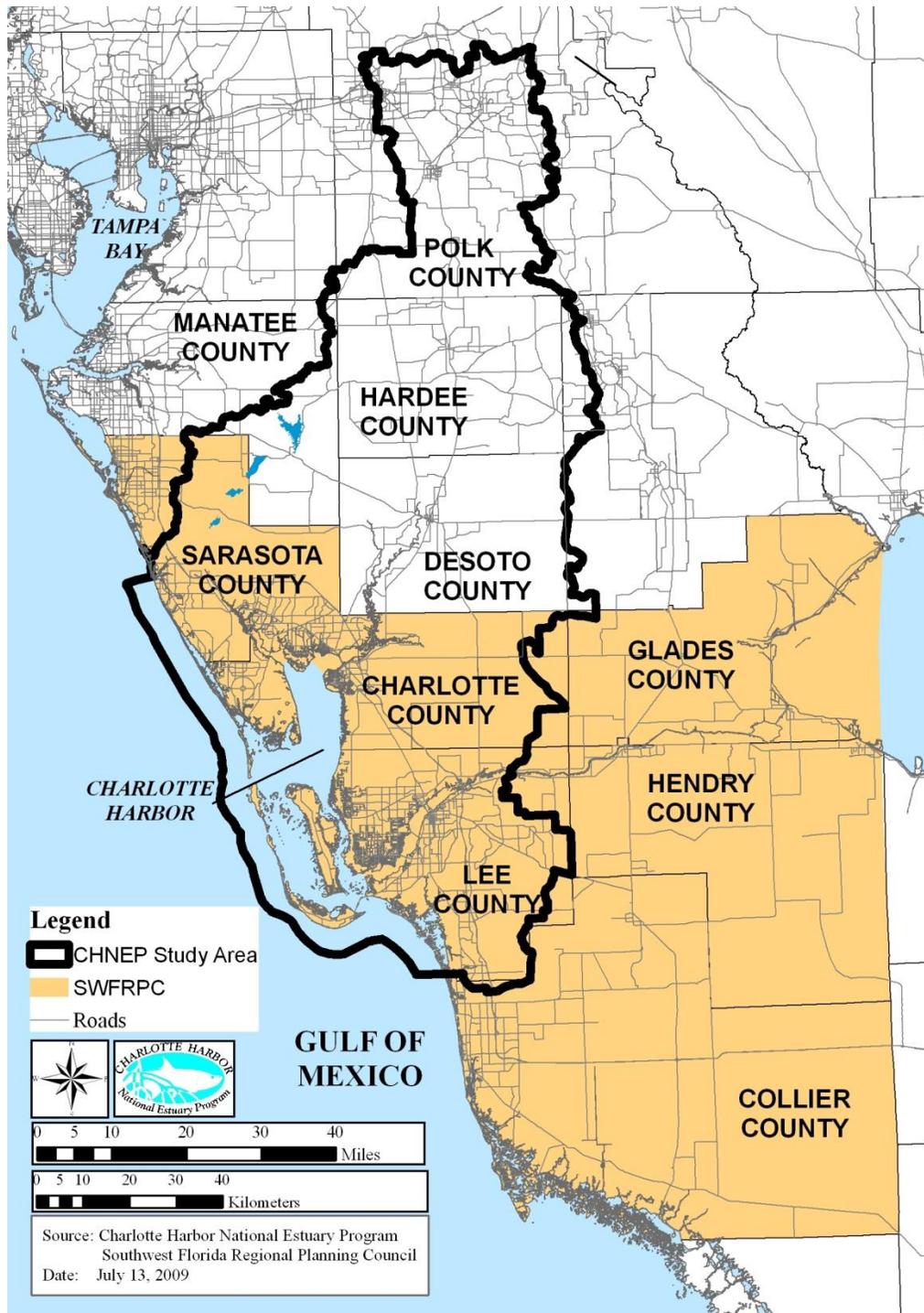


Figure i: Total Study Area of the CHNEP/SWFRPC Climate Change Vulnerability Assessment

# SG-Q

Build capacity for communities and their local leadership to mitigate and adapt to the effects of climate change through joint efforts.

## Background

Modifying the successful model of Climate Friendly Parks, EPA's Office of Water, Oceans & Wetlands and Office of Atmospheric Programs will jointly work with interested NEPs to develop and implement "Climate Ready Estuaries." The primary focus will be on adaptation of coasts to climate change as well as actions to reduce greenhouse gas emissions. The national program will designate NEPs and other coastal communities as "climate ready," allowing the coastal leaders to implement climate adaptation within their communities and market their needs and actions to public and private interests. The CHNEP is particularly well poised to implement this model. The CHNEP's host agency, the Southwest Florida Regional Planning Council, has adopted a set of resolutions that have resulted in actions at the city and county levels to protect water quality.

This priority action helps fulfill SG-3.

## Strategy

- 1) Conduct an initial overview of the significant potential human and ecological effects related to climate change from sea level rise, aquatic and atmospheric temperature rise, changes in rainfall patterns, increased storm intensity and ocean acidification. The goal of such an initial overview would be to identify potentially critical areas to be addressed related to adaptation for the Charlotte Harbor area. Subsequent efforts could evaluate options for minimizing the social and environmental costs of anticipated effects.
- 2) Develop greenhouse gas emission and carbon sequestration inventories for the Charlotte Harbor study area. Results from these inventories could be compared with other areas regarding extent and per capita emissions and sequestration. Potential local and regional policies, consistent with state initiatives, could then be evaluated and promoted by the CHNEP to demonstrate emissions reduction and carbon sequestration.
- 3) Seek assistance from EPA's Office of Atmospheric Programs (OAP), Climate Change Division (CCD) to assess vulnerabilities to sea level rise

and integrating information on climate science, impacts and adaptation. CCD is looking to support application of those tools, particularly in coastal communities.

- 4) Establish a "Climate Ready Estuaries" program to educate, communicate and mitigate climate change and air pollution.
- 5) Develop local tools to address climate change such as:
  - a. Conceptual ecological models that display the dynamics and interactions of climate change.
  - b. Narrative and graphic representation for habitat succession in response to anticipated effects.
  - c. Identification of conflicts in the existing federal wetlands regulatory permitting decision framework, including mitigation practices with the potential to increase the potential for negative climate change wetland losses.
  - d. Best management practices (BMP) methods manual for habitat restoration design that will be resilient and achieve success in the face of a changing climate.
  - e. Coastal management elements and comprehensive plan language and model local ordinances.
- 6) Consider resolutions supporting Florida Governor Crist's Executive Order 07-126.
- 7) Establish an environmental statement or policy for the CHNEP committees to reduce, reuse and recycle. Share the policy with suppliers, facilities and speakers so they can help implement this policy.
- 8) Follow the suggestions from [www.epa.gov/oppt/greenmeetings/](http://www.epa.gov/oppt/greenmeetings/) including increasing conference call, video conferencing and other remote participation methods when available.
- 9) Work with hotel industry to gain green lodging certification ([www.dep.state.fl.us/greenlodging/](http://www.dep.state.fl.us/greenlodging/)) by the state of Florida.

## Potential coordinating organizations

Charlotte Harbor National Estuary Program  
County and municipal governments  
Florida Department of Environmental Protection  
Organizations: Conservation  
Organizations: Nonprofit research

## **Climate change is currently occurring and more change is to be expected.**

The climate is changing. It has been changing since the formation of the atmosphere and the presence of water as vapor, liquid, and ice on the surface of the earth. Since the Pliocene and throughout the Pleistocene and Holocene (Current) Eras, global temperatures have risen and fallen with concomitant changes in air temperature and chemistry, hydrology, geomorphology, habitats, plant and animal species, sea level, and water temperature and chemistry. With the advent of human civilization and the recording of historical records, changes in the climate have changed human economy, human health, human infrastructure and human land use (Thomas 1974).

The question for Southwest Floridians is not *whether* they will be affected by climate change, but *how much* they will be affected and in what ways including the degree to which it will continue, how rapidly change will occur, what type of climate changes will occur, and what the long-term effects of these changes will be (FOCC 2009).

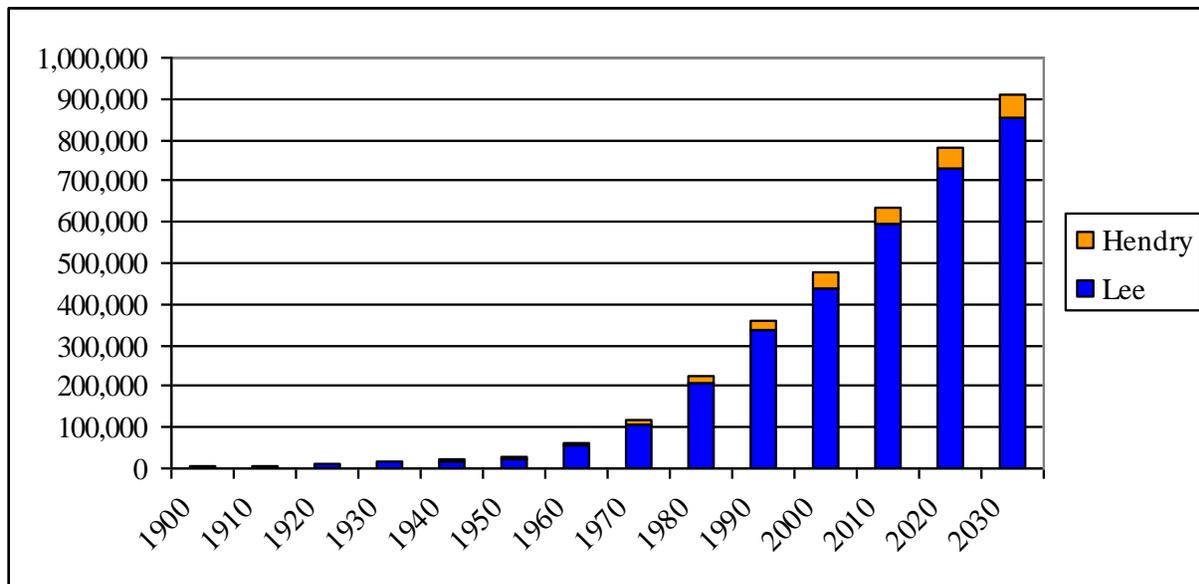
Southwest Florida is particularly vulnerable to the effects of climate change. Topography is flat, naturally poorly drained and not very high above existing sea level. The majority of conservation lands and the regional economy have major investments within close proximity of the coast or lake water bodies. The savanna climate is naturally extreme, even without new perturbations.

The Charlotte Harbor National Estuary Program (CHNEP) watershed extends approximately 130 miles, from the northern headwaters of the Peace River in Polk County to southern Estero Bay in Lee County, including connected waters in Charlotte, DeSoto, Hardee, Lee, Polk, and Sarasota Counties. The CHNEP watershed includes approximately 2,463 miles of coastal shoreline encompassing approximately 220,000 acres from the Dona and Roberts Bays in Sarasota County to southern Estero Bay in Lee County. Within the entire project area, there are 493,133 acres of wetlands, including 413,595 acres of native freshwater wetlands, 73,292 acres of native saltwater wetlands and 6,246 acres of principally freshwater exotic-infested wetlands. Native saltwater wetlands include 52,270 acres of mangroves and 9,218 acres of salt marsh. All types of wetlands constitute 17% of the CHNEP study area. Open waters constitute 13% of the CHNEP study areas and native uplands 19% (CHNEP 2008). Historically, the watershed had over 86,000 acres of wetlands in coastal areas alone. There has been a 12,708 acre (15%) loss of coastal wetlands since pre-Columbian times. Currently, over 41 percent or 1,020 miles of coastal wetland shorelines have been lost or significantly altered in the CHNEP watershed. The most significant coastal wetland losses have been on estuarine rivers and creeks and on barriers islands (CHNEP 2009).

## **Demographics, Population and Urbanized Area Growth**

The following information applies to the CHNEP Region including Charlotte, DeSoto, Hardee, Lee, Polk, and Sarasota Counties. Table references are from the University of Florida Bureau of Economic and Business Research (UFBEER) Warrington College of Business 2008 Florida Statistical Abstract.

Census-designated urban areas have grown. In 1980, urban areas were confined to small zones within Lakeland/Winter Haven and Cape Coral/Fort Myers. By 2000, all counties within the CHNEP study area except Manatee County had census-designated urban areas.



**Figure 1: Comparison of Historic and Projected Population Growth in Lee and Hendry Counties**

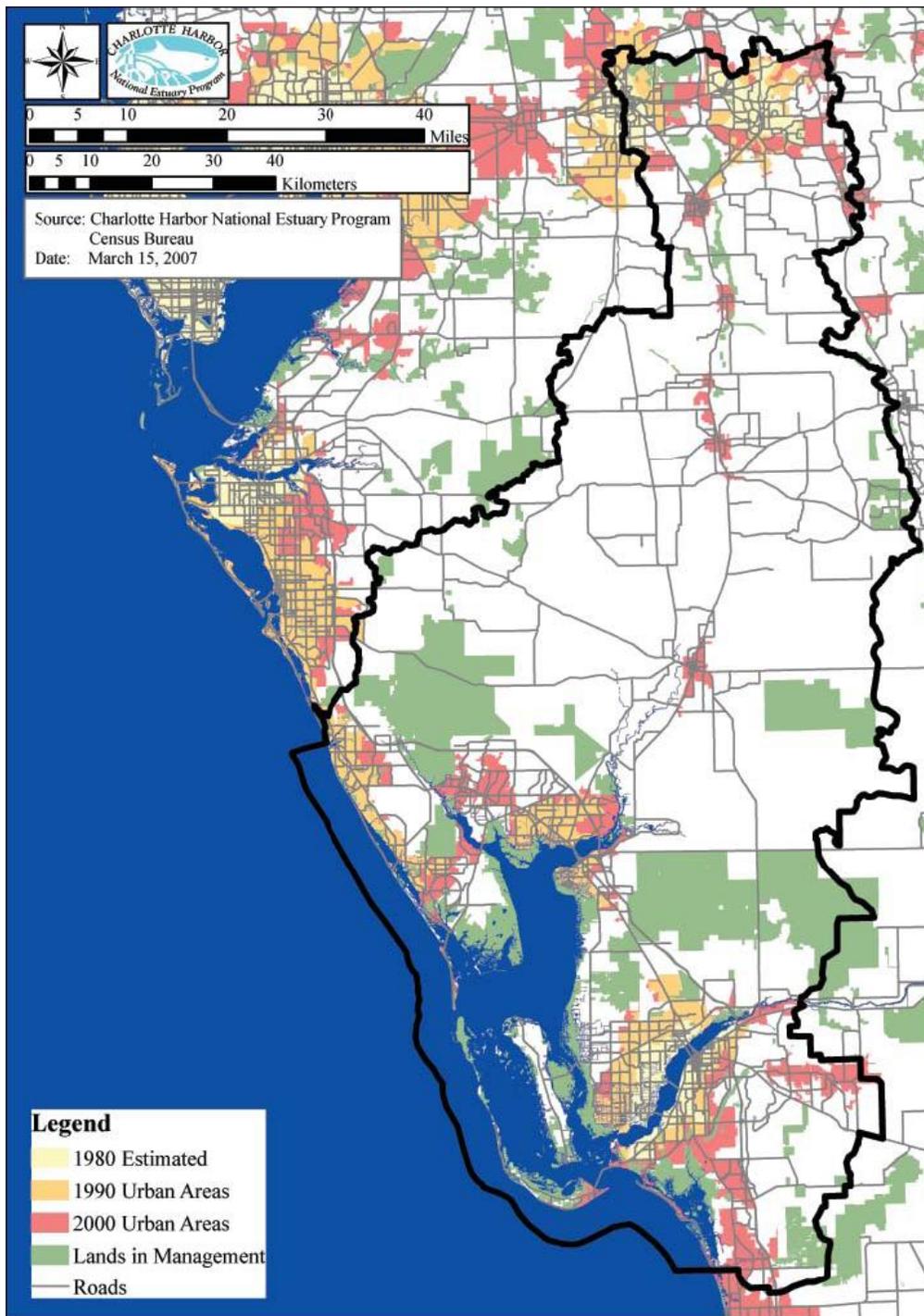
The Census Bureau defines an urbanized area as a contiguous area of over 1,000 people per square mile. The first urbanized area in lower Charlotte Harbor was defined as Fort Myers/Cape Coral as a result of the 1970 census. The geographic boundary of this area did not change much for the 1980 census. The most geographically significant increase of urbanized area for 1990 was in Cape Coral and Punta Gorda. By the year 2000, the urbanized area had greatly expanded in the lower Charlotte Harbor watershed (Figure 1).

The latest decennial census of the population was performed in the year 2000. Geographic Information System (GIS) techniques were used to analyze the study area population. There is double-counting where census blocks cross basin boundaries. Study area population nearly doubled between 1980 and 2000 by which time there were 1,052,344 residents. The study area has been experiencing exponential growth and there is a substantial difference in population between coastal counties and interior counties (see Figure 2).

In the year 2000, it was projected that, by 2025, the CHNEP study area population would be more than 1,750,000. In reality, the total estimated population of the region was already 1,810,347 by 2007, an average increase of about 17% per county across the region from 2000 to 2007. This represents a regional total of 766,299 households (Table 2.05 UFBEER 2008). Lee County’s population increased the most, about 40%, and Hardee County increased the least, about 2% (Table 1.14 UFBEER 2008). The average age across the region is 43.3 with the highest average in Charlotte County (54.4) and the lowest in Hardee County (32.1) (Table 1.38 UFBEER 2008).

Under current local government comprehensive plans with planning horizons of 2010 to 2025, urban uses, more intensive agriculture and phosphate mining are expected to increase. It is anticipated that improved environmental performance in urban, farming and mining activities may minimize the impacts of those operations on water quality and quantity degradation. Most local plans assume that a majority of the new residents will continue to choose traditional single-family housing or multifamily apartment/condominiums. Together with supporting commerce, office and industrial development, the plans project that these urban uses will take over a fifth of the region's land area by the year 2010. At the same time, areas devoted to natural preserves and water resources are not projected to grow at the same pace.

Across the region, there are 271,197 students enrolled in public, private and home school programs in grades K-12 (Tables 4.20, 4.25, 4.26 UFBEER 2008). The average high school graduation rate in the region is 75%, with the high in Sarasota County (83.5%) and the low in DeSoto County (70.5%) (Table 4.80 UFBEER 2008). Approximately 17.8% of region residents have attained at least a Bachelor's degree (Sarasota 28.8%, Hardee 6.9%) (U.S. Census Bureau 2001). In the region, there are about 272 schools, including elementary, secondary, charter and adult education facilities (school district websites).



**Figure 2: Urbanized Area Growth in the CHNEP Study Area**

The Census Bureau identifies urbanized areas with a density of at least 1,000 people per square mile. In 1980, the only urbanized areas within the CHNEP boundaries were Fort Myers/Cape Coral and Lakeland/Winter Haven. By 1990, these areas had increased in size and Venice/Englewood and Punta Gorda/Port Charlotte were added. By 2000, these areas expanded and new urban areas included coastal Estero, Lehigh Acres, North Port, Arcadia, Wauchula, Fort Meade and Bartow. Lands in management that may function as urban buffers are green.

Most of the one million residents of the CHNEP study area live within 10 miles of the Gulf of Mexico or another estuarine coast. These diverse, productive coastal and marine ecosystems provide food and other products, valuable and irreplaceable ecological functions, and aesthetic and recreational opportunities. The state's life-support system, economy, and quality of life depend on preserving and sustaining these resources over the long-term.

## **Vulnerable Human Economy, Human Health and Infrastructure in Southwest Florida**

Residents and visitors alike benefit economically from the natural resources of the CHNEP study area. The multibillion dollar agriculture, championship fishing and tourism industries, for example, are directly related to the quality of the natural environment. Natural resources also provide jobs and industry earnings as well as other public and private benefits such as recharging groundwater aquifer water supplies and providing fish and wildlife habitat.

A functional environment provides clean drinking water for homes, soil and fertilizer for crops, and wading birds and other wildlife to complement a canoe trip through the mangroves. However, none of these resources are limitless, although they are often treated as such. Tourists and residents are drawn to southwest Florida because of many natural amenities. Tourists demand clean beaches or they will seek other destinations with their vacation dollars. Likewise, residents are entitled to a healthy community, yet have a stewardship responsibility to ensure its health. The strength of the economy rests on the quality of the environment and nearly every household and occupation is in some way affected by the health of the ecosystem.

Conversion of natural landscapes to built environments has a cost in addition to that of permits, blueprints, materials and labor: loss of those "goods and services" that derive from natural ecosystems. Natural ecosystems directly or indirectly support a multitude of jobs, provide essential services for communities and make this a place to enjoy. Agriculture and phosphate mining dominate the inland economies of DeSoto, Hardee, Polk and Manatee counties, while tourism, along with residential and commercial development, plays the dominant role in the coastal economies of Sarasota, Charlotte and Lee counties. Although the outputs of goods, services and revenues from all sectors of the economy are constantly changing, it is useful to understand the economic value associated with the current activities, amenities and nonuse satisfaction levels dependent on natural resources. Economic activities that are affected by environmental quality range from recreational fishing to construction. Natural habitats, water quality and freshwater flows are necessary to maintain the amenities and natural resources that sustain fishing, tourism, recreation and a multitude of other businesses. For example, agriculture requires that the water used for irrigation and livestock meet certain water quality standards. Mining operations require adequate quantities of water, but they are also charged with meeting state water quality regulations for any water they release. The quality and economic output of these activities is dependent on the extent and quality of the natural resources they consume.

The economy of Florida is one of the most vibrant in the country, but is also extremely vulnerable to climate change. Because so much of Florida's economy is natural resource-dependent, factors that affect local, regional and global climate will impact the state's future.

This section will describe Florida's major economic sectors, from the estuaries to the inland areas, emphasizing those sectors' vulnerabilities to climate change.

## **Ocean Economy and Coastal Economy**

The "ocean economy" derives from the Gulf of Mexico, the Atlantic Ocean, and associated estuaries, resources being direct or indirect inputs of goods and/or services to an economic activity. A contributor to the ocean economy is defined as: a) an industry whose definition explicitly ties the activity to the ocean, or b) which is partially related to the ocean and is located in a shore adjacent zip code. This is arrived at in part by the definition of an industry in the North American Industrial Classification System (NAICS) (for example, Deep Sea Freight Transportation) and in part by geographic location (for example, a hotel in a coastal town). In 2003, Florida's direct ocean economy (GSP) was an estimated \$13 billion, ranking second in the nation behind California. Florida's total ocean economy that same year (including multipliers) was an estimated \$23.2 billion, which contributed 3.2% of Florida employment and 4.5% of Florida GSP in 2003. Employment forecasts project 73% growth with more than 268,000 new jobs by 2015. The Tourism & Recreation was the fastest growing sector GSP in the ocean economy, far surpassing the others with 90% growth between 1990 and 2003. The Marine Transportation Sector GSP grew 82% during the period 1990-2003. The other four sectors had either minimal growth or negative growth during that period (Kildow 2006).

The ocean economy is dominated by tourism and recreation and appears to be solidly in place for a long time to come. Marine transportation, especially passenger cruise ships, is a major economic force and by all indications will remain strong in the future. Marine construction and living resources, while considerably smaller in size also provide important inputs to Florida's overall economy. It is obvious that Florida's natural assets are the hidden treasure of the economy. Florida's natural resources, particularly its beaches and wild areas, not only draw local and tourist dollars, but they generate added non-market values for the economy. While the tourism and recreation sector was valued at more than \$26 billion in Florida's marketplace in 2003, the non-market-added values for Florida amounted to somewhere between \$3 and \$10 billion annually (Kildow 2006).

For purposes of analyzing the Florida coastal economy, counties are divided between shore-adjacent and inland counties to better illuminate the differences between the shoreline and inland regions. In 2003, Florida's coastal economy (shoreline counties) contributed an estimated \$402 billion, representing 77% of the state's total economy. Florida contributed 9.7% of the national coastal economy GSP in 2003, although the state contains only 4.6% of the total national coastal county land area.

Kildow's (2006) examination of Florida's ocean and coastal economies is a preliminary look at a complex and important foundation of Florida's economy. While there are many more ocean and coastal-related values to be measured, this report provides a solid perspective of the past, present and future of Florida's economy. Most often, population is the principal indicator of changes in coastal areas. For example, as of June 2006, Florida had three cities ranked among the top ten fastest growing cities in the U.S. However, Kildow's study indicates that economic indicators are

also excellent signals of change in coastal areas. In some ways, the economy may be a better indicator of change than population, because it reveals land use footprints for different types of economic activities. For example, between 1990 and 2003, Florida's shoreline county economy grew at a faster rate than population. Wages in coastal counties grew by 49% and GSP grew by 65%, while population grew by just 31%. During the period 1990-2003, Florida's shoreline county/Coastal Economy grew at a faster rate than the Coastal Economy of California, the Gulf States combined, and the nation. In 2003, shoreline counties statewide contributed more than 70% of all employment, population and housing in the state while encompassing only 56% of land area (Kildow 2006).

Beach property values for the State of Florida ranged from \$3.5 billion to \$17.7 billion in 2000, (using 2005 dollars). Florida ranks number one among the nation's destinations for Americans that swim, fish, dive and otherwise enjoy the state's many beaches, coastal wetlands, and shores. More than 22 million people visited the Florida coasts in 2000. The non-market value of recreational fishing along Florida's Gulf coast ranged between just under \$3.4 billion to \$5.6 billion annually in 2000, using 2005 dollars (Kildow 2006).

## **Commercial and sport fisheries and shellfish harvesting**

Florida's recreational fishing industry is of great importance to the state economy. Every year, more than 6.5 million people go on 27 million fishing trips in Florida, landing 187 million fish; another 90 million fish are captured in catch-and-release programs (Hauserman 2007). In 2005, anglers spent an estimated \$4.6 billion in Florida on equipment, access fees, and other trip-related expenses, such as food and lodging; three-quarters of this was spent on saltwater fishing trips, the rest on freshwater fishing (Florida Fish and Wildlife Conservation Commission (FWC) 2005a). Florida has become a premiere fishing destination, accounting for more than 10 percent of total U.S. recreational fishing expenses (US Fish & Wildlife Service (USFWS) 2007a).

From Lemon Bay in Sarasota County, to the Ten Thousand Islands in Collier County, the estuaries of southwest Florida support at least 384 species of bony and cartilaginous fish (Beever 1988), including the common snook (*Centropomus undecimalis*), a state listed species of special concern. Recreational fishermen come to southwest Florida in hopes of landing prized game fish such as spotted seatrout, redbfish (or red drum), snook, tarpon, and marlin. The most widely caught species in 2006 included herring, mullet, pinfish, blue runner, Spanish mackerel, kingfish, spotted seatrout, and gray snapper (National Oceanic & Atmospheric Administration (US NOAA 2007a).

In addition, Florida is the top scuba diving destination in the U.S. and one of the five most popular diving sites in the world; coral reefs and the associated fish provide the major attraction for divers.

Commercial fishing also takes place in the state, although on a smaller scale. In 2005, the dockside value of fish caught in Florida totaled \$174 million, just over 4 percent of the value of all U.S. seafood in 2005 (National Ocean Economics Program NOEP 2007b). There are probably several thousand people employed in commercial fishing, although the exact number is uncertain. While at least 150 varieties of fish and shellfish are caught for sale, more than half of

the commercial catch is shrimp, crab, and lobster, worth a total of \$98 million in 2005 (US NOAA 2007a). Florida shrimp, crab, and lobster represented about 11, 8 and 4 percent, respectively, of the value of the U.S. catch of those products in 2005. In particular, 95 percent of U.S. pink shrimp, 99 percent of Florida stone crab claw, and all Caribbean spiny lobster is Florida-caught (US NOAA 2007a). Among finfish, the top four varieties in 2005, grouper, snapper, mackerel, and mullet, brought in \$45 million, or 27 percent of commercial fishing sales (US NOAA 2007a). Florida catches accounted for 86 percent of all U.S. grouper sales and 62 percent of the mullet market in 2005.

Other fish-related industries, including seafood processing, seafood markets, fish hatcheries and aquaculture, have a larger economic impact than commercial fishing, with an estimated combined contribution of \$530 million to the state economy in 2004 (NOEP 2007a). The seafood markets and processing industries are not entirely dependent on Florida's own catch: in 2004, over 80 percent by weight of seafood processed in Florida was imported (Kildow 2006b).

The most important single variety of seafood, pink shrimp (comprising 15 percent of Florida's commercial fishing catch), is still imperfectly understood, but years of warm water temperatures and intense hurricanes have led to unusually low pink shrimp catches (Ehrhardt and Legault 1999). Climate change will make such conditions more common. In view of the small size of the commercial fishing industry, no estimate of the value of losses is calculated here. This does not mean, however, that climate change is irrelevant to fishing.

Over-fishing has already led to declining fish populations in Florida, and climate change will exacerbate the problem by destroying crucial habitats (FWC 2005b; Schubert et al. 2006). In particular, climate change will have devastating effects on the coral reef and estuarine wetland ecosystems on which many fish species depend. Coral reefs provide food, shelter, and breeding grounds to a number of recreationally and commercially important fish in Florida, including king and Spanish mackerel, red and yellowtail snapper, red grouper, and spiny Caribbean lobster (US NOAA 2007a). In addition, larger species such as marlin are often attracted to the reefs to prey on smaller reef-dwellers. Warmer ocean temperatures and increased acidity, both resulting from climate change, will cause enormous, potentially fatal harm to coral reefs.

Estuaries, which provide habitat to 70 percent of Florida's fish and shellfish species at some point in their life cycles, are severely threatened by climate change as well (FDEP 2004a; Levina et al., 2007, Bell et al. 1982). Estuaries — areas such as river deltas and bays where freshwater from the land mixes with seawater,— host various types of wetlands along Florida's coast, including salt marshes, mangroves, and seagrass beds. Some important recreational fish, like the pinfish, spotted seatrout, and pompano, spend most of their lives in estuaries. Shellfish, like crabs, oysters, and shrimp, rely on the nutrients in freshwater for their growth, making the mix of fresh and saltwater in estuaries critical to their production. For many other fish, including those that spend their adult lives in the open sea, estuaries provide nursery grounds for their young. Mullet and grouper, for example, spawn offshore and let tides and currents carry their eggs to estuaries. Salt marshes, seagrass beds, or mangrove roots then provide both food and protection from prey for the young fish. Larger predators have difficulty passing through the closely knit grasses and roots, and in some cases cannot survive in the lower salinity water (FDEP 2004b). Even fish that do not live in estuaries may be dependent for food on fish that do. Loss of

estuarine habitats can cause ripple effects throughout the marine food chain (National Wildlife Federation and Florida Wildlife Federation 2006).

As sea levels rise, estuarine wetlands will be inundated and vegetated areas will be converted to open water (Levina et al. 2007). If sea levels rise gradually and coastal development does not prevent it, the wetlands and the species they support could migrate landward (Brooks et al. 2006). But rapid sea level rise combined with structures built to protect human development, such as seawalls, prevent landward migration, causing estuarine habitats to be lost altogether. The 27 inches of sea level rise by 2060 projected in one worst case scenario is more than enough to turn most estuarine wetlands into open water (Stanton and Ackerman 2007).

More intense hurricanes also threaten to damage estuarine habitats. During Hurricane Andrew in 1992, large quantities of sediment from inland sources and coastal erosion were deposited in marshes, smothering vegetation (Scavia et al. 2002). The high winds of hurricanes also pose a direct threat to mangrove forests, knocking down taller trees and damaging others (Doyle et al. 2003).

Charlotte Harbor is highly significant to Florida as a nursery ground for marine and estuarine species. Up to 90 percent of commercial and 70 percent of recreational species landed in Florida spend all or part of their lives in estuaries. The main fishery species of commercial value in the CHNEP study area include black mullet (*Mugil cephalus*), spotted seatrout (*Cynoscion nebulosus*), black drum (*Pogonias cromis*), kingfish (*Menticirrhus* spp), southern flounder (*Paralichthys lethostigma*), blue crab (*Callinectes sapidus*), pink shrimp (*Farfantepenaeus duorarum*), stone crab (*Menippe mercenaria*), southern hard clam (*Mercenaria campechiensis*), grouper (*Epinephelus* spp and *Mycteroperca* spp), black sea bass (*Centropristis striata*), snapper (*Lutjanus* spp), Florida pompano (*Trachinotus carolinus*), bluefish (*Pomatomus saltatrix*), sand seatrout (*Cynoscion arenarius*), Spanish and king mackerel (*Scomberomorus maculatus* and *S. cavalla*), sheepshead (*Archosargus probatocephalus*) and several species of sharks.

Recreational fishing in freshwater creeks, rivers and lakes is a popular pastime in inland counties. Snook are caught as far upstream as Fort Meade, while freshwater fish such as largemouth bass (*Micropterus salmoides*), and black crappie (*Pomoxis nigromaculatus*), are also highly prized game fish throughout the CHNEP study area.

The bountiful waters off Charlotte Harbor provide some of the best saltwater sportfishing in the world. Spotted seatrout (*Cynoscion nebulosus*), red fish (*Sciaenops ocellatus*), snook, (*Centropomus undecimalis*), tarpon (*Megalops atlanticus*), grouper (*Epinephelus* spp and *Mycteroperca* spp), snapper (*Lutjanus* spp), Florida pompano (*Trachinotus carolinus*), Spanish and king mackerel (*Scomberomorus maculatus* and *S. cavalla*), sheepshead (*Archosargus probatocephalus*) and several species of sharks are just a few game fish found here. One of every three tourists comes to Florida to fish. As a result, the Charlotte Harbor region derives substantial economic benefits from the maintenance of a healthy estuarine and coastal sport fishery. It is difficult to establish a precise monetary value because of the industry's close relationship to tourism facilities and service, but the Florida Department of Environmental Protection data indicate that 21 percent of the Florida population engages in recreational fishing, and total angling in the region exceeds \$1.1 billion annually.

More than 275 species of shellfish are found throughout the waters of the Charlotte Harbor estuaries. In the ancient past, the Calusa Indians of southwest Florida gathered enormous amounts of shellfish and constructed immense mounds from the shell. These shell mounds still dot the coastal landscape of the CHNEP study area and some are protected as state archaeological sites.

In the more recent past, oysters (*Crassostrea virginica*), clams (*Mercenaria campechiensis*) and scallops (*Argopecten irradians*) were harvested commercially and recreationally throughout Lemon Bay, Gasparilla Sound, Charlotte Harbor and Pine Island Sound. The height of the shellfish industry in the Charlotte Harbor area occurred during the 1940s. Since then the commercial harvest of shellfish has been declining with the disappearance of the scallop fishery in Pine Island Sound in the early 1960s. Shellfish are a reliable measure of the environmental health of an estuary. Because shellfish feed by filtering estuary water, they assimilate and concentrate materials carried in the water. In clean water free from bacteria, red tide and other pollutants, the shellfish can be safely eaten year round. In areas of the estuaries affected seasonally by red tide or nearby urban areas, shellfish may not be safe to consume. Therefore, shellfish must be monitored regularly to protect public health. Currently, about one-third of Pine Island Sound is approved for shellfish harvesting year round. Many areas in Lemon Bay, Gasparilla Sound and the Myakka River are conditionally approved for seasonal harvest when bacteria and red tide levels are at safe levels. Pine Island Sound and Estero Bay are closed to shellfish harvesting throughout the year due to measured or probable bacterial contamination.

The importance of healthy waters for safe shellfisheries has taken on a new significance in Charlotte Harbor. A 1995 state constitutional amendment precluded the use of typical nets used in commercial fishing. Many of the commercial fishermen in the Charlotte Harbor area took advantage of aquaculture training programs. Areas of the submerged estuary bottomlands are leased to individuals by the state for shellfish aquaculture. Areas where such leases have been issued include Gasparilla Sound and Pine Island Sound. Marine shellfish aquaculture in Charlotte Harbor is primarily hardshell clams (*Mercenaria campechiensis*). Clams require proper salinity, oxygen and nutrients to grow at a reasonable rate, as well as good water quality to be safe to eat.

Fish and shellfish landings in 2007 totaled 7,579,918 pounds in the three coastal counties of the region, with Lee County landing the most, 6,154,460 pounds (Table 10.40 UFBEBR 2008).

## **Agriculture**

Agriculture is an economic anchor of Florida, second only to tourism in southwest Florida and the Charlotte Harbor region, but first in the Peace River basin. Florida's farmers and livestock producers contributed \$4.5 billion or about 1 percent of GSP, to the state's economy in 2005, and employed 62,000 workers, or 1 percent of the state's workforce (Bureau of Economic Analysis (BEA) 2007; Bureau of Labor Statistics (BLS) 2007). Florida ranked fifth in the nation in sales of all crops and second in sales of fresh vegetables in 2004 (Florida Department of Agriculture and Consumer Services (FDACS 2006b).

Across the region, in 2006, there were 5,838 farm proprietors employing 4,083 workers for an average of 1.81% of each county's workforce (Table 9.10 UFBEBR 2008). Total net farm income in 2005 was \$74,081,000, but in 2006, the total fell to \$40,818,000 (Table 9.22 UFBEBR 2008). As of 2002, the most recent year figures are available, total land in farms in the region amounted to 1,800,325 acres (Table 9.36 UFBEBR 2008) and farm products had a total market value of \$648,595,000 (Table 9.38 UFBEBR 2008).

<b>Agricultural Sectors</b>		<b>Sales</b>	<b>Employees</b>
<b>Greenhouse and nursery production</b>		<b>1,738</b>	<b>23,487</b>
<b>Fruit and tree nuts</b>		<b>1,614</b>	<b>10,002</b>
	Oranges	1,041	4,322
	Other citrus	284	1,718
	Other	288	3,962
<b>Animal production</b>		<b>1,584</b>	<b>5,930</b>
	Beef cattle	473	1,161
	Dairy cattle and milk production	461	2,000
	Other animal production	224	2,034
<b>Vegetables and melons</b>		<b>1,544</b>	<b>19,504</b>
	Tomatoes	534	N/A
	Other	1,010	N/A
<b>Sugarcane</b>		<b>587</b>	<b>2,141</b>
<b>Other field crops</b>		<b>165</b>	<b>1,394</b>
<b>Total Agricultural Sector</b>		<b>7,231</b>	<b>62,457</b>

**Table 1: Agricultural sales and employees, 2004, shown in millions of 2006 dollars**

Sources: Cash receipt figures from the Florida Agriculture Statistical Directory 2006 (Florida Department of Agriculture and Consumer Services 2006b); employment figures from Bureau of Labor Services, Quarterly Census of Employment and Wages (Bureau of Labor Statistics 2007)

Florida is well known for its \$1.3 billion citrus industry, located primarily in the southern half of the state. Florida oranges, grapefruits, tangerines, and other citrus fruits accounted for more than half the total value of U.S. citrus production in 2004. Oranges alone brought in \$1 billion in 2004, and in 2005 Florida employed 60 percent of all U.S. orange grove workers and 40 percent of all workers in the production of other citrus fruits (FDACS 2006b; BLS 2007). Freezes in the 1980s in northern Florida accelerated the establishment of citrus groves in southwest Florida, notably in Lee and Hendry Counties. More than a dozen citrus varieties are grown, although most acreage goes into juice oranges. In 2006, a total of 193,000 acres of land in the CHNEP study area was dedicated to citrus which is 30 percent of all Florida citrus acreage.

Florida's fresh vegetables and non-citrus fruits are also important to the U.S. food supply. In winter, farms lie dormant in most states, but Florida's mild climate allows produce to be grown year-round. Sales of vegetables and melons totaled \$1.5 billion in 2004, employing 19,500

people (BLS 2007). Florida ranks first in the country in sales of a host of vegetables and fruits, including fresh market tomatoes, bell peppers, cucumbers, squash, and watermelons. Florida's \$830 million in tomato sales accounted for almost half of all fresh tomatoes sold in the United States in 2005 (FDACS 2006c). Florida is also the nation's leading sugarcane producer with \$550 million in sales, more than half of the U.S total for the crop in 2004. Florida's sugarcane is grown almost entirely in the warm climate and nitrogen-rich "muck" soils surrounding Lake Okeechobee including Hendry County (Mulkey et al. 2005; FDACS 2006b; BLS 2007). Florida's greenhouse and nursery plants ranked second in the U.S. in 2005, with \$1.9 billion in sales. Greenhouses and nurseries growing house-plants, hanging baskets, garden plants, fruit trees, and cut flowers employed over 23,000 people in 2004 (U.S. Department of Agriculture (USDA) 2005; FDACS 2006c; BLS 2007).

Regionally, Manatee County produces more cucumbers than any other county in the state. Lee County is ranked second for mangos, fifth for bee products and ninth for cucumbers. Charlotte County is ranked fifth for rabbits and sixth for watermelons. Hardee County is ranked fifth in cattle and fifth in orange production. DeSoto County is ranked sixth in cattle, fourth in oranges and fourth in sod production. All in all, approximately 35 percent of the land in the CHNEP study area is dedicated to agriculture.

Florida's 1.7 million head of cattle generated \$473 million in cattle and calf sales and \$461 million in dairy sales in 2004. Most of Florida's cattle are sold as calves that are shipped to other states to be raised as beef cattle, although in-state feed lots are expanding. Less than 10 percent of the cattle in Florida are dairy cows, producing milk mostly for in-state consumption (USDA 2005; BLS 2007; FDACS 2007b).

Beef cattle follow citrus in agricultural economic importance within the CHNEP/SWFRPC region. In 1996, Polk, Hardee, DeSoto and Manatee counties ranked in the top ten beef producers in Florida. Hardee County leads the region in dairy production with 8,000 cows, and Polk County was the second largest egg producer in Florida. While ranches occupy vast areas of the CHNEP study area, ranching is a relatively benign land use. Fencing interferes little with movements of native wildlife. Natural landscapes are opened up without completely removing wetlands or forested areas. Much of the Peace and Myakka Rivers' natural shoreline beauty results from ranchers' decisions to keep cattle away from wetter areas. Ranchers also use prescribed burns to manage grasslands and native habitats. Runoff from ranch land tends to have few contaminants other than bovine coliform bacteria and nitrogen. Earlier practices of required pesticide use at cattle dipping vats are now prohibited and remediated. Unfortunately, agricultural land clearing, leveling and drainage improvements transform habitats.

Crop Type	Total Acreage	Irrigated Acreage	Million gallons/day
Citrus	834,802	99%	1,825
Sugarcane	436,452	93%	857
Greenhouse and nursery	142,580	96%	409
Vegetable Crops	239,674	88%	401
Field Crops	445,861	29%	148
Other Fruit Crops	28,955	66%	40
Livestock			32
<b>Total Agricultural Sector</b>	<b>2,139,774</b>	<b>80%</b>	<b>3,923</b>

**Table 2: Acres of irrigation by crop type, 2000 water use**

Source: U.S. Geological Survey Scientific Investigations Report 2004 (Marella, 2004)

Note: Greenhouse and nursery combines four subcategories of "ornamentals and grasses": field grown, greenhouse grown, container grown, and sod, but excludes pasture hay and other crops and grasses that utilize reclaimed water. Agricultural sector total does not include pasture hay.

Total freshwater use for agriculture has trended upward in the past several decades, reaching an average of 2 billion gallons per day in 1970, 3 billion in 1980, 3.5 billion in 1990, and almost 4 billion in 2000 (Marella 2004). Furthermore, these averages mask large seasonal variations; farmers need water most at the driest times of the year, when surface water supplies are likely to be most limited. Irrigation required more than seven times as much water in April as in July in the year 2000 (Marella 2004).

Overall, the greatest water demand in Florida is for agriculture (FDEP 2000). Over-pumping of the Floridan aquifer has already caused large decreases of groundwater pressure and also increases the potential for saltwater intrusion. Mineralized groundwater used for irrigation purposes may escape agricultural areas by runoff or seepage and add to stream flows, changing the natural water chemistry of Myakka and Peace River tributaries. Fertilizers and pesticides, which may find their way into surface and groundwater, are being addressed through recently adopted agricultural best management practices.

Growing demands for water for domestic and other purposes, combined with declining natural supplies and the potential requirements of Everglades restoration, could make it difficult to maintain even the current flow of irrigation water in the future. This is among the greatest challenges to sustainable development in Florida even in the best case scenario, where impacts develop relatively slowly.

Curiously, as Florida loses record levels of wetlands and native uplands to improved farmland, the state also leads the nation in ranches and farmland lost to development. Former ranches and farms in coastal counties are especially vulnerable to wholesale transformation into residential communities. Speculative economic pressures particularly from national and multi-national entities endanger future ranching. Some original Florida native families state the federal tax code

can compel them to sell ranches to sell farms in order to pay estate taxes. Others ranches will lease ranchland to improved agriculture that often degrade land, soils and water. Despite some Greenbelt Exemptions, development potential assessments have raised the tax base of some ranches to critical levels as nearby rural lands are developed. Citrus and vegetables can remain in the field unpicked as crop prices fluctuate unpredictably. Citrus canker and citrus greening have also added unpredictable aspects and costs to growers. Preserving the economic viability of ranches and family farms while at the same time providing for regional ecological integrity is one of the greatest economic and land use challenges in southwest Florida. The rural quality of the interior portions of the CHNEP/SWFRPC region depends on the maintenance of the ranching heritage.

## Forestry

Forestry and forest product industries contributed approximately \$3.5 billion to Florida's GSP and provided an estimated 30,000 jobs in 1997 (Hodges et al. 2005; U.S. Census Bureau 2007). Florida's forestry industry output ranks 22<sup>nd</sup> in the nation, producing a wide variety of timber and related products, like paper, mulch, and plywood (Hodges and Mulkey 2003; Hodges et al. 2005; FDACS 2007c). Almost half of the state's land area is covered by forest, roughly 29,000 square miles, mostly in northern Florida (Natural Resources Defense Council (NRDC) and Florida Climate Alliance 2001; FDACS 2007c). Four fifths of Florida's forested land is privately owned (NRDC and Florida Climate Alliance 2001).

There is no National Forest land in the SWF region (Table 10.25 UFBEER 2008). As of 2006, there were 1,007,134 acres of forest in the region, with 943,758 of those acres in timber. Polk County has the highest acreage in the region, with 304,236 acres of forest (Table 10.01 UFBEER 2008).

Climate change will affect the distribution of forest tree species (Box et al 1999, Crumpacker et al 2001). Many species will experience increased productivity from higher levels of atmospheric carbon dioxide, up to an optimum level. For some species, temperatures will increase beyond their tolerance for survival. Higher temperatures will increase water stress from more evapotranspiration (water loss through leaves) and decreased soil moisture (NRDC and Florida Climate Alliance 2001). Sea level rise will also threaten coastal and low-lying forests.

Each species has different tolerances for temperature and precipitation, and thus will respond differently to climatic variations. As trees die from unfavorable conditions in one place and begin to spread into and flourish in new areas, a forest could be said to have migrated. Tree species that currently coexist may migrate together to areas more closely matching their optimal climate. Or, the species composition of forests may change as some trees are able to migrate faster than others, or to tolerate a greater range of climatic conditions. In the northern and panhandle regions of the state, the current mixed conifer and hardwood forests are likely to shift northward out of the state as temperatures rise. This could make way for tropical evergreen broadleaf forests moving northward, or if drier conditions prevail, existing forests could be reduced and pasture or another Florida ecosystem, the dry tropical savanna, could take over. Dry

tropical savanna could actually increase in forest density and become more of a seasonal tropical forest (USEPA 1997).

Florida's loblolly-shortleaf pines and longleaf-slash pines will be adversely affected as increases in temperatures surpass the upper limits of these species' optimal growth temperatures: 73 to 81°F (McNulty et al. 1996; Iverson and Prasad 2001). In contrast, oak trees, including combined zones of oaks with hickories and oaks with pines, will be positively affected, because they thrive at higher temperatures (Iverson and Prasad 2001). Higher temperature, therefore, will lead to a replacement of loblolly-shortleaf pines with oak-pine combined forests in Florida (Iverson and Prasad 2001). In general, the migration of forest ecosystems is not as simple as a uniform northward shift. Many forests will be unable to migrate because they are adjacent to developed or agricultural lands. Instead of moving with their accustomed climate, these forests will decline in health and productivity. Even where forests have the physical space to shift, there may be increased costs for the forestry industry as commercial forests move further away from current processing plants.

With less annual precipitation and a higher possibility of drought, forests will grow weaker. This added stress will make them more susceptible to pests and diseases. Due to their shorter lifecycles and mobility, pests and diseases are likely to respond to the warmer temperatures by spreading their ranges and to do so at a quicker rate than trees can migrate.

## **Other Economic Activities.**

The land-sale development that began in the 1950s dramatically and permanently changed the character and use of southwest Florida and cast the form of future development. Thousands of acres of land were subdivided over the next three decades. Pastures and croplands were drained and cleared, taking productive land out of use. Coastal lowlands were dredged and filled to create developable home sites by the tens of thousands. Canals were dug and streets were paved years in advance of when the land would actually be needed for housing. Even though some of this land was platted and sold almost 40 years ago, today a large percentage of it remains sparsely populated. The pre-existing residential centers such as Venice, Englewood, Punta Gorda, Fort Myers, North Fort Myers, Fort Myers Beach, Bonita Springs, Sanibel/Captiva, and Naples have expanded and grown. New residential entities were created out of speculative development including North Port, Port Charlotte, Punta Gorda Isles, Cape Coral, Estero, the Treeline corridor from SR 82 to Corkscrew, the Immokalee- Livingstone Road corridor, Golden Gate and Golden Gate Estates, and Marco Island.

Land and home values increased rapidly through the end of the last century and peaked in 2007. Construction employed 66,289 people in 2007 (Table 11.20 UFBEBR 2008). Subsequently home values across the region have decreased generally over the past two years. According to Zillow.com (2009) the average median price for homes in the region is about \$155,000, a decrease of about 7.5% over the previous 12 months.

Per capita income in 2006 ranged from \$19,545 in Hardee County to \$52,772 in Sarasota County (Table 5.10 UFBEBR 2008). Economic sectors generating the most non-farm total earnings for regional residents in 2006 were construction and healthcare (Table 5.34 UFBEBR 2008).

Health care and social assistance employed over 75,000 residents in 2002 (Table 20.03 UFBEBR 2008). As of 2007, there were at least 25 hospitals and at least 273 nursing and residential care facilities (Table 20.11 UFBEBR 2008).

According to the Southwest Florida Regional Planning Council (2009), building permits across the region have decreased in number and in value significantly over the past year, falling about 60%. As of January 2009, the average unemployment rate in the region was 9.7%, with the high in Lee County (11.5%) and the low in Hardee County (7.8%). All counties have experienced increases in the unemployment rates over the previous 12 months.

The value of manufacturing shipments from the region totaled \$7,105,336 in 2002, the most recent year with available data (UFBEBR 2008 Table 12.06). DeSoto and Hardee Counties had no manufacturing shipments in that year. Wholesale trade sales in the region amounted to more than \$10 billion in 2002, the most recent year figures were available (Table 16.06 UFBEBR 2008), with retail sales totaling over \$17 billion.

In 2007, there were a combined 142 banks and credit unions operating in the region (Tables 17.09 and 17.31 UFBEBR 2008) and 1,142 insurance carriers (Table 17.43 UFBEBR 2008).

2007 figures show regional participation in broadcasting, telecommunications, publishing, motion picture and sound production, and computer-related communications industries that employs at least 17,000 people (UFBEBR 2008 Tables 14.05, 14.06, 14.36, and 14.37 ).

As of January of 2009, there are 1,452 state, county and municipally-owned bridges in the region, along with 14,697 centerline miles of all types of roadways. Drivers traveled 55,960,301 daily vehicle miles. As of 2007, there were 2,000,197 registered motor vehicle tags in the region (UFBEBR 2008 Table 13.31). There are 17 commercial and general aviation airports in the region that had well over a half million take-offs and landings in 2007 (UFBEBR 2008 Table 13.9).

## **Tourism**

Tourism plays a major economic role in southwest Florida. Many residents initially came to the area for work, military service or on vacation and then decided to make the region their home (CHNEP CCMP 2008). Surveys indicate that beaches remain the top attraction for both domestic and international visitors (CHNEP CCMP 2008). Each year, visitors make 85 million trips to Florida's scenic beaches, rich marine ecosystems and abundant amusement parks, staying for an average of five nights per trip. Of these trips to Florida, 78 million are taken by domestic travelers, or one trip per year for every fourth U.S. resident, and 7 million trips by international visitors, one third of which are Canadian. A further 13 million Florida residents take recreational trips within their home state, and many more travel on business within the state, or participate in

recreational activities near their homes (VISITFLORIDA 2007a; b). In 2006, almost a tenth of the state economy (9.6 percent, or \$65 billion), Florida's gross state product (GSP), came from tourism and recreation industries including restaurants and bars; arts, entertainment and recreation facilities; lodging; air transportation; and travel agencies. An additional \$4 billion was collected in sales tax on these purchases and \$500 million in the "bed tax" charged by some counties on stays in hotels, motels, vacation rental condos, and campgrounds (VISITFLORIDA 2007a; b).

On a regional basis for the upper Charlotte Harbor watershed (DeSoto, Hardee and Polk Counties), tourism is considered the "third industry," behind citrus production and phosphate mining. In the upper Peace River basin, tourists are attracted to Cypress Gardens, Bok Tower and its botanical gardens, and major league baseball training sites. Tourists and winter visitors are drawn to natural resource attractions in the inland parts of the CHNEP study area such as the Winter Haven Chain of Lakes, the Peace River and the Highlands Hammock State Park. Canoeing and freshwater fishing are common attractions in central Florida lakes, canals and rivers.

In coastal southwest Florida (Collier, Charlotte, Lee and Sarasota Counties), tourism has been an important element of the economy since the nineteenth century. In Lee County alone, tourism employs 1 out of every 5 people. Approximately 5 million visitors a year generate approximately \$3 billion in economic impact. In 2008, the tourist tax collection generated \$23.1 million dollars. Seasonal residents spend extended periods of time enjoying the temperate winter climate and warm Gulf waters. Longer visits are also common by international travelers from places such as Canada and Germany. The coastal area also attracts vacationing tourists and business travelers for shorter periods of time. The total coastal population increases by more than 30 percent above the permanent population because of seasonal, business and vacationing tourists. Coastal residents and tourists alike enjoy renowned boating and fishing, shelling and bird watching and baseball spring training. Attractions include a number of state parks in CHNEP's coastal area. In recent years, polluted water and red tide have threatened the tourism economy of the area.

Across the six counties comprising the SWFRPC, arts, entertainment, recreation, accommodation and food services accounted for more than \$2,550,000,000 in 2002 (Table 19.05 UFBEBR 2008). Over 128,000 recreational and commercial boats were registered in 2007 (Table 19.45 UFBEBR 2008). There are 17 state parks and over 23,000 hotel and motel units (Tables 19.52 and 19.60 UFBEBR 2008).

### **Lee County**

In Lee County, tourism employs 1 out of every 5 people. Approximately 5 million visitors a year generate approximately \$3 billion in economic impact. In 2008, the tourist tax collection generated \$23.1 million dollars.

During the 12-month period from July 2007 through June 2008, Lee County hosted an estimated 4.9 million visitors. More than half of these visitors stayed with friends or relatives while visiting (2.7 million), and 2.2 million stayed in paid accommodations. Lee County's top international markets for the 2007/2008 year include Canada (138,422 visitors), Germany (129,194), and the

United Kingdom (122,602). Visitors from the UK were more likely to visit during the summer months; German visitors were more likely to visit in the fall; and Canadian visitors, during the winter months. Among US residents staying in paid accommodations, ten percent of Lee County's visitors were Floridians, with more than 160,000 visitors from July 2007-June 2008. The bulk of these came during the warmer months of spring and summer. In total, visitors spent an estimated \$2.9 billion in Lee County from July 2007-June 2008. Visitor expenditures were highest during the winter 2008 season (January-March), which, coincides with the region's dry season. One-third of the annual visitor expenditures were brought into the County during this three-month period which represents only one quarter of the days in the year. The average Lee County visitor spent \$131.68 per day while visiting.

## **Collier County**

The Naples, Marco Island, Everglades Convention and Visitors Bureau (CVB), reports for the 2008 year end statistics, show that short-term visitors staying in hotels, vacation rentals and campgrounds create an annual economic impact of over \$1.25 billion in Collier County, and the more than 31,000 employees in tourism and hospitality made Collier County the destination of choice for over 1.4 million visitors, an increase of 1.4% over 2007. New survey results indicate that 40.8% of visitors included nature activities, 15% included cultural activities and 34% were attracted by Collier County's clean environment. 82.9% indicate they plan to return in the future, with 55.2% saying they will return in 2009.

## **Mining**

Mining is a surprisingly significant part of Florida's economy and comes with environmental impacts that contribute to the vulnerability of regional natural resources. Mineral production figures were only available on a statewide basis; figures for 2005 are reported here.

In 2005, 35,215,000 metric tons of sand and gravel were mined at a value of \$219,410,000. 115,000,000 metric tons of crushed stone were mined at a value of \$994,000,000 (Table 10.71 UFBEBR 2008). The phosphate industry is a significant factor in resource management within the CHNEP watershed. The "Bone Valley" phosphate deposit, of more than 500,000 acres, lies principally within the Peace River watershed. This deposit is a large resource, used for agricultural fertilizer production. Mineable reserves within the Bone Valley deposit are projected to last until at least 2050. The deposit provides approximately 75 percent of the phosphate required by U.S. farmers and about 25 percent of the world supply.

Approximately 240,000 acres have been mined in Polk, Hillsborough, Hardee and Manatee counties. Previous mining in Polk County accounts for more than 197,000 acres of the total mined area. Additional mines are under consideration for Hardee, DeSoto and Manatee counties at this writing. In total, approximately 6 percent of the land in the CHNEP study area is dedicated to phosphate and rock mining. The phosphate industry is an important segment of the economy within the central and northern portions of the CHNEP watershed. The Florida phosphate industry employs more than 5,000 people with a total annual payroll of more than \$400 million. In addition, the industry contributed nearly \$86 million in severance, property,

sales and other taxes in 2003. The first \$10 million collected in severance tax each year is directed to the Florida Forever Trust Fund. The state of Florida uses this money to purchase environmentally sensitive lands throughout the state. Since 1979, the state land acquisition program has received more than \$530 million from the phosphate industry severance tax. Since 1975, all mined lands have been required to be reclaimed to the landforms that existed prior to mining and, today, all lands are required to be reclaimed with native plant species. Current industry practices promote coordinated reclamation, allowing for the integration of habitat networks and habitat buffers into protected environmentally sensitive areas. Mining and reclamation processes have significantly changed the landform of large areas within the CHNEP watershed. However, with the advent of regulation in the 1970s, subsequent regulatory enhancements and improved mine planning and operating techniques, environmental impacts have been reduced. The visual impact of mining, especially prior to reclamation, is nevertheless significant. Real and perceived environmental impacts due to mining and chemical processing are a source of significant public concern. The nature of that concern contributes toward differing perspectives of the industry held by citizens of the CHNEP study area.

## **Water Supply and Use**

The recent record-breaking drought (SFWMD 2009) to the contrary, Florida is generally a wet state and southwest Florida some of the wettest of the wet (Bradley 1972). The area averages 54 inches of rainfall per year, a level matched only by a few other states in the Southeast, and by Hawaii. Huge aquifers can be found under all regions of the state, and many areas have abundant surface water as well. Indeed, the majority of south Florida was a vast wetland less than 100 years ago. Current agricultural and residential development is dependent on the massive drainage efforts of the twentieth century. Florida has succeeded all too well in draining its former “excess” of water, adding to recent shortages, as well as a long and expensive process of environmental restoration of the Everglades and other wetland ecosystems.

However, the abundance of rainfall is deceptive. Precipitation is not evenly distributed throughout the year, but is heavily concentrated in the rainy season, June through October. In that hot, wet period, most of the rainfall, as much as 39 of the 54 inches, evaporates before it can be used. Demand for water, on the other hand, is highest during the dry months of the winter and spring, driven by the seasonal peak in tourism and by the irrigated winter and spring agriculture.

The study area includes two major water supply/use designated districts: the Lower West Coast Planning Area (LWCPA) of the South Florida Water Management District (SFWMD) and the Southern Water Use Caution Area (SWUCA) of the Southwest Florida Water Management District (SFWMD).

### **SFWMD LWCPA**

The southern part of southwest Florida is encompassed in the approximately 5,100 square-mile Lower West Coast Planning Area (LWCPA) of the South Florida Water Management District. This includes the watersheds of the Caloosahatchee River Basin, Estero Bay and the Big Cypress

Swamp. The LWCPA includes all of Lee County, most of Collier and Hendry counties, and portions of Glades, Charlotte and mainland Monroe counties. The population in the area is expected to increase from 908,500 in 2005 to about 1.6 million by 2025 (U.S. Bureau of the Census 2001). Most of this growth is projected to occur in Collier and Lee counties where population increases of 67 percent and 91 percent, respectively, are projected. Urban water demand (municipal, domestic self-supply, recreational and commercial) in this area will increase by 113 million gallons per day (MGD) in association with the population increase, and water demand associated with proposed new power generation facilities will increase by 67 MGD over the next 20 years. By 2025, agricultural acreage under cultivation is projected to increase by 13,400 acres, in part reflecting a shift in agricultural operations from Lee and Collier counties to Glades and Hendry counties, and requiring an additional 17 MGD in supply.

Traditional water sources for urban and agricultural use in the LWCPA have included supplies from surface water, primarily the Caloosahatchee River (C-43 Canal), and three major aquifer systems: the Surficial Aquifer System, the Intermediate Aquifer System and the Floridan Aquifer System. The Surficial and Intermediate aquifer systems typically contain fresh water, while the Floridan Aquifer, in the planning area, contains brackish water. Multiple factors, including water quality deterioration, interference with other existing users and protection of wetlands, continue to limit development of additional fresh groundwater supplies. For example, efforts to protect Lake Okeechobee from high water levels and concerns for the integrity of the Herbert Hoover Dike result in freshwater releases during the wet season, when they are not necessary. But new supplies from the Caloosahatchee River during the dry season are withheld. Alternatives to development of additional traditional freshwater sources to meet increased water needs include development and treatment of brackish groundwater in the Lower Hawthorn Aquifer; expansion of the reclaimed distribution and supply system; the capture of seasonally available surface water; and, improved storage opportunities for surface and reclaimed water.

The projected high rate of population growth in the LWCPA through the year 2025 will require the region's increased commitment to water conservation and alternative water supply development. Comparison of population projections with the water supply and conservation projects listed by SFWMD indicates that existing and proposed new supplies will be adequate to meet the projected future needs. The SFWMD has committed to maintaining efforts to assess water resources, coordinate critical resource protection strategies and projects, and restore vital environmental systems throughout the LWCPA and south Florida.

Water demand projections through 2025 were made by SFWMD in five-year increments for each of six water supply categories. Key results in terms of user/customer demands (see Figure 3) specific to the Lower West Coast Planning Area for the period of 2005 to 2025 include:

- Region wide, public water supply demands are expected to increase by 97 MGD, or 76 percent, by 2025, at which time this water supply category will represent approximately 27 percent of the region's total water demands.
- Agricultural water use, which is projected to increase by about 17 MGD, or 4 percent, will remain the largest consumer of water in the LWCPA.

- Thermoelectric power generation self-supply is a rapidly growing water use category. Future demand projections reflect that nearly 67 MGD will be required to serve new power generation facilities planned by Florida Power & Light (FPL).
- The remaining water use categories—domestic self-supply, commercial and industrial, recreational and landscape—will also experience increased demands totaling 16 MGD by 2025.

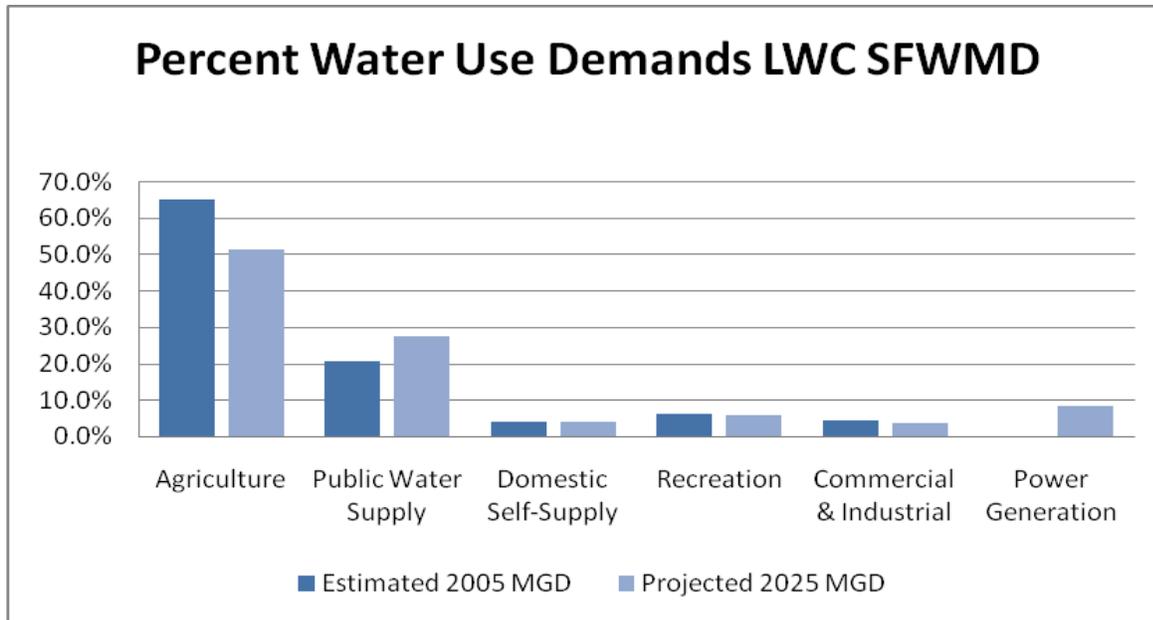


Figure 3: User/Customer Demands- Water Categories as a Percentage of Total Demand

User Demands	Agriculture	Public Water Supply	Domestic Self-Supply	Recreation	Commercial & Industrial	Power Generation	Total
<b>Estimated 2005 MGD</b>	404.8	128.1	24.4	39.5	26.6	0.5	623.9
<b>Projected 2025 MGD</b>	421.8	225.5	31.1	46.6	28.9	66.9	820.8
<b>% Change MGD</b>	4.2%	76.0%	27.5%	18.0%	8.6%	13280.0%	31.6%

Table 3: Average Year Demands and Percentage of Growth

Withdrawal demands are comparable to the use demand estimates presented in previous Lower West Coast water supply plans. The water withdrawal demands differ from the user/customer demands for public water supply, recreational self-supply and agricultural uses. The differences are caused by inefficiencies in delivery or treatment that prevents all the water being withdrawn from being available to meet the user/customer demands.

<b>County</b>	<b>Population 2005</b>	<b>Public Water Supply 2005</b>	<b>Domestic Self-Supply 2005</b>	<b>Projected Population 2025</b>	<b>Public Water Supply 2025</b>	<b>Domestic Self-Supply 2025</b>
<b>Collier</b>	317,601	272,130	45,471	608,002	532,037	75,965
<b>Lee</b>	541,398	457,634	83,764	906,199	828,383	77,816
<b>Hendry</b>	37,097	26,697	10,400	51,821	41,393	10,428
<b>Glades</b>	6,283	3,156	3,127	7,889	3,947	3,942
<b>Charlotte</b>	6,163	0	6,163	8,673	0	8,673
<b>Totals</b>	908,542	759,617	148,925	1,582,584	1,405,760	176,824

**Table 4: Population in the LWCPA, 2005–2025**

*Source: U.S. Bureau of the Census, 2001 and the University of Florida Bureau of Economic and Business Research 2006*

## **SWFWMD SWUCA**

An assessment of existing and potentially available sources of water supply in the Southwest Florida Water Management District portion of the CHNEP watershed includes surface water/storm water; reclaimed water; desalinated seawater; desalinated brackish groundwater; fresh groundwater; and conservation.

Historically, about 85 percent of the water supply in the SWFWMD Water Resource Planning Region has been provided by fresh groundwater from the Upper Floridan aquifer. For the 2006 Regional Water Supply Plan (RWSP), as was the case for the 2001 RWSP, it was assumed that the amount of water supply needed to meet projected water demands over the planning period would principally come from sources other than fresh groundwater. This assumption was based largely on the impacts of groundwater withdrawals on water resources in the Southern Water Use Caution Area (SWUCA) (SWFWMD, 1996; SWFWMD, 1993) and previous direction from the SWFWMD Governing Board. Limited additional fresh groundwater supplies were made available from the surficial and intermediate aquifers, and from the Upper Floridan aquifer, subject to a rigorous, case-by-case permitting review.

Many water users throughout the region have implemented conservation measures to reduce their water demands. Such conservation measures will continue to enable the water supply system to support more users with the same quantity of water and hydrologic stress. However, the region's

continued growth will also require techniques and technologies such as improved water treatment methods, aquifer storage and recovery (ASR), aquifer recharge systems, and off-stream reservoirs to meet the projected demands.

Within the SWFWMD portion of the CHNEP watersheds, the major river/creek water supply systems include the Myakka, and Peace Rivers; Myakkahatchee and Shell Creeks; and Cow Pen Slough. As is typical in west-central Florida, flows are highest during the four-month summer rainy season (June through September) and lowest at the end of the spring dry season in May. Major public supply utilities utilize the Peace River, Myakkahatchee Creek and Shell Creek. Shell Creek has an in-stream dam that forms a reservoir for storage. The City of Punta Gorda currently withdraws 4.0 MGD from the Shell Creek reservoir.

The entire southern portion of the SWFWMD, including the CHNEP, encompassing the Southern Groundwater Basin, was declared the Southern Water Use Caution Area (SWUCA) in October of 1992. The SWUCA encompasses approximately 5,100 square miles, including all or part of eight counties. In response to growing demands from public supply, agriculture, mining, power generation and recreational uses, groundwater withdrawals steadily increased for nearly a century before peaking in the mid-1970s. These withdrawals resulted in declines in aquifer levels throughout the basin, which in some areas exceeded 50 feet. Although groundwater withdrawals have since stabilized as a result of management efforts, depressed aquifer levels continue to cause saltwater intrusion, and contribute to reduced flows, including zero flow, in the upper Peace River, and lowered lake levels of some of the more “leaky” lakes in the upland areas of Polk and Highlands counties.

The proposed 1994 SWUCA rule had three main objectives: (1) significantly halt saltwater intrusion into the confined Upper Floridan aquifer along the coast; (2) stabilize lake levels in Polk and Highlands counties; and (3) limit regulatory impacts on the region’s economy and existing legal users.

The District has established Minimum Flows and Levels (MFLs) in the SWUCA for the Upper Floridan aquifer in coastal Hillsborough, Manatee and Sarasota counties, the upper Peace River and eight lakes in the Lake Wales Ridge in Polk and Highlands counties. Since nearly all of these proposed minimum flows or levels are not currently being met, the District has prepared a Recovery Strategy. The Recovery Strategy is designed to restore minimum flows to the upper Peace River and minimum levels to lakes in Highlands and Polk counties as soon as practical.

Approximately 409 MGD of additional water supply will need to be developed and/or existing use retired to meet demand in the Planning Region through 2025. Public supply water use will increase by 227.4 MGD over the planning period. This accounts for nearly 56 percent of the projected increase in the Planning Region and is the largest increase of all the water use categories. Environmental restoration is next at 132 MGD or 32 percent of the projected increase.

While the SWFWMD asserts that there will be significant reductions in water use as agricultural and mining areas are urbanized, these areas will be supplied principally by alternative sources, not the retired groundwater quantities from converted agriculture and mining.

County	User	2000	2005	2010	2015	2020	2025	Change in MGD	% Change
<b>Charlotte</b>	Agriculture	18.8	17.7	16.5	15.4	14.3	13.6	-5.2	-28%
<b>Charlotte</b>	Industrial & Commercial	1.6	0.2	0.2	0.2	0.2	0.2	-1.4	-88%
<b>Charlotte</b>	Public Supply	19.3	20.4	22.8	25	27.1	29	9.6	50%
<b>Charlotte</b>	Recreation and Aesthetics	3	3.6	4.2	4.8	5.3	5.8	2.8	93%
<b>Charlotte</b>	Subtotal	42.7	41.9	43.7	45.4	46.9	48.6	5.8	14%
<b>Desoto</b>	Agriculture	78.7	56.4	48.1	45.3	44	43.4	-35.3	-45%
<b>Desoto</b>	Industrial & Commercial	1.4	0.1	0.1	0.1	0.1	0.1	-1.3	-93%
<b>Desoto</b>	Public Supply	3.5	3.6	4	4.4	4.8	5.1	1.5	46%
<b>Desoto</b>	Recreation and Aesthetics	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0%
<b>Desoto</b>	Subtotal	83.8	60.3	52.4	50	49.1	48.8	-35	-42%
<b>Hardee</b>	Agriculture	55.3	57.6	61.2	68.3	75.7	83.2	27.9	50%
<b>Hardee</b>	Industrial & Commercial	5.9	7.7	12.5	12.8	13.2	13.5	7.6	129%
<b>Hardee</b>	Public Supply	2.5	2.5	2.6	2.8	2.9	3	0.5	20%
<b>Hardee</b>	Recreation and Aesthetics	0.1	0.2	0.2	0.3	0.3	0.3	0.2	200%
<b>Hardee</b>	Subtotal	63.8	68	76.5	84.2	92.1	100	36.2	57%
<b>Polk</b>	Agriculture	107.7	104.3	97.4	91.1	85.3	79.7	-28	-26%
<b>Polk</b>	Industrial & Commercial	81.6	71.9	66	67.5	69.1	70.6	-10.9	-13%
<b>Polk</b>	Public Supply	73.4	82.8	91.5	99.5	106.8	113.1	39.7	54%
<b>Polk</b>	Recreation and Aesthetics	8.8	10.2	11.4	12.6	13.8	15.1	6.2	72%
<b>Polk</b>	Subtotal	271.5	269.2	266.3	270.7	275	278.5	7	3%
<b>Sarasota</b>	Agriculture	12.7	12.8	13	13.1	13.7	14.1	1.3	11%
<b>Sarasota</b>	Industrial & Commercial	0.6	0.7	0.8	0.8	0.8	0.8	0.2	33%
<b>Sarasota</b>	Public	41.4	45.3	50.1	54.6	58.7	62.3	20.9	50%

	Supply								
<b>Sarasota</b>	Recreation and Aesthetics	8.2	9.1	10	10.9	11.8	12.6	4.4	54%
<b>Sarasota</b>	Subtotal	62.9	67.9	73.9	79.4	85	89.8	26.8	43%

**Table 5: Demand Projections Summary by County (MGD)**

Combining the information for the two water management districts for the entire study area, the 2005 and the 2025 projected water supply use is summarized in Table 6.

		Agriculture	Public Water Supply	Recreation	Commercial, Industrial, Power Generation, Self Supply	Total
<b>SFWMD</b>	2005 MGD	698.1	145.3	39.5	51.5	623.9
<b>SWFWMD</b>	2005 MGD	413.1	227.7	31.5	92.8	765.1
<b>Subtotal</b>	2005 MGD	1111.2	373	71	144.3	1699.5
<b>SFWMD</b>	2025 MGD	729.2	272.2	46.6	126.9	820.8
<b>SWFWMD</b>	2025 MGD	372.9	328.4	35.9	97.8	835
<b>Subtotal</b>	2025 MGD	1102.1	600.6	82.5	224.7	2009.9
<b>SFWMD</b>	% Change	4	87	18	146.4	32
<b>SWFWMD</b>	% Change	-9.7	44.2	14.0	5.4	9.1
<b>Total</b>	% Change	-0.8	61.0	16.2	55.7	18.3

**Table 6: 2005 and projected 2025 water use by sources for the CHNEP/SWFRPC study area**

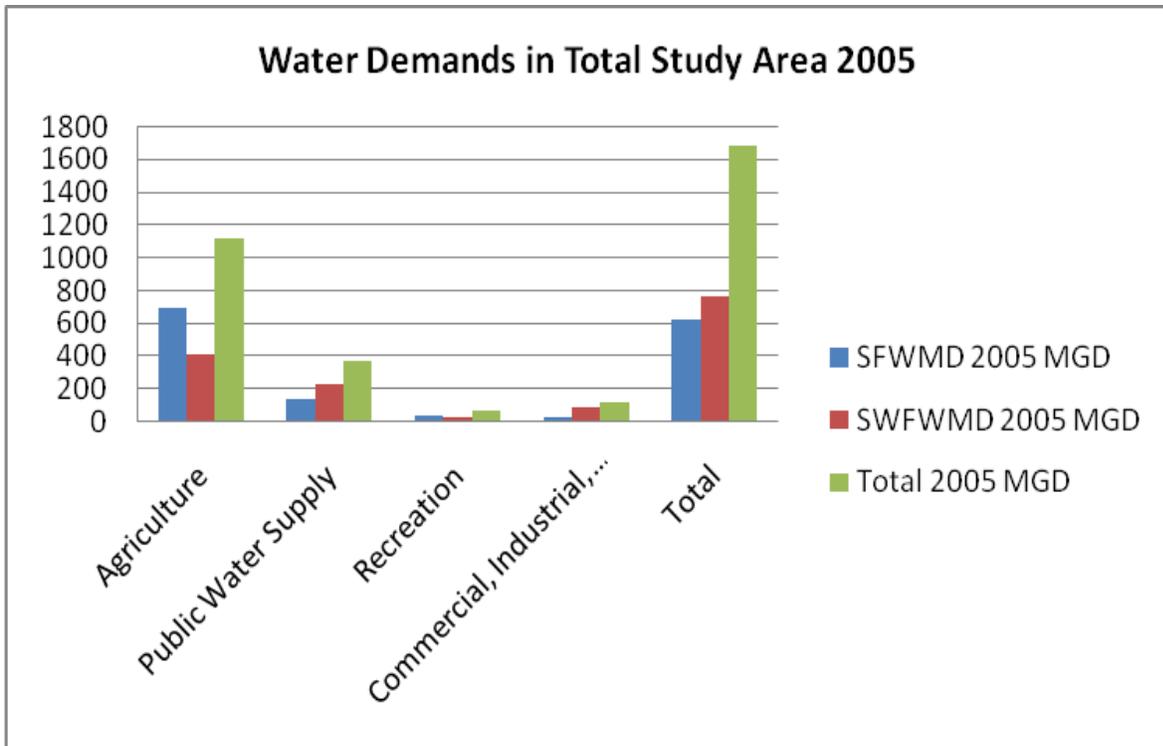


Figure 4: Water demands in the total CHNEP/SWFRPC study area 2005

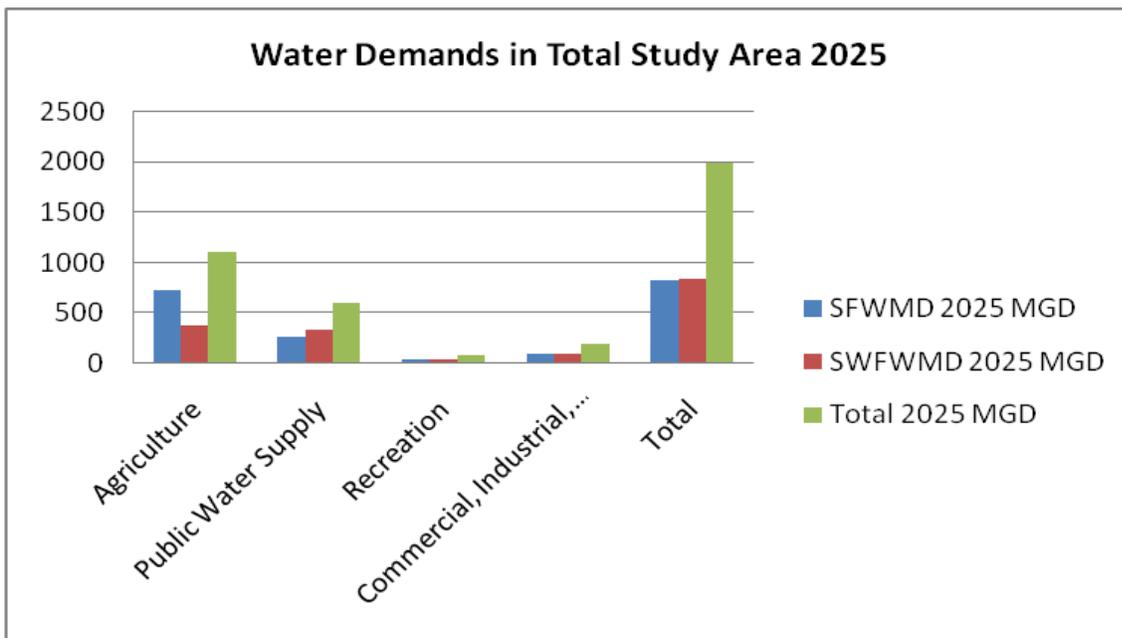
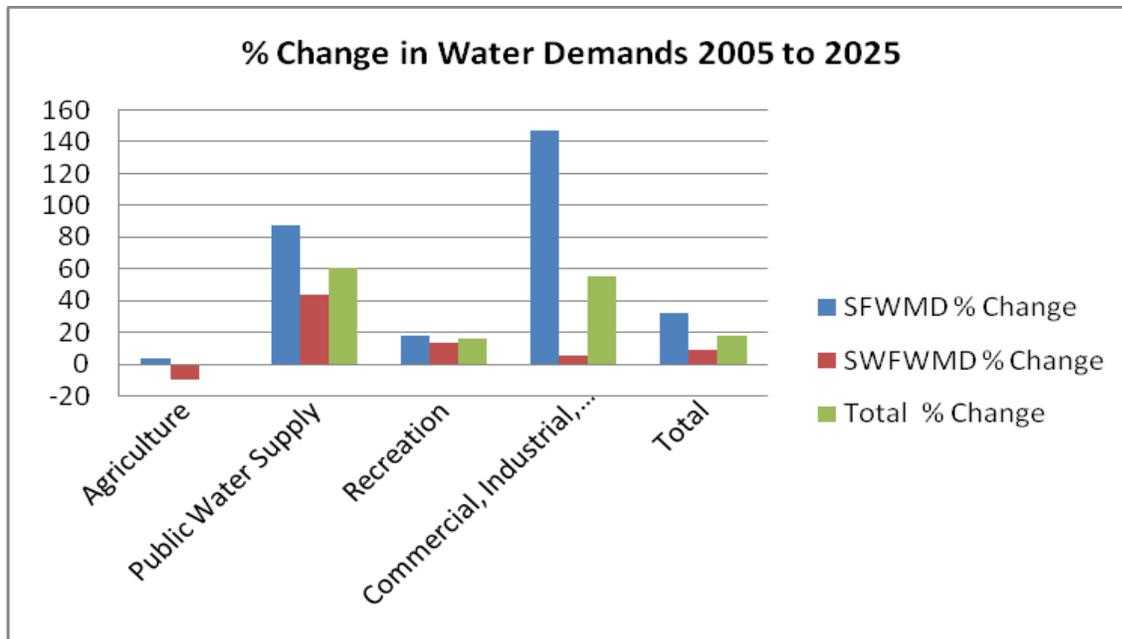


Figure 5: Water demands in the total CHNEP/SWFRPC study area 2025

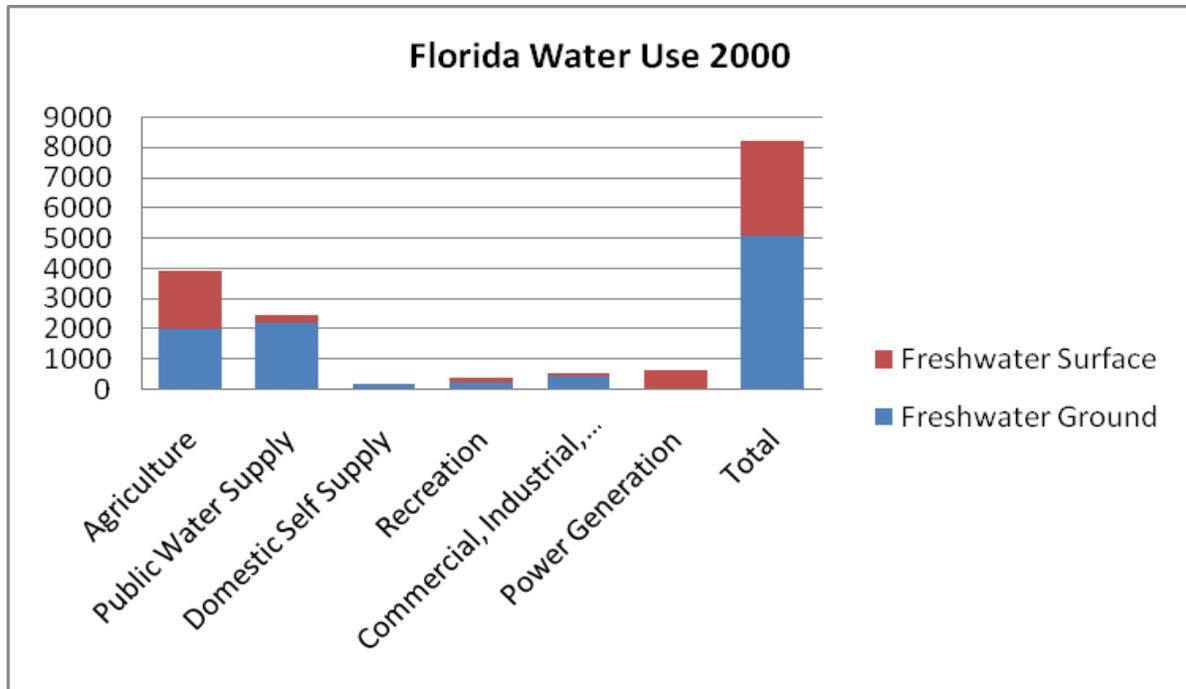


**Figure 6: Percentage change in water demands in the total CHNEP/SWFRPC study area 2005-2025**

The year 2000 is the most recent date available for the full record of total statewide water use (Florida Statistical Abstract 2006). To put the CHNEP/SWFRPC information in a state-wide perspective: in 2000, Florida used 12,000 million gallons per day (MGD) of saltwater and 8,200 MGD of freshwater. The saltwater is used almost exclusively for power plant cooling requirements (Marella 2004). Of the freshwater sources, 3,100 MGD came from surface water, and 5,100 MGD from groundwater, or aquifers. Surface water is taken from a number of sources throughout the state; however, more than 40 percent of all surface water use occurs in only two counties in Palm Beach and Hendry, the two counties directly south of Lake Okeechobee. Most surface water, statewide, is used for irrigation.

Groundwater comes, above all, from the Floridan Aquifer that underlies the entire state. There were withdrawals from the Floridan Aquifer in all but one county in 2000, accounting for 62 percent of the state's groundwater supply (Marella 2004). In the south of the state it is located farther underground than in the north and is more brackish. The Biscayne Aquifer, which lies above the Floridan Aquifer in the southeast, provided 17 percent of the state's groundwater, in Miami-Dade, Broward, and parts of Palm Beach County. Smaller aquifers elsewhere supplied the rest.

Reclaimed wastewater is a small but growing source, replacing about 200 MGD of freshwater in 2000. In addition, more than 100 desalination plants are in operation around the state, almost all used to reduce the salinity of brackish groundwater. Most are quite small, but there are a handful of 10-40 MGD plants (FDEP 2007a). The first large scale attempt at the more difficult and expensive task of desalination of ocean water, the new Tampa Bay facility, is discussed later in this report.



**Figure 7: Total water use in MGD in Florida 2000**

Source: U.S. Geological Survey Scientific Investigations Report 2004 (Marella 2004)

More than half of the freshwater used in Florida is for irrigation including both agriculture and “recreational irrigation” of golf courses, sports fields, parks, cemeteries, and public spaces. Related household uses, such as watering lawns, are included in “public supply” or “domestic self-supplied” water. In 2002, Florida had 2.31 million acres of harvested cropland, of which 1.70 million acres, or 74 percent, were irrigated (Marshall et al. 2003). The irrigated area represented 5 percent of the total land area of the state. Citrus fruits, sugar cane, greenhouse and nursery crops, and vegetables account for most of the irrigated area, and most of the irrigation water use, as shown in Table 2, above. Recreational irrigation, accounting for about 5 percent of all freshwater use, is primarily for golf course irrigation, although other uses are also included. Recreational use of freshwater has been growing rapidly in recent years (Marella 2004). After irrigation, the largest category of water use is the public water supply, at 30 percent of the freshwater total. Per capita usage in 2000 amounted to 174 gallons per day for the population served by the public water supply (most but not all of the state), just below the national average of 180 gallons per day. Public supply includes some commercial, industrial, and public uses (e.g., firefighting), as well as household use. Florida’s household use of public water supply averaged 106 gallons per person per day in 2000, down from 144 gallons per person per day in 1980, as a result of conservation efforts that have already been implemented (Marella 2004).

## Power and Energy

Currently crude oil and gas production in the region is limited to Lee and Collier Counties which produced 242,590 barrels of oil and 22,669 cubic feet of natural gas in 2007 (UFBEBR 2008 Table 15.09).

Florida's electricity is expensive, and high energy prices can be expected well into the future, even without the added strain of climate change (Stanton and Ackerman 2007). The electricity sector in Florida includes 138 power plants, 24 of which represent over 56 gigawatts (GW) of capacity. (A gigawatt is a million kilowatts.) Florida's power plants are spread statewide, and the oldest date to the 1950s. The size of new plants increased dramatically through the early 1980s, with the addition of nuclear plants and natural gas plants. From the mid-1980s, new plants were primarily smaller natural gas generators (USEPA 2006). Currently, the system relies heavily on power plants that burn natural gas (33 percent) and coal (29 percent); oil and nuclear power (12 percent each) make up the remainder. Twenty five planned new plants will primarily burn natural gas, and it is expected that oil plants will be converted to burning gas or be phased out by 2015. The southwest Florida region is served by three investor-owned electric utilities, four generating and non-generating municipal electric utilities, and two non-generating rural electric cooperatives (UFBEBR 2008 Table 15.14) that utilize coal, oil, natural gas and nuclear fuels.

The transmission system reflects the location of power plants, with large lines extending down the center of eastern and western coastal counties. As coal plants have become less attractive politically, financially, and environmentally, the state has increased its reliance on natural gas plants, causing concern about the lack of diversity in Florida's energy portfolio (Platts 2007). Florida's electricity market has been affected by rising gas and oil prices, which have caused electricity prices to jump from 6.9 to 8.8 cents per kilowatt-hour (kWh) between 2000 and 2005. The U.S. Energy Information Administration (EIA) estimates that energy prices will stabilize at approximately 8.1 cents per kWh over the next two decades if oil prices settle at \$60 a barrel. Floridians were projected to draw a peak demand of nearly 47 GW in 2007, 3 percent higher than the peak of 2006 (North American Electric Reliability Corporation 2006; Stanton and Ackerman 2007).

Early power plants were built near the coastline, and now, numerous power plants and transmission lines remain close to the coastline, exposing significant energy infrastructure, and thus power system reliability, to storm damage, even without the more intense hurricanes that climate change may produce (Florida Public Service Commission 2006).

Florida's energy infrastructure is particularly vulnerable to sea level rise and storm impacts (Karl et al. 2009). Most of the petroleum products consumed in Florida are delivered by barge to three ports, two on the east coast and one on the west coast. The interdependencies of natural gas distribution, transportation fuel distribution and delivery, and electrical generation and distribution were found to be major issues in Florida's recovery from recent major hurricanes. (Bull et al. 2007).

The Gulf Coast is home to the U.S. oil and gas industries, representing nearly 30 percent of the nation's crude oil production and approximately 20 percent of its natural gas production. One-third of the national refining and processing capacity lies on coastal plains adjacent to the Gulf of Mexico. Currently the southwest coast of Florida is not subject to oil exploration or extraction but the Florida legislature and an active lobbying group from Texas is attempting to open up Florida's nearshore areas of the Gulf of Mexico to this activity. Proponents of Gulf drilling have stated that the off-shore drilling is unaffected by hurricanes and negative climate effects. This position is not supported by the facts (Karl et al. 2009).

Several thousand offshore drilling platforms, dozens of refineries, and thousands of miles of pipelines are vulnerable to damage and disruption due to sea level rise and the high winds and storm surge associated with hurricanes and other tropical storms. For example, Hurricane Ivan in 2004 destroyed seven platforms in the Gulf of Mexico, significantly damaged 24 platforms, and damaged 102 pipelines. Hurricanes Katrina and Rita in 2005 halted all oil and gas production from the Gulf, destroyed more than 100 platforms and damaged 558 pipelines, and disrupted nearly 20 percent of the nation's refinery capacity. Chevron's \$250 million "Typhoon" platform was damaged beyond repair. Plans are now being made to sink its remains to the seafloor (Karl et al. 2009; CBO Testimony 2005).

Relative sea level rise in parts of the Gulf Coast region (Louisiana and East Texas) is projected to be as high as 2 to 4 feet by 2050 to 2100, due to the combination of global sea level rise caused by warming oceans and melting ice and local land sinking (Potter et al. 2008).

Combined with onshore and offshore storm activity, this would represent an increased threat to this regional energy infrastructure.

### **The economic value of the CHNEP study area**

In 2008, the SWFRPC study area supported 652,037 full-time and part-time jobs, not including employed illegal aliens or criminal employment activity, and \$44.6 billion in total sales annually (SWFRPC 2009). According to the 1998 Estimated Value of Resources study commissioned by the CHNEP, in 1998, the CHNEP study area supported 124,000 full-time and part-time legal jobs and \$6.8 billion in total sales annually. Based on the 1998 level of economic activity, the watershed also provides about \$9.5 billion per year in net value to recreation users and produces about \$3.2 billion per year total income to the area. Assuming a linear extrapolation, the 2008 values would be about \$1.8 billion per year in net value to recreation users and production of about \$16.8 billion per year total income to the area. Table 7 summarizes consumer surplus and total income derived from natural resources in the watershed in a one-year estimate based on the best information available for 1994 through 1996.

In addition to these billions of dollars in annual benefits, the public receives uncounted benefits such as clean air to breathe and the scenic beauty of a river, values difficult to quantify yet still tied to the quality of the environment. What happens to these counted and uncounted economic benefits if natural resources are damaged? Certainly the quantity of wildlife will decline and so will other natural benefits such as purifying and recharging the drinking water supply. While jobs in mining or construction may be created, if there are declines in environmental quality, more environmental jobs may be destroyed and higher pollution costs imposed. Economic and natural resource decisions are connected. When considering land-use changes, should only the initial project payoffs be considered or, on the other hand, should both the short- and long-term costs and benefits be considered? For example, building roads and causeways not only increases access to public lakes, trails and beaches, but it also increases the value of adjacent private lands for more intensive use. Therefore, the cost of such new facilities should include the natural

benefits lost not only from the right-of-ways, but also from the adjacent lands opened up for urban development. Are these total costs considered when planning for the future?

Measuring the economic value of the environment and its quality is a difficult assessment. Although it is rarely considered, the economic value associated with the current uses of resources, such as tarpon fishing in Charlotte Harbor, or “nonuse” values, such as the wetlands naturally providing treatment of storm water, are extremely important to the regional economy (CHNEP CCMP 2008).

Assessments of the value of natural resources must make certain assumptions and use estimates. These assumptions make the results imprecise and may overestimate some economic values and underestimate others. Economists use two methods to estimate the total economic value of CHNEP study area natural resources: consumer surplus and total income.

Consumer surplus may be thought of as consumer “profit.” Although this money does not actually change hands, it represents the value of human satisfaction from using the resource. For example, if a family on vacation rented kayaks at a wildlife refuge for \$100 but had been willing to pay up to \$120, they would receive a \$20 benefit in consumer surplus.

Total income cannot be added to consumer surplus, it simply reflects value differently. It includes income from direct, indirect and induced wages. Any business that relies on natural resources to make money usually also requires goods and services from other businesses. Typically, this support includes food, transportation, utilities, office supplies and professional services. These related goods and services also produce an income and additional benefits, such as jobs. The combined income of a business and the related sales it generates from other companies is the total income that a particular business generates in the regional economy. For example, the same family on vacation that rented kayaks also likely spent money for gas, meals and hotel lodgings. In this case, total income attempts to account for the additional expenditures required to use the resource.

<b>Resource Activity/Amenity</b>	<b>Consumer Surplus</b>	<b>Total Direct, Indirect and Induced Income</b>
Tourism and Recreational Industries	in Other Recreational Activities	\$2,889,431,681.35
Commercial Fishing	*	\$29,770,581.73
Recreational Fishing	\$141,028,291.35	in Tourism
Other Recreational Activities**	\$1,064,592,096.69	in Tourism
Agriculture	*	\$883,266,944.13
Mining	*	\$355,435,013.89
Nonuse Value of Wetland Areas in CHNEP study area	\$1,162,680,033.63	NA
<b>TOTAL</b>	<b>\$2,368,300,421.67</b>	<b>\$4,157,904,207.95</b>

\*Not Provided due to information disclosure constraints

\*\* e.g. boating, swimming, and other water sports, nature observation

**Table 7: Annual consumer surplus and annual total income in the CHNEP study area adjusted to 2008 dollars**  
*Source: Hazen and Sawyer 1998*

Economic assessments help people to understand the basic linkage between the natural and economic geography. Natural resources are commonly taken for granted or simply discounted when assessed with more traditional methods of economic valuation. By considering the economic value of natural resources, it is possible to avoid passing on the costs of the present natural resource alterations to future generations.

## **The Current Climate of Southwest Florida**

In discussions of climate change, it is important to note the difference between weather and climate. The difference largely amounts to time scale and trends. While “weather” is generally accepted to be the atmospheric conditions over a short period of time, “climate” refers to the long term, accumulated trends in atmospheric conditions. According to the IPCC, “climate change” refers to changes in those trends over time scales of not less than “decades or longer” (IPCC editor A.P.M. Baede document named WG-1 <http://www.ipcc.ch/pdf/glossary/ar4-wg1.pdf> accessed on 6/29/09).

The climate of southwest Florida is subtropical or tropical savanna (Hela 1952). This results in alternating wet season flooding (between June and September) and severe dry season drought from November to April). Typically, between 18 to 23% of annual rainfall occurs in dry season and 60 to 72% of the rainfall occurs in wet season (Drew and Schomer 1984). Seasonal wetlands, such as hydric pine flatwoods, become saturated and attain standing water in the middle to late wet season (Beever and Dryden 1992). It is interesting to note that the distribution of large, landscape scale hydric pine flatwoods in southern Collier and southern Lee Counties corresponds with areas of higher rainfall isoplethes of 60+ inches annually (Bamberg 1980). Rainfall in the wet season follows a bimodal pattern, with the first peak in May or June and the second in September or October. It is of note that this pattern corresponds with peak flowering periods for the understory components of the freshwater wetland plant community.

Thunderstorms are more frequent (over 100 annually) in the Fort Myers area, in the center of the southwest Florida, than at any other location along the eastern Gulf coast (Jordan 1973) and seventy-five percent of these storms occur in the summer (Jordan 1973, Duever et al. 1979). Short duration, high intensity thundershowers are the result of cyclic land-sea breeze convection in a diurnal pattern peaking during late afternoon or early evening. Thunderstorm rainfall can be very local, resulting in differences of up to five inches per month between areas less than five miles apart (Duever et al. 1976). Individual cloud volumes during thunderstorms in south Florida can range from 200 to 2,000 acre-feet (Woodley 1970).

Wind patterns of south Florida are determined by the interaction of prevailing easterly tradewinds, local diurnal convective patterns in the summer, and continental cold fronts in the winter. Summer wind patterns are dominated by a daily wind shift that peaks between noon and 2:00 P.M., with an onshore sea breeze during the day and an offshore land breeze at night. Winter dry season cold fronts occur approximately once a week (Bamberg 1980). On a seasonal basis, the highest average wind speeds occur in late winter and early spring, and the lowest

speeds occur in the summer. Localized strong winds of short duration are generated by summer thundershowers, extreme cold fronts, and tropical storms (Bradley 1972). On a typical day, wind speed is lowest at night, increasing through the day to the afternoon, and decreasing again in the evening (Gutfreund 1978).

Temperature in southwest Florida is primarily controlled by latitude and maritime influences (Bradley 1972). The mean annual temperature is 74 degrees Fahrenheit, the average January temperature is 64 to 65 degrees Fahrenheit, and the average August temperature is 82 degrees Fahrenheit. Southwest Florida is one of only two areas in the southeastern United States where air temperatures exceed 90 degrees Fahrenheit more than 120 days of the year. Typically, there is a 1 degree Fahrenheit difference between Charlotte County and Collier County. More inland areas display a greater daily range in temperature than coastal habitats.

In winter, sharp drops in temperature occur following cold fronts containing cool, dry arctic air from Canada. Cooling begins after sunset and reaches the lowest temperatures at dawn. Temperature gradients of about six to 15 degrees F can occur between coastal and inland areas a few miles apart. A similar gradient of about six to 10 degrees F occurs between high, dry land (xeric pine flatwoods) and adjacent moist lowlands (hydric pine flatwoods). On calm, cold, clear nights, frost may form in moist inland areas. A severe freeze occurs approximately once every 20 years (Bamberg 1980). According to the Federal Emergency Management Agency, since 1953, disaster declarations were made in Florida six times for freezing conditions (FEMA 2009).

The mean annual relative humidity averages approximately 75% with the highest (80-90%) in early morning and lowest (50-70%) in the afternoon. Seasonal differences are not great: mean relative humidity tends to be lowest in April (71%) and highest in summer and fall (80%).

“Evapotranspiration” refers to the sum of evaporation and plant transpiration into the atmosphere. Evapotranspiration from the saturated soils of wetlands is an important control of sea breeze intensity and the formation of convective thunderstorms. Because evapotranspiration is a cooling phenomenon, land-to-water gradients are reduced, convective processes are reduced, and recently rained-upon areas receive less rainfall. The effect is a natural feedback mechanism that results in a more even spatial distribution of seasonal rainfall (Bamberg 1980). This can also ameliorate the tendency towards formation of tornadoes over hot convective dry lands.

Evapotranspiration estimates for southwest Florida range from 30 to 48 inches per year (Drew and Schomer 1984).

Southwest Florida is particularly vulnerable to weather related disasters including hurricanes and coastal storms, tornadoes, seasonal floods, landscape scale wildfires, thunderstorms/high wind, drought/heat waves, coastal erosion, sinkholes, and winter storms and freezes.

Hurricane season (June 1 to November 30) is especially brutal on southwest Florida. No one in the region lives more than 75 miles from the coast, and while storms have effects wherever they strike, they have particularly heavy impacts in coastal areas. Storm surges, wave action, high winds, and heavy rainfall can all combine to produce effects that slow or shut down life in coastal communities, disrupt normal activities, damage property, and injure people (Florida Sea Grant Coastal Storms website).

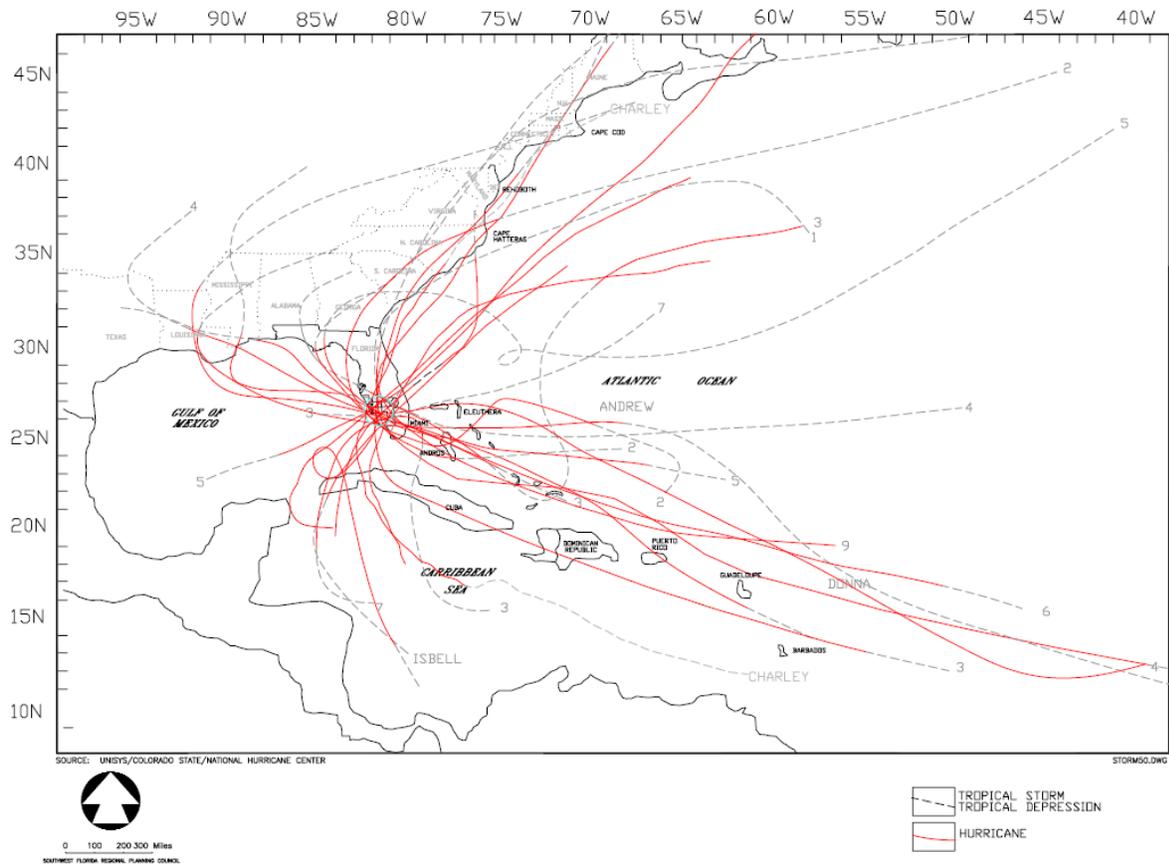
South Florida is subject to more hurricanes than any other area of equal size in the United States (Gentry 1974). The area is subject to both Atlantic and Caribbean hurricanes. Of the 38

hurricanes that passed over southwest Florida from 1901 to 1971, 30 occurred between August and October (Jordan 1973). Tropical storms strike about once every three years in southern Collier County and once every five years in the northern extents of the Southwest Regional Planning Council area (Bamberg 1980).

The three primary climatic effects of hurricanes are high wind, storm surge, and heavy rain. Wind force increases by the square of the wind speed such that a 93 mph wind exerts four times as much force as a 47 mph wind. When hurricane winds attain 249 mph, as in the 1935 Labor Day hurricane, the effects on forested ecosystems, including tree fall, substrate disturbance, and propagule (cone) distribution, can be devastating.

Hydrometeorological hazards associated with hurricanes include coastal flooding caused by storm surge; windstorms due to extremely strong winds; riverine flooding caused by heavy rains; and, tornadoes. The low sea level hugging topography, over population of the near coastal zone and limited to inadequate evacuation and helter systems place southwest Florida in the danger zone for major disaster.

From 1873 to 1993, Southwest Florida experienced forty-nine tropical cyclones of hurricane intensity. The map below shows the hurricanes that passed by and through the Region, including earlier years, going back to 1851 (Southwest Florida Regional Hurricane Evacuation Study 2005).



ATLANTIC HURRICANES 1851 - 2004  
 HURRICANES PASSING WITHIN 50 MILES OF 26.6N, 81.9W

Between 1994 and 2004 alone, there were 15 hurricanes and tropical storms. These more recent storms resulted in 16 deaths, 833 injuries, \$5.8 billion in property damage and \$300.5 million in crop damage.

While studies have shown that there is no clear, long-term trend in the number of tropical storms per storm season (IPCC 2007b; Webster et al. 2005), there have been multi-decadal scale trends in storm frequency. These trends indicate that southwest Florida is currently in an active period (Goldenberg et al. 2001). While storms can occur at any time of year, over 97 percent of North Atlantic tropical storm activity occurs from June to November (Landsea et al. 1994). Storm intensity trends indicate that the power of Atlantic tropical cyclones is rising rather dramatically and that the increase is correlated with an increase in the late summer/early fall sea surface temperature over the North Atlantic (IPCC 2007b).

## Assessment of Significant Potential Climate Changes and Their Effects

Florida is one of the most vulnerable areas in the world to the consequences of climate change, especially from increased hurricane severity, sea level rise, and climatic instability leading to

drought and flood. Regardless of the underlying causes of climate change, global glacial melting and expansion of warming oceans are causing sea level rise, although its extent or rate cannot as yet be predicted with certainty.

The five major stressors of climate change addressed in this document are: changes in the ratio of atmospheric gases; changes in air temperature and water vapor; changes in water body temperature; changes in water chemistry; and changes in sea level. In conceptual modeling these changes are called “drivers,” and for each driver, the effects on southwest Florida’s coastal resources are described in terms of what is known, what is probable, and what is possible. “Probable” means that an effect is highly likely to occur in the future, while “possible” means that it may occur, but that predicted impacts must be carefully qualified to reflect the level of variable certainty. Currently, none of the predicted effects is expected to benefit Florida’s natural resources or human population, although this perspective may change as new knowledge becomes available. The potential impacts of climate change on the state’s infrastructure, human health, and economy are significant (FOCC 2009).

The Intergovernmental Panel on Climate Change (IPCC), a scientific intergovernmental body, was established in 1988 by the World Meteorological Organization and the United Nations Environment Programme (UNEP). It is made up of a large, diverse group of scientists, governmental representatives, and individuals from around the world (IPCC 2008, FOCC 2009). The panel uses a scientific peer review process to assess the latest scientific, technical, and socioeconomic findings, providing decision makers and others with an objective source of information concerning climate issues (IPCC 2008). In 2007, both the Intergovernmental Panel on Climate Change and former U.S. Vice President Al Gore Jr. were awarded the Nobel Peace Prize "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change" ((IPCC 2008, FOCC 2009, Nobel Foundation 2007).

In 2007, the Panel issued its fourth report on global climate change (previous reports were issued in 1990, 1995, and 2001, with supplements and additional reports in intervening years) (IPCC 2007a). Building on earlier work, the report presents the findings of three major working groups: physical science of climate; impacts, adaptation, and vulnerability; and mitigation (IPCC 2008, FOCC 2009). The work of the IPCC (2008) forms some of the assumptions this report is based upon.

In this report, the list of significant potential effects on the human and native ecosystems in the southwest Florida project study area from anticipated climate change was derived from review of 354 professional source documents from federal, state, local, academic and planning sources. These documents are listed under in the Citations.

A total of 84 potential effects, in 12 categories, **Air Temperature and Chemistry, Altered Hydrology, Climate Instability, Geomorphic Changes, Habitat and Species Changes, Sea Level Rise, Water Temperature and Chemistry, Human Economy, Human Health, Infrastructure, Land Use Changes, and Variable Risk** were identified and are listed as follows:

### **Air Temperature and Chemistry**

1. Elevated atmospheric carbon dioxide
2. Increased rate of smog formation from higher temperatures
3. Hydrology, water quality and habitats in wetlands affected by increased air temperatures
4. Geomorphology and habitats at coastlines changed by increased air temperatures
5. Increased unhealthful levels of ozone pollution
6. Increased global surface temperatures
7. Disruption of timing of seasonal temperature changes

### **Altered Hydrology**

8. Altered timing of seasonal changes
9. Erosion, flooding and runoff at coastlines from changes in precipitation
10. Agricultural yields altered due to changes in rainfall patterns and amounts
11. Drought caused by increased atmospheric temperatures
12. Lower stream flows caused by droughts
13. Increased frequency of droughts and floods resulting from rising sea temperatures
14. Increased flooding from higher base water level stage at coast and in groundwater

### **Climate Instability**

15. Higher humidity from increased atmospheric/aquatic temperatures
16. Higher maximum temperatures, more hot days and heat waves over nearly all land areas
17. Higher, stronger storm surges
18. Increased hurricane intensity
19. Increased precipitation including heavy and extreme precipitation events
20. Increased storm frequency and intensity
21. 5 to 10% increase in hurricane wind speed due to rising sea temperatures
22. Sustained climate change
23. Wildfires resulting from increased atmospheric temperatures (in combination with increased drought)
24. Altered rainfall and runoff patterns

### **Geomorphic Changes**

25. Ground subsidence caused by sea level rise
26. Increased ground subsidence due to sediment changes from sea level rise
27. Coastlines altered by erosion
28. Reduced ability of barrier islands to shield coastal areas from higher storm surges.
29. Greater instability of beaches and inlets
30. Slower drainage of freshwaters through flooded estuaries and river mouths.

### **Habitat and Species Changes**

31. Regional increase or decrease of wetlands due to changes in precipitation
32. Changes to phenology of anadromous fishes
33. Changes to amphibian populations' ranges, health, and phenology
34. Changes to phenology of pest and beneficial insects

35. Conversion of wetlands to open water
36. Decreased animal health affected by increased air temperatures
37. Northward relocation of ecosystems
38. Increased harmful algal blooms
39. Increased numbers and altered ranges of jellyfish
40. Die-offs of sponges, sea urchins, and seagrasses (immobile fauna) due to increased sea surface temperatures
41. Coral bleaching and death of corals due to increased sea temperatures
42. Migration of low marsh into high marsh
43. Moth phenology shifts to earlier dates.
44. Loss of wetlands due to retreating shorelines
45. Migration/depletion of seagrass beds due to sea level rise
46. Changes in wetlands due to sea level rise
47. Shift in bird behavior phenology
48. Spread of invasive native species
49. Spread of invasive non-native species
50. Decreased biodiversity due to increased temperatures
51. Changes in aquatic food webs
52. Changes in terrestrial food webs
53. Major faunal range shifts

#### **Sea Level Rise**

54. More rapid sea level rise than previously predicted
55. Alteration of hydrology, water quality and habitats in wetlands
56. Erosion caused by sea level rise
57. Geomorphologic, hydrological and water quality changes at coasts
58. Sea level rise resulting from increased temperature and expansion of water volume
59. Sea level rise resulting from the melting arctic ice sheet
60. Higher high tides
61. Larger wind driven waves in deeper estuaries

#### **Water Temperature and Chemistry**

62. Acidification of marine waters
63. Increase in hypoxia (low dissolved oxygen)
64. Changes in sea water and estuarine water salinity
65. Geomorphologic, hydrologic, and ecologic changes at the coastline caused by increased sea surface temperatures
66. Coastlines affected by increased sea surface temperatures
67. Marine thermal stratification
68. Increased salinity in aquifers and groundwater
69. Increased winter lake temperatures
70. Changes in nutrient supply and nutrient recycling, and food webs

#### **Human Economy**

71. Ecosystem services affected by changes in estuarine water quality
72. Increased threats to coastal potable water supplies
73. Reduction in ecosystem services due to adaptations to climate change

- 74. Economic consequences for
  - commercial fisheries,
  - sports fisheries,
  - coastal tourism,
  - coastal development,
  - transportation development, and
  - critical facilities.
- 75. Increased potential financial damage from storms resulting from increasing population growth and wealth structure
- 76. Alteration of the state's tourist economy due to highly variable temperatures

### **Human Health**

- 77. Changes in waterborne disease and parasitism due to increased temperatures

### **Infrastructure**

- 78. Additional regulation of energy providers (power plants)
- 79. Physical changes in infrastructure from higher atmospheric temperatures
- 80. Physical stress on infrastructure due to sea level rise

### **Land Use Changes**

- 81. Human habitation pushed inland due to sea level rise
- 82. Reduction in the amount of land available for conservation due to sea level rise

### **Variable Risk**

- 83. Insurance risk models become obsolete due to increased atmospheric and/or aquatic temperatures
- 84. Insurance risk models become obsolete due to sea level rise

A useful tool that can be used to organize thinking regarding important ecosystem components and climate change processes is the nomenclature and hierarchy of conceptual ecological models (National Research Council 2000). Conceptual ecological models show how ecosystems have become stressed, identify the sources of these stressors, identify the major ecological effects of these stressors, and identify appropriate indicators (attributes) of these ecological effects. The links in the models between the stressors and attributes in effect become the working hypotheses that explain why the natural systems have been altered and degraded (National Research Council 2000). Changes in **Air Temperature and Chemistry**, and **Water Temperature and Chemistry**, are the stressors that result in **Climate Instability**, and **Sea Level Rise**. Subsequent ecological effects include **Altered Hydrology**, **Geomorphic Changes**, **Habitat and Species Changes**, and **Land Cover/Land Use Changes**. Consequences for human ecosystems will be expressed in **Human Economy**, **Human Health**, **Infrastructure**, **Land Use Changes**, and **Variable Risk**.

## **Potential Climate Futures**

This study initially considered three climate change “severity” scenarios: *least case* (90% probability of occurrence), *moderate case* (50% probability of occurrence), and *worst case* (5% probability of occurrence). These scenarios are based upon the USEPA Report "The Probability of Sea Level Rise." Basically, the formula multiplies the historic sea level rise (2.3 mm/yr) in southwest Florida (closest point used is St. Petersburg, Fl., Table 9-2) by the number of future years from 1990, plus the Normalized Sea Level Projections in Table 9-1.

Probability (%)	2025		2050		2075		2100		2150		2200	
	cm	inches										
<b>90 (best)</b>	7	2.8	13	5.0	20	7.7	26	10.4	40	15.7	53	21.0
<b>80</b>	9	3.6	17	6.6	26	10.1	35	13.9	53	20.8	71	28.1
<b>70</b>	11	4.4	20	7.8	30	11.6	41	16.3	63	24.7	85	33.6
<b>60</b>	12	4.7	22	8.6	34	13.2	45	17.8	72	28.3	99	39.1
<b>50 (moderate)</b>	13	5.1	24	9.4	37	14.4	50	19.8	80	31.4	112	44.2
<b>40</b>	14	5.5	27	10.6	41	16.0	55	21.8	90	35.4	126	49.7
<b>30</b>	16	6.3	29	11.3	44	17.1	61	24.1	102	40.1	146	57.6
<b>20</b>	17	6.7	32	12.5	49	19.1	69	27.3	117	46.0	173	68.2
<b>10</b>	20	7.9	37	14.5	57	22.3	80	31.6	143	56.2	222	87.5
<b>5 (worst)</b>	22	8.7	41	16.1	63	24.6	91	35.9	171	67.2	279	110.0
<b>2.5</b>	25	9.9	45	17.6	70	27.4	103	40.7	204	80.2	344	135.6
<b>1</b>	27	10.6	49	19.2	77	30.1	117	46.2	247	97.2	450	177.3
<b>Mean</b>	13	5.1	25	9.8	38	14.8	52	20.6	88	34.6	129	50.9

**\*The results of this table are based on using Tables 9-1 and 9-2 of the USEPA Report "The Probability of Sea Level Rise".**

**Table 8: Sea level projection by year for southwest Florida**  
*Source: IPCC 2007*

While the IPCC (2007) has been a standard for current planning purposes, several researchers and scientists that express non-empirical opinions (Rahmstorf 2007) based on other methods of modeling consider the IPCC projections to be conservative and expect climate changes to be more severe. This is because the scenarios presented in IPCC’s Fourth Assessment Report (2007) exclude some of the feedback mechanisms that could accelerate the melting of the Greenland and Antarctic ice sheets.

During our literature review we found that Stanton and Ackerman (2007) foresee a different set of climate future extremes that include either a response to climate change by humans to reduce green house gases, or inaction, a likely scenario at the time of their report’s publication. Stanton and Ackerman (2007) compared the two scenarios: an optimistic *rapid stabilization case* and a pessimistic *business-as-usual case*. The scenarios represent extremes of what is expected to happen if the world succeeds in a robust program of climate mitigation, versus what is expected to happen if very little to nothing is done to address climate change. The difference between the two allows numerical calculation of climate change damage to Florida resources and economics. This calculation can be perceived as the benefits of mitigation, or, from an opposite perspective, the costs of inaction.

The *rapid stabilization case* (of green house gas (GHG) emissions) includes the lowest levels of future emissions under discussion today including a 50% reduction in current global emissions and an 80% reduction in current U.S. emissions by 2050, where precipitation remains stable and hurricane intensity remains in the current ranges. The *business-as-usual case* or *no-action case* includes steadily increasing GHG emissions throughout this century modeled on the high end of the likely range of the IPCC's A2 scenario (2007). This includes climate instability impacts of less rain in Florida and increased hurricane intensity (IPCC 2007).

	2025	2050	2075	2100
<b>Annual Average Temperature (in degrees F above year 2000 temperature)</b>				
Rapid Stabilization Case	0.6	1.1	1.7	2.2
Business-as-Usual Case	2.4	4.9	7.3	9.7
<b>Sea Level Rise in Florida (in inches above year 2000 elevation)</b>				
Rapid Stabilization Case	1.8	3.5	5.3	7.1
Business-as-Usual Case	11.3	22.6	34	45.3

**Table 9: Two other alternate future climate scenarios for Florida**

Source: Stanton and Ackerman 2007 Table ES-2

The Stanton and Ackerman (2007) “Rapid Stabilization Case” is the scenario with the highest probability and least impact related to Table 8 above, which shows the IPCC (2007) scenarios. The more severe “Business-as-Usual Case” is the scenario with approximately 1% probability and greatest impact according to Table 8. So, one could consider the “Rapid Stabilization Case” as the very best and the “Business-as-Usual Case” as the very worst case scenarios.

New projections using the MIT Integrated Global Systems Model, Sokolov, et al. (2009) indicate a median probability of surface warming of 5.2 degrees Celsius by 2100, with a 90% probability range of 3.5 to 7.4 degrees. This falls between the IPCC worst case scenario and the Business-as-Usual “worstest” case scenario of Stanton and Ackerman (2007). Therefore this extent of severity is accounted for in this project.

The level of sea level rise discussed for Florida in the recent report entitled “Global Climate Change Impacts in the United States” (Karl et al. 2009) falls between the moderate case and worst case scenarios predicted by the IPCC (2007) with a 30% probability of 24 inches of sea level rise by the year 2100.

Projecting future sea level rise presents special challenges (Karl et al. 2009). Scientists have a well-developed understanding of the contributions of thermal expansion and melting glaciers to sea level rise, so the models used to project sea level rise include these processes. However, the contributions to past and future sea level rise from ice sheets are less well understood. Recent observations of the polar ice sheets show that a number of complex processes control the movement of ice to the sea, and thus affect the contributions of ice sheets to sea level rise. Some

of these processes are already producing substantial loss of ice mass. Because these processes are not well understood it is difficult to predict their future contributions to sea level rise. (Alley et al. 2005)

Because of this uncertainty, the 2007 assessment by the IPCC could not quantify the contributions to sea level rise due to changes in ice sheet dynamics, and thus projected a rise of the world's oceans from eight inches to two feet by the end of this century (Meehl et al, 2007). More recent research has attempted to quantify the potential contribution to sea level rise from the accelerated flow of ice sheets to the sea or to estimate future sea level based on its observed relationship to temperature (Rahmstorf 2007). The resulting estimates exceed those of the IPCC, and the average estimates under higher emissions scenarios are for sea level rise between three and four feet by the end of this century. An important question that is often asked is "What is the upper bound of sea level rise expected over this century?" Few analyses have focused on this question. There is some evidence to suggest that it would be virtually impossible to have a rise of sea level higher than about 6.5 feet by the end of this century (Pfeffer et al. 2008). The changes in sea level experienced at any particular location along the coast depend, not only on the increase in the global average sea level, but also on changes in regional currents and winds, proximity to the mass of melting ice sheets, and on the vertical movements of the land due to geological forces (Mitrovica et al. 2009). The consequences of sea level rise at any particular location depend on the amount of sea level rise relative to the adjoining land. Although some parts of the U.S. coast are undergoing uplift (rising), most shorelines are subsiding (sinking) to various degrees from a few inches to over two feet per century (Karl et al. 2009).

## **Air Temperature and Chemistry**

### **Known Air Temperature and Air Chemistry Changes and Events**

Over the last 650,000 years, levels of atmospheric carbon dioxide have both increased and decreased. The rate of change in increases in carbon dioxide has been about 100 times faster in recent decades than over the past 650,000 years. Concentrations of other gases, such as methane and nitrous oxide, have also increased significantly. Concentrations of greenhouse gases, especially carbon dioxide, have increased. Since the Industrial Revolution, atmospheric carbon dioxide (CO<sub>2</sub>) levels have increased by more than 30 percent, reaching concentrations higher than any observed in the last 420,000 years (Petit et al. 1999). These increasing levels of CO<sub>2</sub> and other greenhouse gases have contributed to a rise in global temperatures of about 0.7 to 1.4 degrees Fahrenheit since 1900, with the warmest temperatures occurring in the past 20 years (Houghton et al. 2001). Carbon dioxide emissions grew by 80 percent between 1970 and 2004. Eleven of the last 12 years have seen the warmest temperatures since 1850 (FOCC 2009). Mean global atmospheric temperature has increased by more than 0.6 degrees Celsius since 1901 (IPPC 2007b). Since the 1980s, the atmospheric column average water vapor concentration has increased by 1.2 percent (IPPC 2007b). All this being said, coastal air temperature observations around Florida since the 1830s do not show any statistically significant trend (Maul and Sims 2007).

## Potential Future Climate Changes

Florida’s future climate depends on overall emissions of greenhouse gases today and in the decades to come, and, because carbon dioxide persists in the atmosphere for a century or more, on the impacts of accumulated past emissions (Stanton and Ackerman 2007). If the world fails to achieve reductions in GHG emissions, the business-as-usual case assumes steadily *increasing* emissions, along with uncertain extreme weather, in which atmospheric concentrations of carbon dioxide exceed the critical 450 parts per million (ppm) threshold by 2030 and reach 850 ppm by 2100. Reaching this threshold is considered “likely” by the IPCC, so understanding that air temperature and air chemistry are interrelated is critical. Ocean acidity, global average temperatures, smog formation, heat waves, humidity (water vapor) and other conditions are affected by air chemistry and air temperature.

	2025	2050	2075	2100
<b>Best Rapid Stabilization Case</b>	0.6	1.1	1.7	2.2
<b>Worst Case</b>	2.4	4.9	7.3	9.7

**Table 10: Two future climate scenarios for Florida annual average temperature in degrees F above year 2000 temperature**

*Source: Stanton and Ackerman 2007*

Elevated atmospheric carbon dioxide will increase dissolved carbon dioxide in the oceans and waters associated with coastal areas and wetlands. This can be expected to acidify these waters and increase the frequency of algal blooms (Holman 2008; Ebi et al. 2007; Uhland 2007; Lee County Visitor and Convention Bureau 2008). Carbonate deposition in marine shell-forming taxa will be reduced, causing reductions in the health of and populations of animals ranging from conchs to barnacles to corals. Increased coral reef die-off should be expected, along with changes in plant growth and plant biomass turnover with a near-term increase in vegetative biomass at early stages (Holman 2008; Ebi et al. 2007; Uhland 2007; LCVCB 2008).

Temperature Predictions	Climate Scenario	Pre-development	1891-1995	2009	2025	2050	2100
<b>Mean Annual Air Temperature</b>	With Mitigation	73.6	73.8	74	74.6	75.1	76.2
	Least	73.6	73.8	74	75.1	74.5	77.1
	Moderate	73.6	73.8	74	75.5	77	80.4
	Worst	73.6	73.8	74	76	78.9	83.7
	“Worstest”	73.6	73.8	74	76.4	78.9	84.4

**Table 11: Mean annual temperature changes for southwest Florida**

Derived from Intergovernmental Panel on Climate Change (IPCC) (2007b), Florida Oceans and Coastal Council (FOCC) 2009, Stanton, E.A., and F. Ackerman 2007

Water vapor, the most abundant greenhouse gas, is an important factor causing uncertainty in climate prediction models. As air temperature increases, the capacity of the air to hold water vapor increases. However, clouds can have a cooling or heating effect, and cloud processes are one of the largest sources of uncertainty in climate change projections. Correctly characterizing the effects of water vapor greatly complicates climate forecasts (FOCC 2008).

Higher air temperatures and changing air chemistry are expected to increase the rate of smog formation in locations adjacent to and within denser urban areas (Fiedler et al. 2001; Southeast Climate Change Partnership (SCCP) 2005), and increased unhealthful levels of ozone pollution are expected (Holman 2008; Ebi et al. 2007; Uhland 2007; Lee County Visitor and Convention Bureau (LCVCB) 2008).

In the case outlined above, Florida's average annual temperatures will be 5° F higher in 2050 than today, and 10°F higher in 2100. Sea level rise will reach 23 inches above mean sea level by 2050, and 45 inches by 2100. The timing of seasonal temperature changes is expected to be disrupted with earlier springs, shorter winters, unseasonable freezes, and extended droughts (Peterson et al. 2007).

Increased air temperatures will affect hydrology, water quality and habitats in saltwater and freshwater wetlands with surface water supplies decreasing and drought in some portions of the region. Altered salinity gradients, altered species distributions, negative species interactions and increased metabolic activity; increased risk of disease and parasitism; creation of opened niches for invasive species; and increased evaporation of surface water are all expected to occur (USEPA CRE 2008; Holman 2008; FOCC 2009).

Warming effects will likely be greatest in the northern parts of this study area (FOCC 2009). Air temperature in south Florida may also increase because of changes in land use and land cover, such as urbanization and the reduction of wetlands (Pielke et al. 1999; Marshall et. al. 2003), multiplying the effect of climate change. Heat waves will become more severe and more common, with new record temperatures and a gradual decline in nighttime cooling. The average "heat index" (temperature combined with humidity) in summer will be 15–20 percent higher in much of the state. South Florida is estimated to become several degrees hotter than today's Bangkok (probably the world's hottest, most humid major city at present), and daily highs in many Florida cities will exceed 90 degrees F nearly two-thirds of the year (Stanton and Ackerman 2007).

Increases in surface temperatures will affect coastlines, wetlands species, water supplies; and power supplies in population centers by a reduction in water quality due to increased growth of nuisance algae and lower oxygen levels. Extirpation of cooler-water species, altered reproductive rates and maturation leading to declining fish and animal populations, increased evaporation of surface water, increased demand for electricity for cooling indoors and increased demand for power plants can be expected (USEPA CRE 2008, Rubinoff et al. 2008; Holman 2008;

USNOAA 2008)

Timing of seasonal temperature changes will disrupt the flora and fauna of estuaries resulting in disturbance of predator/prey availability, food and reproductive cycles, life-cycles and upstream migration, temperature-driven behavior, photoperiod-driven behavior and, biological ocean-estuary exchanges (Peterson et al. 2007).

## **Water Temperature and Chemistry**

### **Known Water Temperature and Water Chemistry Changes and Events**

Florida, situated between the Gulf of Mexico and Atlantic Ocean, is subject to contrasting environmental effects because each body of water has its own characteristic temperature regimes and patterns of change (FOCC 2009), but there has been a cyclical rise in sea level and global ocean temperatures (Wang and Enfield et al. 1998). As well, ocean chemistry is changing at least 100 times more rapidly today than at any time during the 650,000 years prior to the industrial era (Kleypas et al. 2006).

As oceanic carbon dioxide has increased in recent decades, the world's oceans have become more acidic, with pH decreasing by 0.1 standard units since 1750 (Archer 2005). This represents a 30 percent increase in ocean acidity.

Additionally, global average sea-surface temperature has risen 1.1 degrees Fahrenheit (0.6 degrees Celsius) over the past 100 years (IPCC 2007b). Water temperatures at the sea surface rose by an average of 0.3 degrees Celsius between the 1950s and 1990s in tropical and subtropical waters (Wilkinson and Souter 2008; Florida Oceans and Coastal Council (FOCC) 2009). The year 2005 was the warmest in the wider Caribbean than any in the last 100 years, and coincided with the area of sea surface temperatures known as the Western Hemisphere Warm Pool being in an expanded state (Wang and Enfield et al. 1998; Wilkinson and Souter 2008).

Warm water holds less dissolved oxygen than cold water, thus, hypoxia, or low oxygen, occurs when the levels of oxygen dissolved in water fall with rising water temperatures to levels injurious to ocean and coastal life. This can lead to what is called a "dead zone." Excess nutrients can cause or exacerbate hypoxic conditions by causing certain organisms to proliferate, leading to further decreased dissolved oxygen as they die and decay. Terrestrial nutrients are introduced into the marine environment through precipitation and runoff, thus, hypoxia can occur as a natural phenomenon and also as a human-induced or exacerbated event (Turner et al. 2006). Precipitation and runoff amounts and distribution have changed over recent years and will continue to change as climate change progresses (UNEP 2006). Over the past 30 years, increased sea surface temperatures have led to episodic die-offs of sponges, seagrasses, and other important components of coastal and marine ecosystems (FOCC 2009).

## Potential Future Climate Changes

Sea-surface temperatures will continue to rise at least at the rate at which they have been rising for the past 100 years (IPCC 2007b). It is probable that water temperatures at the sea's surface will continue to increase at the average rate of 0.3 degrees Celsius over 40 years in tropical and subtropical waters (FOCC 2009). If Florida's ocean temperatures increase at the same rate that the IPCC models predict for the Gulf of Mexico and Atlantic as a whole, they would increase by 2 degrees Celsius over the next 100 years (IPCC 2007b).

As sea-surface temperatures continue to rise, the coastal and marine environments most stressed by nutrients from land-based sources of pollution will be most adversely affected (Wilkinson and Souter 2008). Increased stormwater runoff in some parts of the state, coupled with human population increases, will increase the transport of nutrients to coastal waters, contributing to hypoxia (low oxygen) and eutrophication (FOCC 2009).

More oxygen-poor (hypoxic) waters in areas like Charlotte Harbor may occur as a result of human development depending on the amount of nitrate-laden freshwater discharged by the Peace River. The complex interaction of nutrient load and amount of runoff will make future projections challenging. A 20 percent increase in river discharge, as some climate models project, could increase the risk of hypoxia and expand the oxygen-poor "dead zone" (Twilley et al. 2001; Ebi et al. 2007; USNOAA 2008; FOCC 2009; USEPA CRE 2008).

Increased sea surface temperatures will lead to increased temperature stratification and changed water current circulation with reduced dissolved oxygen (USEPA CRE 2008; NOAA 2008; FOCC 2009). Gulf of Mexico currents may shift (Wilkinson and Souter 2008).

Winter lake temperatures may increase (USEPA CRE 2008), interfering with the life cycle of species that require cooler temperatures for behaviors like aestivation and torpor.

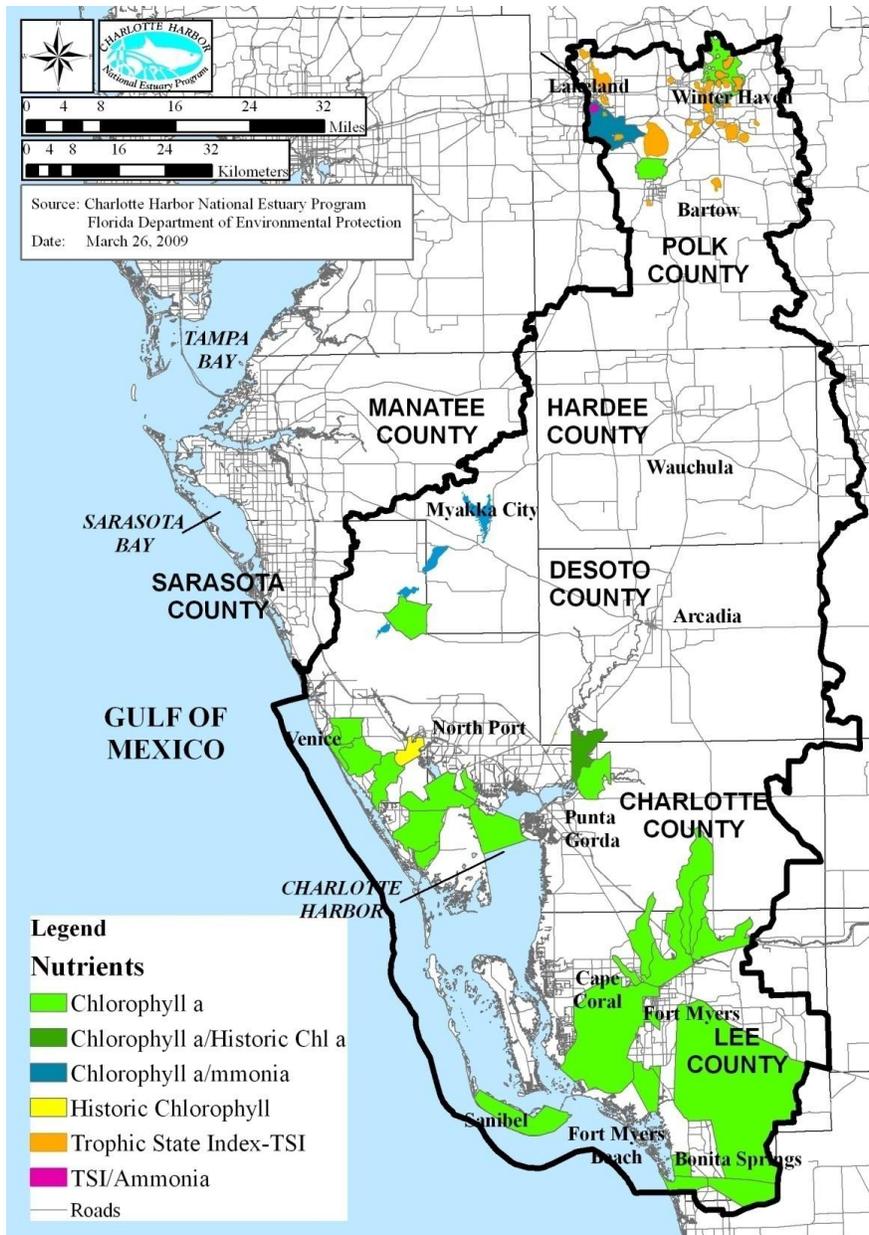
The average pH of the world's oceans may decrease by as much as 0.1 to 0.4 pH units over the next 90 years, due to increasing absorption and solution of carbon dioxide into warmer ocean waters (Royal Society 2005: 29; Kuffner et al. 2008; Ishimatsu et al. 2005). Evidence from studies in the waters surrounding volcanic vents shows that, around the vents, pH fell as low as 7.4, the number of species was 30% less than neighboring areas, coral was absent, and species of algae that use calcium carbonate were displaced in favor of species that do not use it. Snails showed signs of dissolving shells. There were no snails at all in zones with a pH of 7.4. Meanwhile, seagrasses thrived, perhaps because they benefit from the extra carbon in the water (Martin et al. 2009).

Increased acidification of marine waters will cause increased trace metal toxicity and dissolution of carbonate structures, like marine animal shells (Peterson et al. 2007, SCCP 2008, Florida Oceans and Coastal Council (FOCC) 2009, USEPA CRE 2008, Orr et al. 2005).

<b>Higher numbers indicate alkalis, lower values signify acidic liquids</b>	
<b>13</b>	Bleach
<b>10</b>	Soap
<b>8.2</b>	Pre-1750 oceans (average)
<b>8.1</b>	Current oceans (average)
<b>7.8</b>	Oceans in 2100 (projected average)
<b>7</b>	Pure water
<b>3</b>	Vinegar
<b>0</b>	Battery acid

**Table 12: The pH Scale**

*Source: NMEA*



**Figure 8: Nutrient impairments in the CHNEP watershed**

In inland areas, lakes, rivers and streams will show water quality climate change effects. Although sea level rise itself is generally not thought of as becoming a significant effect of climate change in inland areas, modeling shows that rising sea level will intrude far inland, extending past Interstate 75, via canals, creeks, and rivers (SWFRPC 2009). Another effect will be more severe and longer lasting droughts. This could result in lower lake levels, concentrating pollutants and nutrients. More intense rain storms and tropical systems may also result in increased urban and suburban stormwater runoff into lakes, increasing their pollutant and nutrient loads. The effects of increased water and air temperatures, reduced pH (from increased

amounts of atmospheric CO<sub>2</sub> dissolved into water bodies and falling in rain), droughts and flooding will take many forms in Florida's inland lakes.

Dissolved oxygen levels are reduced with increased water temperatures in inland lakes as well as in coastal water bodies. Hypoxia is a regular natural event in the upper part of Charlotte Harbor occurring seasonally and following some hurricane events, and occurs in the Caloosahatchee River from excessive polluted lake water discharges. In lakes, when DO drops to 0, during both natural and human-induced anoxic events, pH changes. This frees heavy metals from the substrate and redistributes them into the water column. This could result in absorption of these metals into fish tissue, perhaps leading to fish kills and increased toxicity in fish consumed by vertebrates, including humans. Lower water levels resulting from drought may serve to concentrate these effects, increasing toxic levels even further. Care should be taken to prevent polluted waters such as these from being drawn upon for irrigation or consumption.

Chlorophyll-a is used as a measure of water quality because it indicates the amount of phytoplankton and/or algae present in a water body. These organisms take up carbon dioxide and produce oxygen, but an overabundance leads to eutrophication. Increases in temperatures are often accompanied by increases in biological process rates (Day 1989). This would indicate an increase in photosynthesis in phytoplankton, encouraging growth and reproduction, and further increasing amounts of chlorophyll-a. This cycle would continue up to an optimal temperature. Subsequent temperature increases beyond the optimal result in a decrease in phytoplankton growth (Day 1989). Lower pH serves to increase concentrations of CO<sub>2</sub> in the water available for metabolism through photosynthesis. This will increase growth of phytoplankton, adding to the chlorophyll-a load in the lake.

Nutrients such as nitrogen and phosphorus are taken up by algae, phytoplankton and other plants and used in growth processes. The characteristics and availability of these substances do not appear to be affected by climate change (once present in the water column), but nitrogen and phosphorus in lakes will magnify other responses. Increased algal/phytoplankton growth resulting from increased air and water temperatures will utilize nitrogen and phosphorus, fueling expansion, possibly to the point of eutrophication. In intense rain events, stormwater runoff could be expected to increase, introducing higher loads of these nutrients from excess fertilizer from urban and suburban landscapes.

Salts, or dissolved solids, will become more soluble with increasing water temperature, allowing higher concentrations to be maintained in lakes. Decreased pH in lakes, resulting from more CO<sub>2</sub> in the atmosphere, will affect different dissolved solids differently. Some suspended and dissolved solids will come out of solution, while others will be able to increase their concentration in solution. Drought accompanied by lower water levels, will increase concentrations, which may, in turn, force some solids out of suspension or solution. Flood conditions, with higher water levels, may reduce concentrations.

Depending on the content of shoreline soils, there could be increased turbidity from destabilized soil particles, increased total suspended solids, and increased nutrient levels. (Titus 1998; Florida Center for Environmental Studies 2007; Peterson et al. 2007; USNOAA 2008; Volk 2008; USEPA CRE 2008).

Finally, increased temperature increases metabolic rates, increasing growth and reproduction of bacteria. pH tolerance varies from species to species in bacteria and can affect maximum growth rates in varying ways. Bacteria should not be affected directly by drought or flood, but may respond to other limiting factors that are altered by changing water levels and concentrations.

## **Climate Instability**

### **Known Climate Instability Changes and Events**

Precipitation in Florida varies naturally and under human influence in many ways. Annual rainfall is affected by decadal-scale variability in tropical storms, such as the Atlantic Multidecadal Oscillation and the El Niño-Southern Oscillation warming phenomenon in the Pacific Ocean (Enfield et al. 2001; Jones et al. 1999; Shepherd et al. 2007). Summer rainfall varies over periods of a few decades (Jones et al. 1999). Human alterations to freshwater inflow into estuaries, such as increased overland flow due to urbanization or decreased flow caused by dams and water withdrawals, have changed estuarine circulation patterns, salinity regimes, and patterns of animal use (Scavia et al. 2002).

While studies have shown that there is no clear, long-term trend in the number of tropical storms (IPCC 2007b; FOCC 2009; Webster et al. 2005), there have been changes in storm frequency over periods of a few decades. Although southwest Florida is currently in an active period, it may eventually enter a less active period (Goldenberg et al. 2001). Intense hurricanes and active seasons have occurred regardless of trends in sea-surface temperatures (Virmani et al. 2006). And, while storms can occur at any time of year, over 97 percent of North Atlantic tropical storm activity occurs from June to November (Landsea et al. 1994).

The power of Atlantic tropical cyclones, a function of wind speed, is rising rather dramatically and the increase is correlated with an increase in the late summer/early fall sea surface temperature over the North Atlantic. There is debate concerning the nature of these increases. Some studies attribute them to a natural climate fluctuation known as the Atlantic Multidecadal Oscillation (AMO), and others suggest climate change related to anthropogenic increases in radiative forcing from greenhouse-gases. Tests for causality using the global mean near-surface air temperature and the Atlantic sea surface temperature records during the Atlantic hurricane season have been applied. Results show that global mean near-surface air temperature is useful in predicting Atlantic sea surface temperature, but not the other way around (Enfield et al. 2001; Jones et al. 1999; Elsner 2006; Shepherd et al. 2007). This has provided additional evidence in support of the climate change hypothesis (Elsner 2006).

### **Potential Future Climate Changes**

The development of tropical storms and hurricanes depends not only on sea-surface temperature and water vapor content, but also on factors such as wind shear, which plays a significant role. Wind shear appears to have an inverse relationship with storm intensity. Recent examples of

rapid storm intensification are associated with storms passing over deep, warm ocean pools and through regions of low wind shear (Shay et al. 2000). Storm frequency and intensity may, therefore, decrease with increasing sea-surface temperatures (Knutson et al. 2008) because wind shear will increase in a warming planet (Vecchi and Soden. 2007; Wang and Lee 2008.). Other studies indicate that severe hurricanes (Category 3 or higher) may become more frequent with increasing sea-surface temperatures (Webster et al. 2005), and that rising sea temperatures are expected to cause a 5 to 10% increase in hurricane wind speeds (USNOAA 2008; FOCC 2009; USEPA CRE 2008).

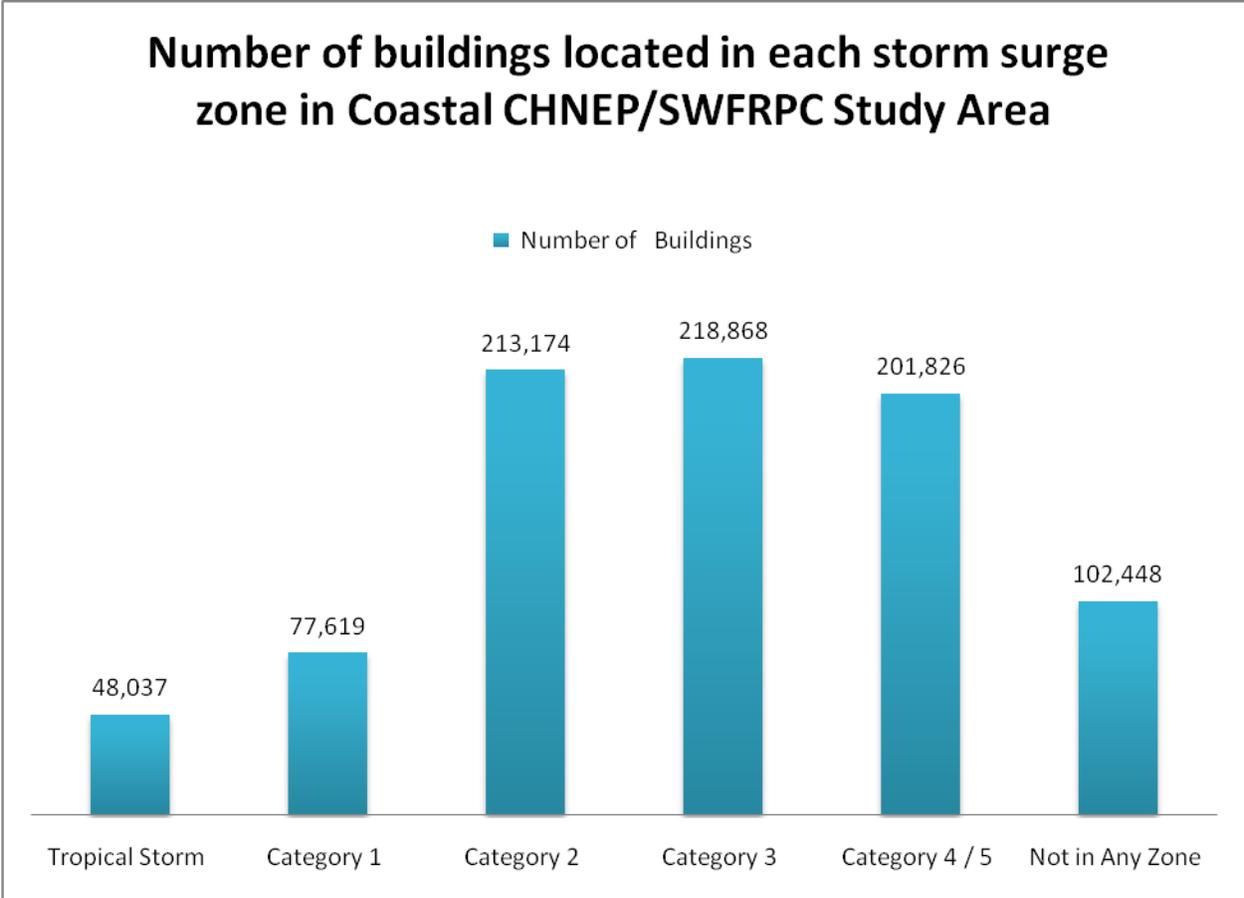
Higher water temperatures in the Gulf of Mexico and Atlantic Ocean may cause more intense hurricanes, which will cause more damage to coastal and inland habitations, infrastructure and human economy (Elsner 2006; Peterson et al. 2007; USNOAA 2008; USEPA CRE 2008).

Damage will multiply as the effects from more intense hurricanes are added to more severe storm surges resulting from higher sea levels. More intense hurricanes will cause more damage to both coastal and inland habitations and will increase the devastating effects of hurricanes to infrastructure and human economy (Elsner 2006; Peterson et al. 2007; USNOAA 2008; USEPA CRE 2008). Damage will multiply as the effects from more intense hurricanes are added to more severe storm surges resulting from higher sea levels. This increased magnitude of coastal storms will cause geomorphic shifts in barrier islands and habitats at coastlines through coastal erosion and inundation. There will be habitat loss/migration due to erosion/inundation (University of Washington Center for Science in the Earth System 2007; Peterson 2007; FOCC 2009; USEPA CRE 2008; USEPA 2008; USNOAA 2008). Clearly, climate change effects will magnify the effects of hurricanes and tropical storms.

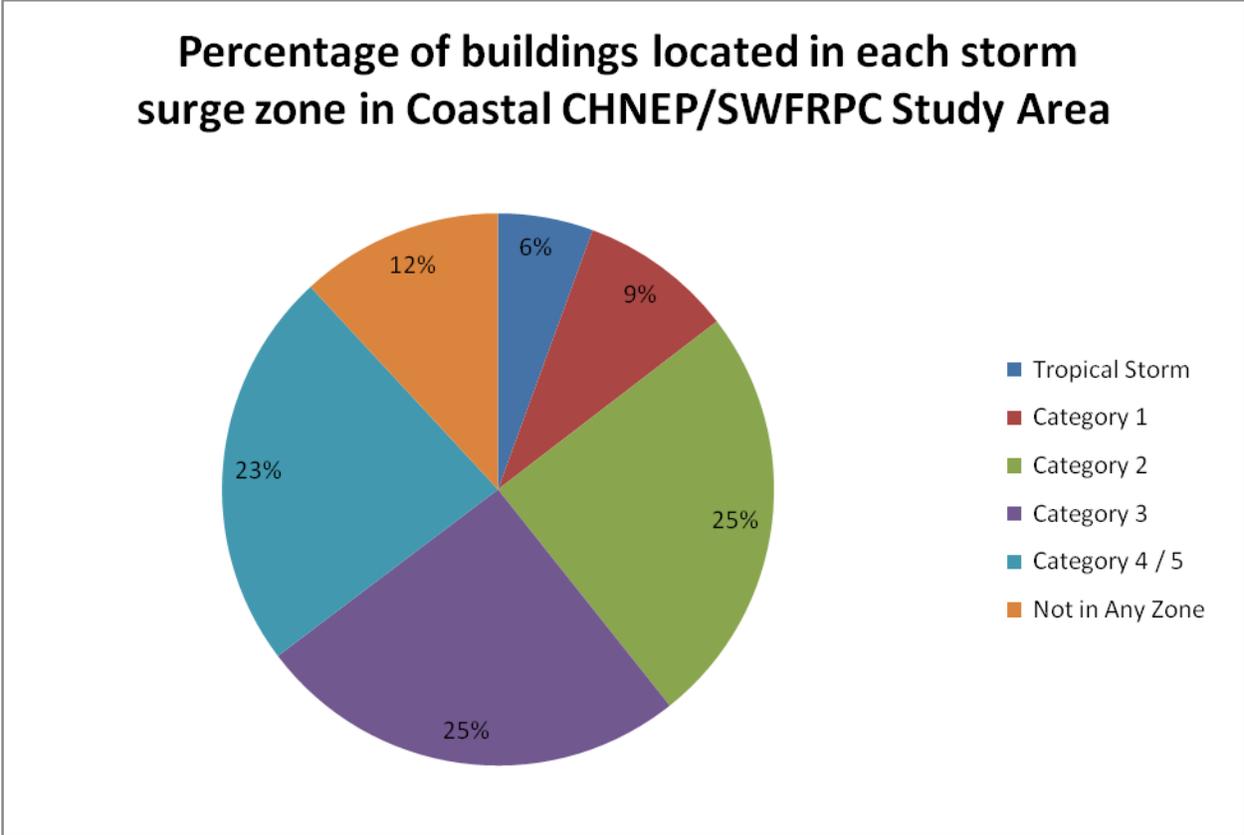


**Photograph 1: Red mangrove fringing forest killed by Hurricane Charley August 2004.** This is a site of CHNEP restoration effort studies.  
*Source: CHNEP 2008*

Each of the coastal counties in this study have developed Local Mitigation Strategies (LMS) for anticipated natural disasters including flooding and the impacts of tropical storms and hurricanes. Each LMS estimates the effects of different levels of tropical storm impacts on the infrastructures and properties of their jurisdictions and estimates potential financial losses/damages from such events. The last updates are from 2005. Unfortunately, there is not a consistent reporting method or format for the different jurisdictions so, for example, Sarasota County does not provide estimates for tropical storms as an individual category, but includes it with Category 1 hurricanes. For some statistics there is full reporting. The following figures indicate the magnitude of the vulnerability of the region to these extreme weather events that are considered likely to impact southwest Florida within the time period of the projected futures analyzed in this study.

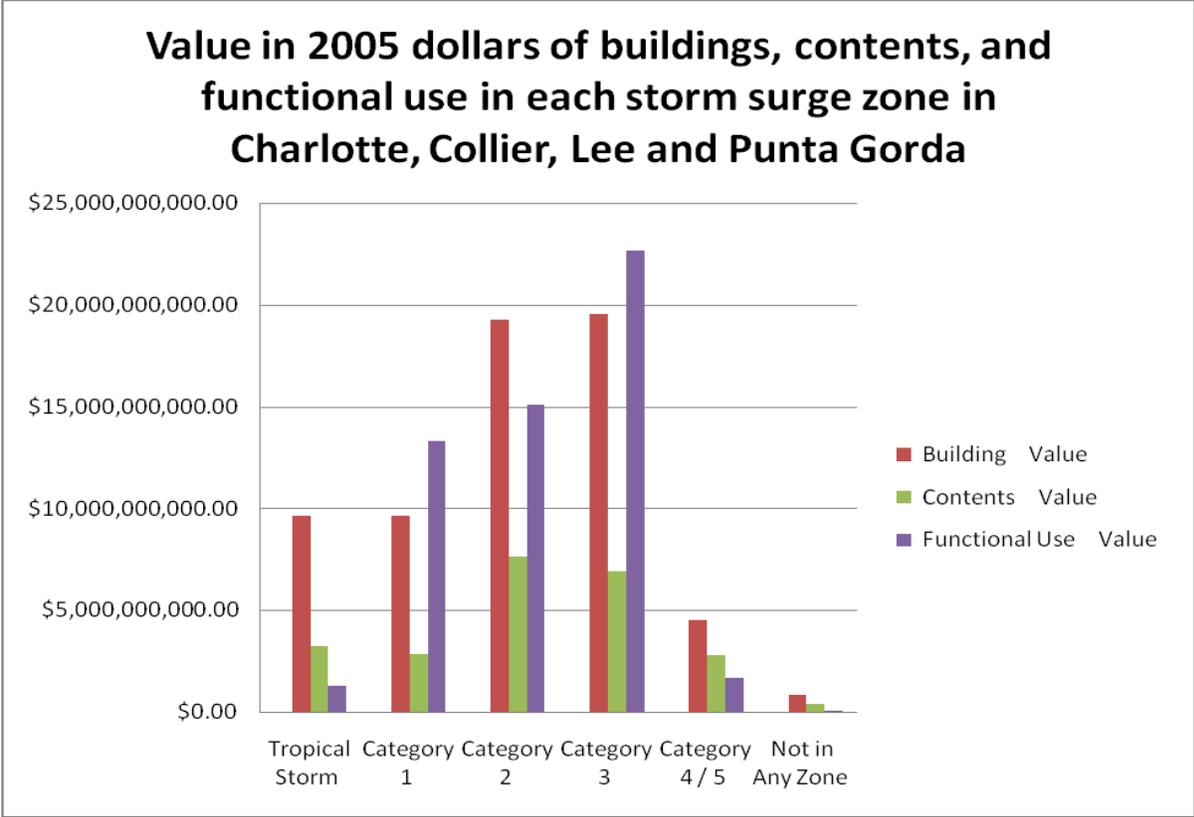


**Figure 9: Number of buildings located in each tropical storm and hurricane storm surge zone in coastal CHNEP/SWFRPC study area**



**Figure 10: Proportion of buildings located in each tropical storm and hurricane storm surge zone in coastal CHNEP/SWFRPC study area**

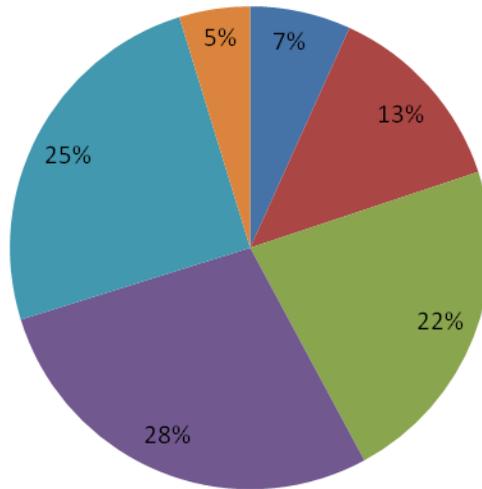
With climate change, higher, stronger coastal storm surges will reach farther inland. This may lead to saltwater intrusion in zones not tolerant of higher salinity, causing plant and animal mortality and contamination of surface and aquifer drinking water supplies. The higher waves, wave action, and hydrodynamic pressure will lead to deeper flooding. A 20 to 25% increase in the 100-year floodplain area is expected. Salt deposition from such surges and flooding can lead to physical and chemical destruction of habitats and infrastructure. Larger floating debris and increased beach erosion will have negative impacts on human infrastructure. Shorter storm evacuation time windows prior to storms may be expected (USCCSP 2008; Fiedler et al. 2001; Peterson et al. 2007; USNOAA 2008; USEPA CRE 2008).



**Figure 11: Monetary value in 2005 dollars of buildings, contents, and Functional use in each storm surge zone in Charlotte County, Collier County, Lee County and the City of Punta Gorda**

## Percentage of monetary value in 2005 dollars of properties in each storm surge zone in Coastal CHNEP/SWFRPC

■ Tropical Storm  
 ■ Category 1  
 ■ Category 2  
 ■ Category 3  
 ■ Category 4 / 5  
 ■ Not in Any Zone



**Figure 12: Percentage in monetary value in 2005 dollars of properties in each storm surge zone in coastal CHNEP/SWFPC study area**

Rainfall over the Florida peninsula depends on the winds (e.g., sea breezes), especially in the summer, and on hurricanes and tropical storms. Rainfall variations are highly cyclical (Enfield et al. 2001). Climate change, land use, and other factors may result in greater variations in observed patterns, conflicting trends, and regional differences within the state. Distinguishing Florida-specific rainfall and runoff trends from future global trends is a critical research need (FOCC 2009).

Since 1979, there has been a change in the type of rainfall in the tropics, with more frequent heavy and light rains, and less frequent moderate rains (Lau and Wu 2007). Air pollution also may cause more rainfall during weekdays (Bell et al. 2008). An increase in precipitation of 5-10% over the levels of the 20th century, including heavy and extreme precipitation events could be expected, affecting all land surfaces and receiving waterbodies in the entire area of southwest Florida (UWCES 2007; USNOAA 2008; SECCP SDRT LCCP 2005, FOCC 2009, USEPA CRE 2008). If the frequency of extreme rainfall events increases, or if river volume increases and the timing of freshwater flows to estuaries changes, it will exacerbate already altered conditions in estuaries such as increased nutrient delivery and eutrophication (Alber 2002; Peterson et al. 2008; Easterling et al. 2000). However, as mentioned previously, rainfall in south Florida also

may be decreasing from changes in land use and land cover, such as urbanization and the reduction of wetlands (Pielke et al. 1999). Climate change effects will be variable, and in some cases, will combine to create even more complex and/or extreme outcomes.

Higher maximum temperatures should be expected, with more hot days and heat waves over nearly all land areas. This will negatively affect wetlands, freshwater bodies, and human communities and activities. Due to increased evaporation and evapotranspiration, the volume of bodies of freshwater will be reduced. This will concentrate the solutes in same waters increasing toxic effects (Ebi et al. 2007; USNOAA 2008; SCCP 2005; FOCC 2009; USEPA CRE 2008). Increases in hot extremes will be associated with heavier precipitation (FOCC 2009); storm intensity, even when not associated with tropical systems, will likely increase (FOCC 2009); and periods of drought between these rain systems may be longer (FOCC 2009).

Higher humidity will result from increased atmospheric/aquatic temperatures, allowing more water vapor to exist in the air column. This will result in increased heat stress for people, plants and animals; growth of harmful molds leading to increased negative health consequences; and more bacterial infections (FOCC 2009).

Wildfires, resulting from higher atmospheric temperatures in combination with increased drought, will destroy habitat and allow increased erosion from a lack of vegetative cover. Decreased air quality from particulates and other air pollutants released by the fires (USNOAA 2008; USEPA CRE 2008) can also be expected. Rising air temperatures increase evaporation, contributing to dry conditions, especially when accompanied by decreased precipitation. Even where total annual precipitation does not decrease, precipitation is projected to become less *frequent* in many parts of the country (Gutowski et al. 2008).

Drought is expected to be an increasing problem in southwest Florida and will have impacts on transportation. For example, wildfires during droughts could threaten roads and other transportation infrastructure directly, or cause road closures due to fire threat or reduced visibility, as has occurred in south Florida along Alligator Alley (Interstate 75) in the spring of 2009. Airports could also be affected by decreased visibility due to wildfires. River transport is seriously affected by drought, since lower water levels cause reductions in the routes available, shipping season, and cargo carrying capacity (Karl et al. 2009).

Sustained climate change instability threatens advanced computer technology and human dependency on computers and wireless communication systems. Storage media could be damaged by sustained heat, humidity, extreme storm disasters, flooding, and electromagnetic surges (USEPA CRE 2008).

## **Sea Level Rise**

### **Known Sea Level Changes and Events**

Florida's geologic history has consisted of cycles of sediment deposition and erosion in response to sea level changes over the last 65 million years (Figure 13) (Florida's Geological History and Geological Resources (FGHGS) 1994). The most "recent" geologic history (1.8 million years

ago to present) has been a time of worldwide glaciations, widely fluctuating sea level and the emergence of humankind (FGHGS 1994). This geologic period is called the Quaternary Period and is made of two geologic epochs, the Pleistocene Epoch (1.8 million to 10,000 years ago) and the Holocene (Recent) Epoch (10,000 years ago to the present).

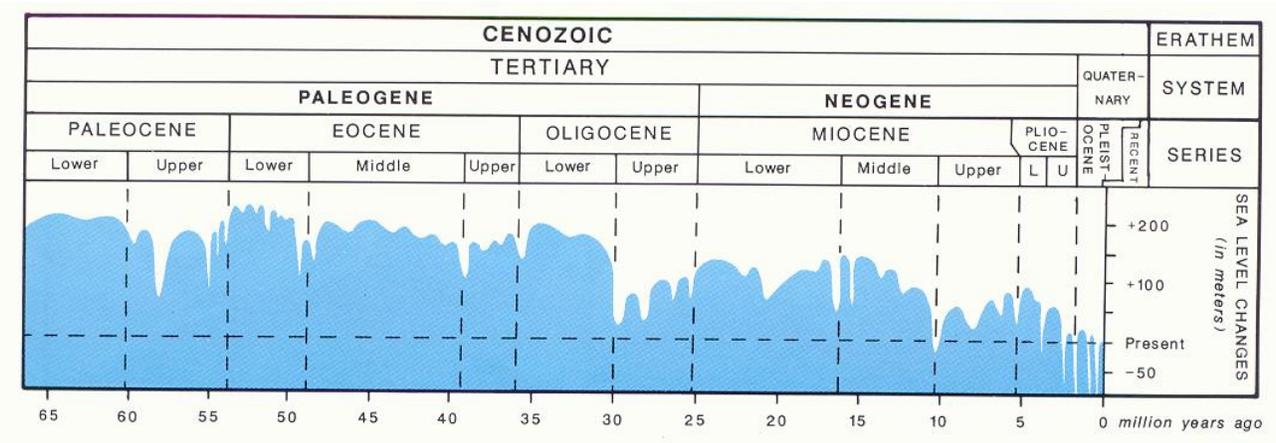


Figure: 13 Sea level changes during the last 65 million years

The Pleistocene Epoch is known as the “Ice Age” and includes at least four great glacial periods. During each period huge ice sheets covered much of the northern United States. Seawater was the primary water source for the expanding glaciers, causing sea level to drop as much as 300 feet below present level. Between glaciations the Florida shoreline attained heights 150 feet above present sea level (Figure 14).

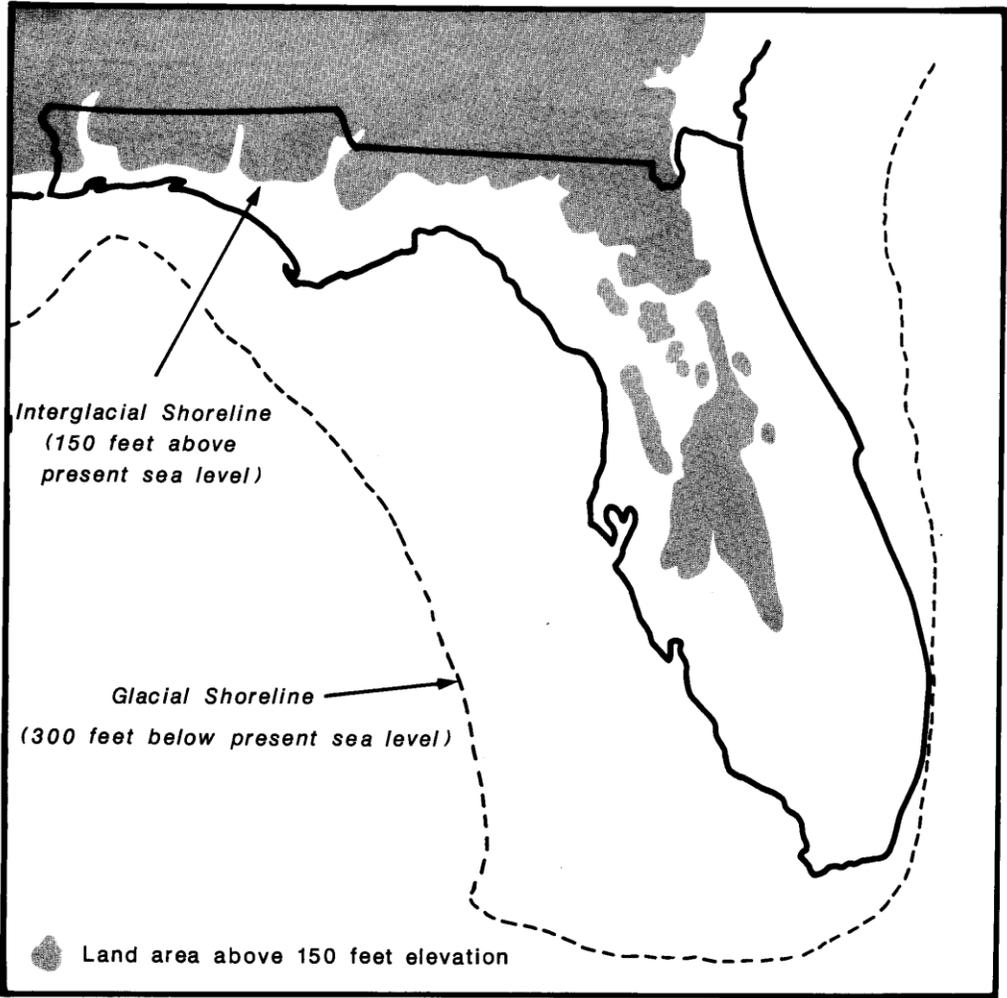


Figure 14: Shoreline of Florida between 1.8 million to 10,000 years ago

The large drop in sea level during the most recent ice age increased the land area of Florida dramatically, by as much as 100 miles west of current position (Figure 14) (FGHGR 1994). Considerably warmer interglacial intervals melted the glaciers, raising sea level and flooding the Florida peninsula as least 100 to 150 feet above the present level and creating islands.

The Holocene Epoch began 10,000 years ago during a slow warming of the Earth's climate. From a glacial low about 18,000 years ago, sea level climbed intermittently to its present level (FGHGR 1994). Beginning roughly 6,000 years ago, as two of the major ice sheets melted, sea level rose to two meters higher than its present level; evidence for this "high" stand can be seen in many parts of the state's coast (Atlas of Florida 1992).

Over the past 6000 years, as Figure 15 indicates, the sea has been rising. Throughout South Florida, during the first half of this period, the rate of rise was about 23 centimeters per century, then the rate slowed to about 4 centimeters per century. During the last one hundred years, the rate of rise has been at a rapid pace of 30-40 centimeters (Wanless et al. 1994).

## Sea Level Compilation

1. 23 cm / 100 yrs
2. 4 cm / 100 yrs
3. 30-40 cm / 100 yrs

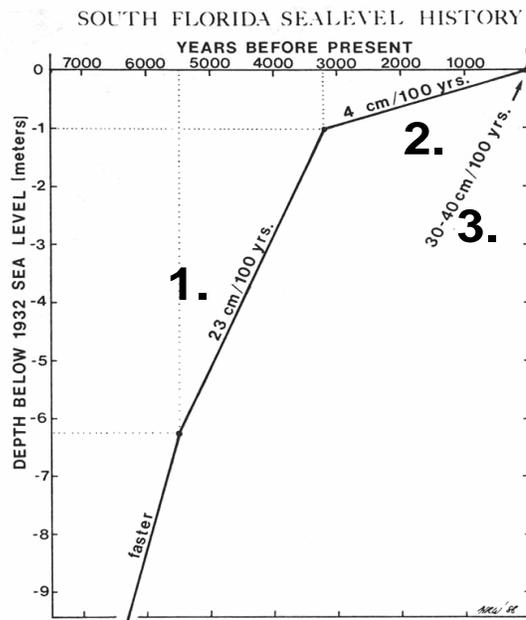
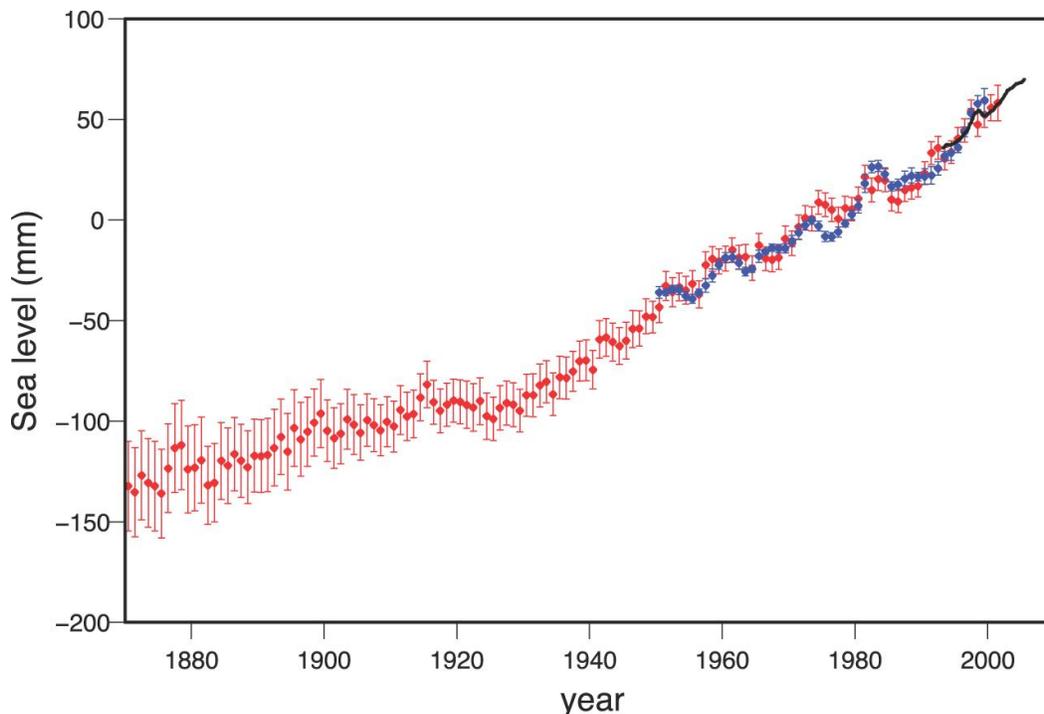


Figure 15: Sea level rise rates compiled by Wanless et al. (1994)

For the past few thousand years, the sea level around Florida has been rising very slowly, although a persistent upturn in the rate of relative sea level rise may have begun recently (IPCC 2007b). Geological studies show that, in the past, the sea level of Florida, as well as the rest of the globe, changed much more rapidly than it has in more recent times. Distinguishing Florida-specific sea level trends from future global trends is a critical research need.

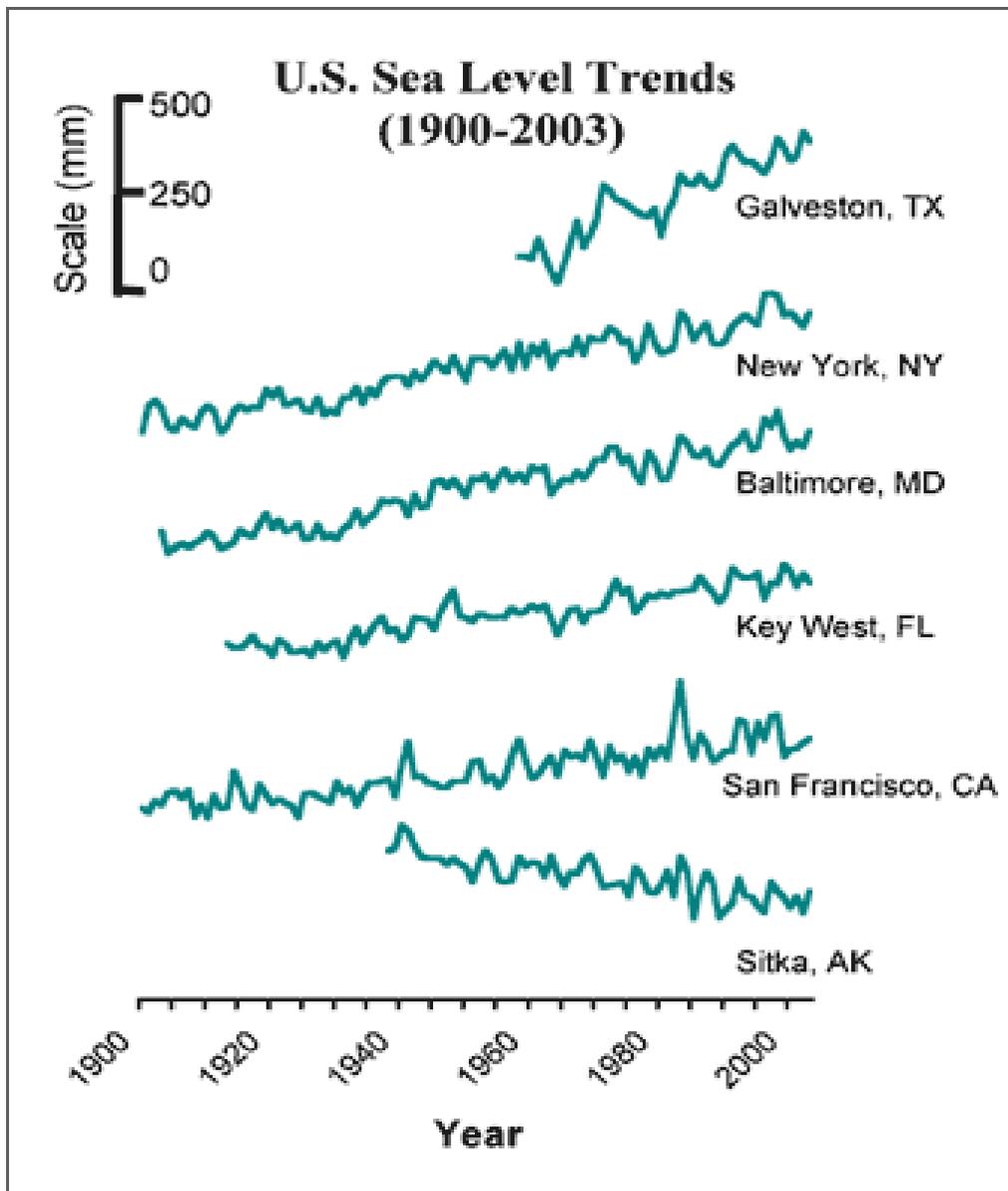


**Figure 16: Annual averages of global mean sea level in millimeters**

The red curve shows reconstructed sea level fields since 1870 (updated from Church and White, 2006); the blue curve shows coastal tide gauge measurements since 1950 (from Holgate and Woodworth, 2004) and the black curve is based on satellite altimetry (Leuliette et al., 2004). The red and blue curves are deviations from their averages for 1961 to 1990, and the black curve is the deviation from the average of the red curve for the period 1993 to 2001. Error bars show 90% confidence intervals.

Source: Intergovernmental Panel on Climate Change (2007) fig-5-13

The *rate* at which sea level rises is equally as important to coastal resources as how much it rises. The rate of global sea level rise increased from the 19th to the 20th century (IPCC 2007b) and has increased further since 1993 (FOCC 2009). Sea level has been rising at a rate of 0.08-0.12 inches per year (2.0-3.0 mm per year) along most of the U.S. Atlantic and Gulf coasts. The rate of sea level rise varies from about 0.36 inches per year (10 mm per year) along the Louisiana Coast (due to land sinking), to a *drop* of a few inches per decade in parts of Alaska (because land is rising). See Figure 17 for sea level trends in selected cities.



**Figure 17: U.S. Sea Level Trends**

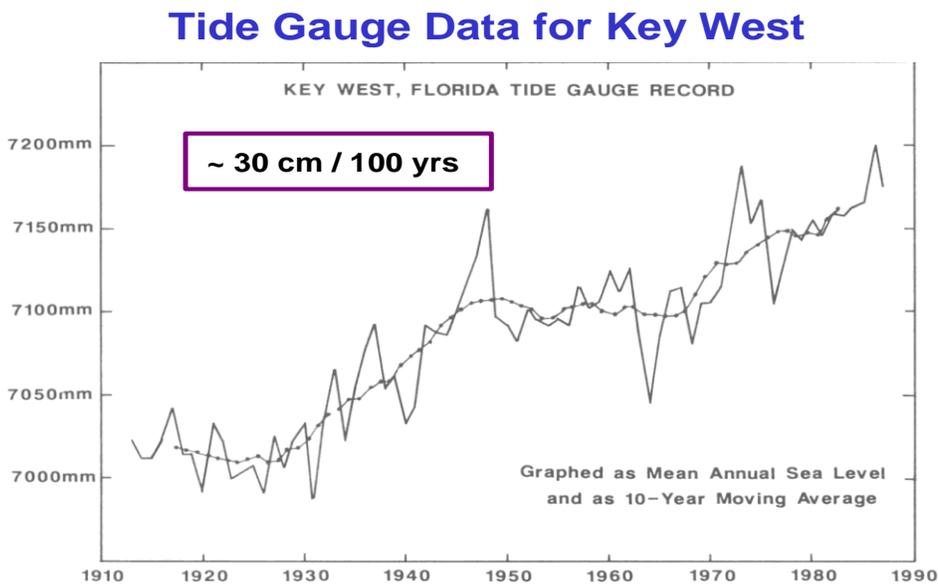
*Source: Monthly and Annual Mean Sea Level Station Files from the Permanent Service for Mean Sea Level (PSMSL) at the Proudman Oceanographic Laboratory*

Around Florida, relative sea level has been rising at a slow but constant rate, about an inch or less per decade (Maul and Martin 1993; FOCC 2009). The historic (1947-2009) sea level rise in southwest Florida measured at St. Petersburg is 2.3 mm/yr (Walton 2007, FOCC 2009). Figure 18 provides further evidence specific to southwest Florida, measured at Key West, that sea level has been rising at an estimated rate of 3 mm/yr (Maul and Martin 1993; Savarese et al. 2002).

Since 1933, the Permanent Service for Mean Sea Level (PSMSL) has been responsible for the collection, publication, analysis and interpretation of sea level data from the global network of

tide gauges. It is based in Liverpool at the Proudman Oceanographic Laboratory (POL) which is a component of the UK Natural Environment Research Council (NERC). The PSMSL is a member of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS) established by the International Council for Science (ICSU). It is supported by FAGS, the Intergovernmental Oceanographic Commission (IOC) and NERC.

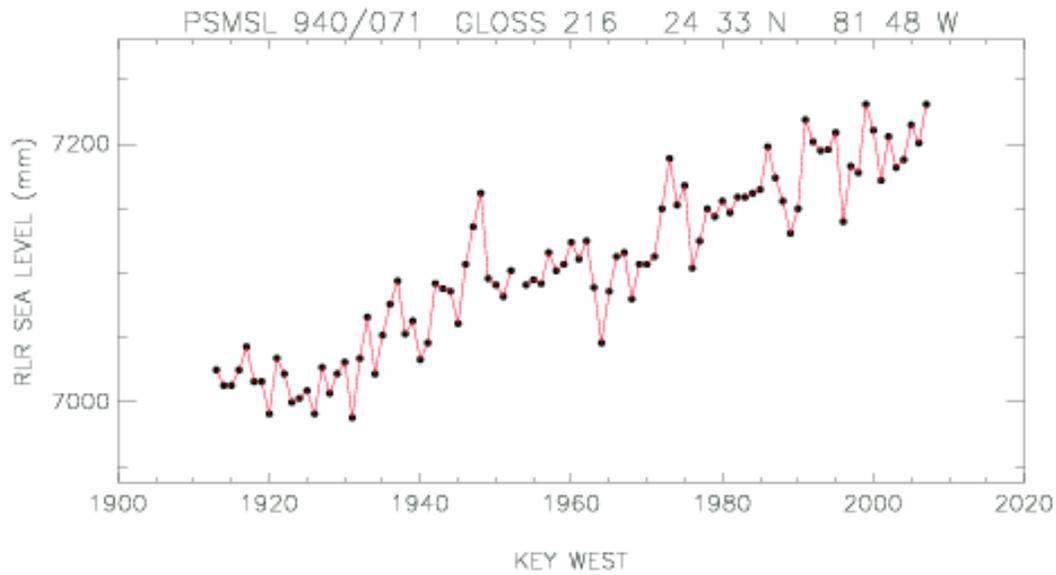
As of December 2006, the database of the PSMSL contained over 55,000 station-years of monthly and annual mean values of sea level from almost 2,000 tide gauge stations around the world received from almost 200 national authorities. On average, approximately 2,000 station-years of data are entered into the database each year (Woodworth and Player, R. 2003). Local sea level information from PSMSL is found below.



From Maul & Martin 1993

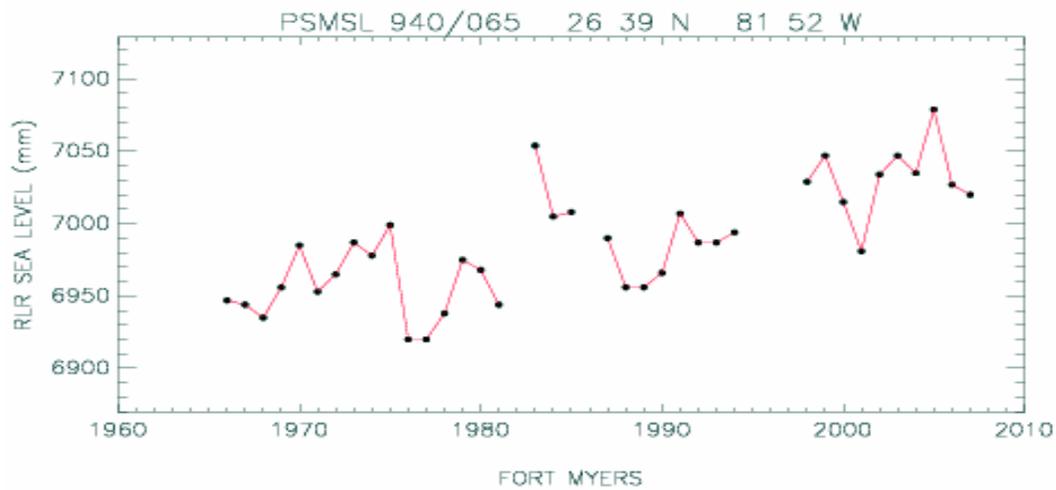
**Figure 18: Mean annual sea level at Key West, Florida 1910-1990**

Key: 7000 mm is 275.6 inches, 7200 mm is 283.5 inches, and 30 cm is 11.8 inches in 100 years of record



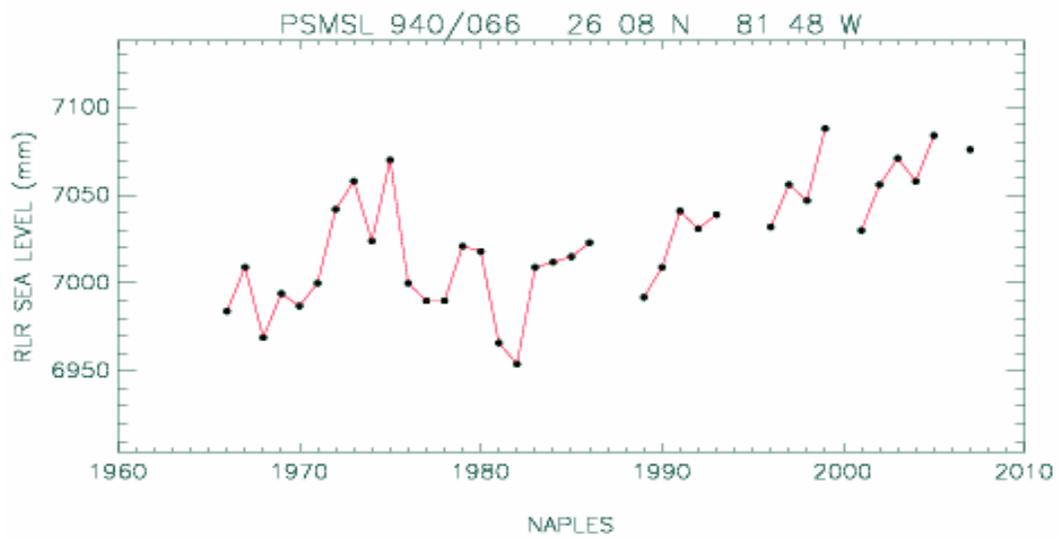
**Figure 19: Mean Annual Sea Level at Key West, Florida 1910-2009**

Source: Permanent Service for Mean Sea Level (PSMSL), hosted at the Proudman Oceanographic Laboratory (POL)



**Figure 20: Mean Annual Sea Level at Fort Myers, Florida 1910-2009**

Source: Permanent Service for Mean Sea Level (PSMSL), hosted at the Proudman Oceanographic Laboratory (POL)



**Figure 21: Mean Annual Sea Level at Naples, Florida 1910-2009**

Source: Permanent Service for Mean Sea Level (PSMSL), hosted at the Proudman Oceanographic Laboratory (POL)

## Potential Future Climate Effects: Sea Level

The five sea level rise “severity” scenarios were discussed in the Potential Climate Futures section beginning on page 44:

Probability (%)	2025		2050		2075		2100		2150		2200	
	cm	inches										
<b>Rapid Stabilization Case</b>	41	1.8	9	3.5	13	5.3	18	7.1	22	8.8	27	10.5
<b>90 (least)</b>	7	2.8	13	5.0	20	7.7	26	10.4	40	15.7	53	21.0
<b>80</b>	9	3.6	17	6.6	26	10.1	35	13.9	53	20.8	71	28.1
<b>70</b>	11	4.4	20	7.8	30	11.6	41	16.3	63	24.7	85	33.6
<b>60</b>	12	4.7	22	8.6	34	13.2	45	17.8	72	28.3	99	39.1
<b>50 (moderate)</b>	13	5.1	24	9.4	37	14.4	50	19.8	80	31.4	112	44.2
<b>40</b>	14	5.5	27	10.6	41	16.0	55	21.8	90	35.4	126	49.7
<b>30</b>	16	6.3	29	11.3	44	17.1	61	24.1	102	40.1	146	57.6
<b>20</b>	17	6.7	32	12.5	49	19.1	69	27.3	117	46.0	173	68.2
<b>10</b>	20	7.9	37	14.5	57	22.3	80	31.6	143	56.2	222	87.5
<b>5 (worst)</b>	22	8.7	41	16.1	63	24.6	91	35.9	171	67.2	279	110.0
<b>2.5</b>	25	9.9	45	17.6	70	27.4	103	40.7	204	80.2	344	135.6
<b>1</b>	27	10.6	49	19.2	77	30.1	117	46.2	247	97.2	450	177.3
<b>Business as Usual</b>	29	11.3	57	22.6	86	34	115	45.3	247	97	450	177

\*The results of this table are based on using Tables 9-1 and 9-2 of the USEPA Report "The Probability of Sea Level Rise". Basically, the formula is multiplying the historic sea level rise (2.3 mm/yr) in Southwest Florida (closest point used is St. Petersburg, Fl., Table 9-2) by the future number of years from 1990 plus the Normalized Sea Level Projections in Table 9-1 and Table ES-2. Two Future Climate Scenarios for Florida Stanton and Ackerman 2007

**Table 13: Combined Sea Level Projections by Year for Southwest Florida**

One cause of sea level rise is increased temperature and the subsequent expansion of the warmer water volume (Titus 1998; USEPA CRE 2008). The rate of global average sea level rise has increased during the late 20th century (Church and White 2006) and will accelerate further because of ocean warming and contributions from land-based ice melt from glaciers and the ice sheets of Greenland and Antarctica (IPCC 2007b). Sea level rise will continue well after 2100 even if greenhouse gas concentrations are stabilized by then (IPCC 2007b). Major inputs of water from the melting of high latitude and high altitude ice reservoirs could cause several meters of sea level rise over the centuries to come (Hansen 2007).

As a result of these increasing sea levels, Florida will probably become more vulnerable to coastal flooding and storm surges (FOCC 2009). Sea levels around the state will probably continue to rise at historical or accelerated rates in upcoming decades (FOCC 2009).

Increases in sea level will probably increase shoreline erosion. Barrier islands will likely continue to erode and migrate towards the mainland or along prevailing lateral pathways (FOCC 2009), which could eventually threaten the ecological integrity of natural communities in estuaries, tidal wetlands, and tidal rivers (FOCC 2009). As sea levels rise, shallow coastal aquifers and associated public drinking water supplies are at risk from saltwater intrusion (FOCC 2009).

Sea level rise will also exacerbate many other effects of climate change. For example, coastal shorelines, beaches, mangroves, low marsh, river and creek shorelines will experience higher tides including higher high tides, higher normal tides, and higher low tides (Titus 1998; USEPA CRE 2008; Folland & Karl 2001; IPCC 2001c).

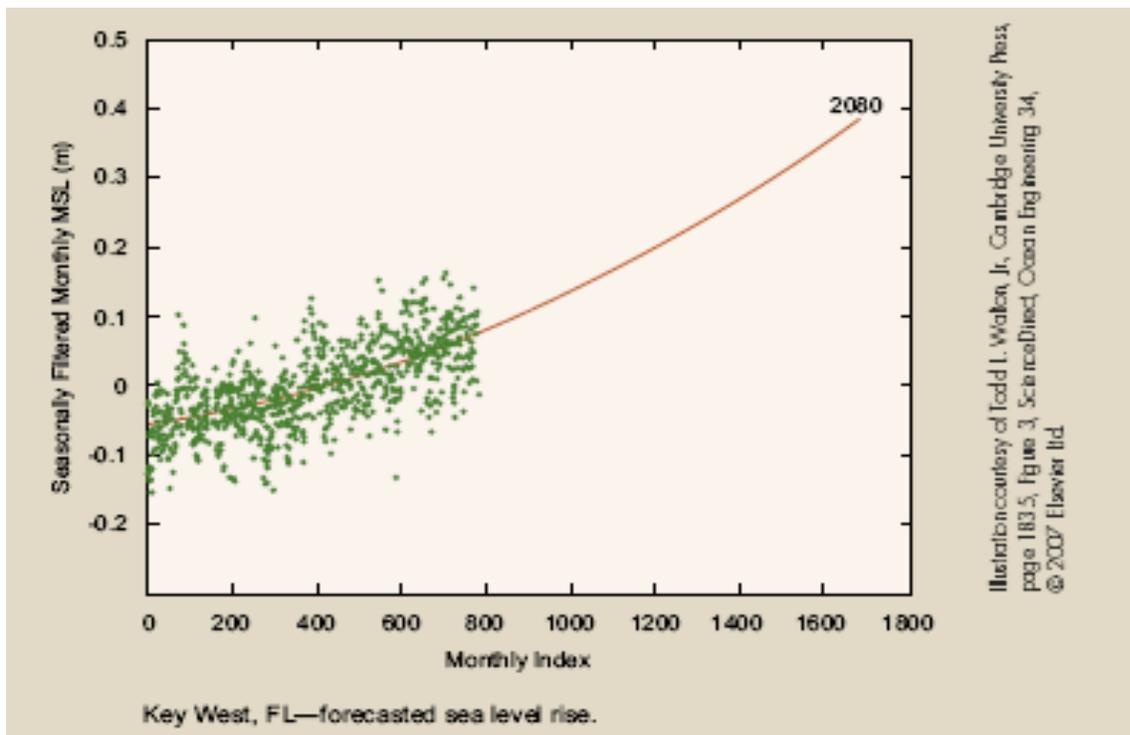
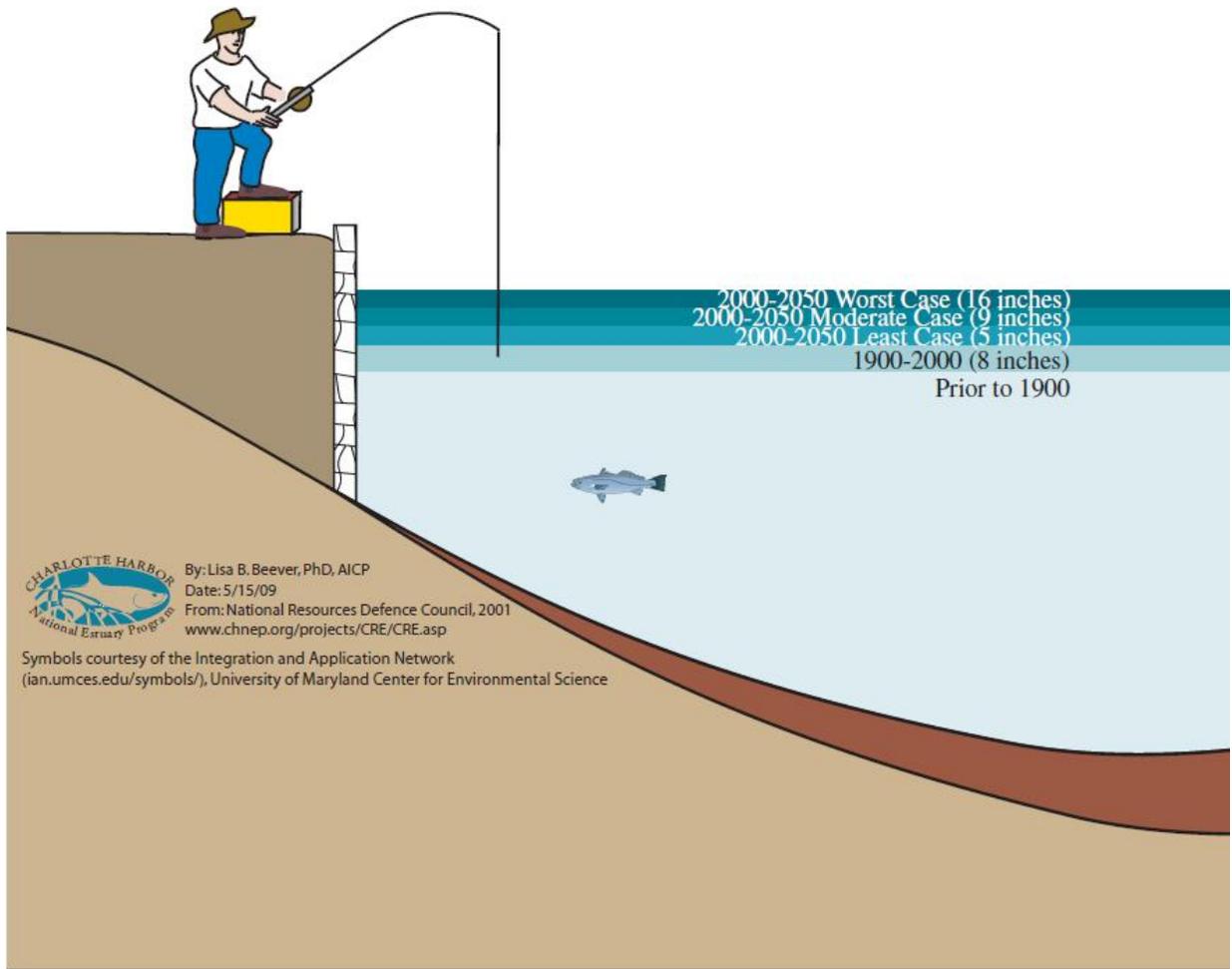


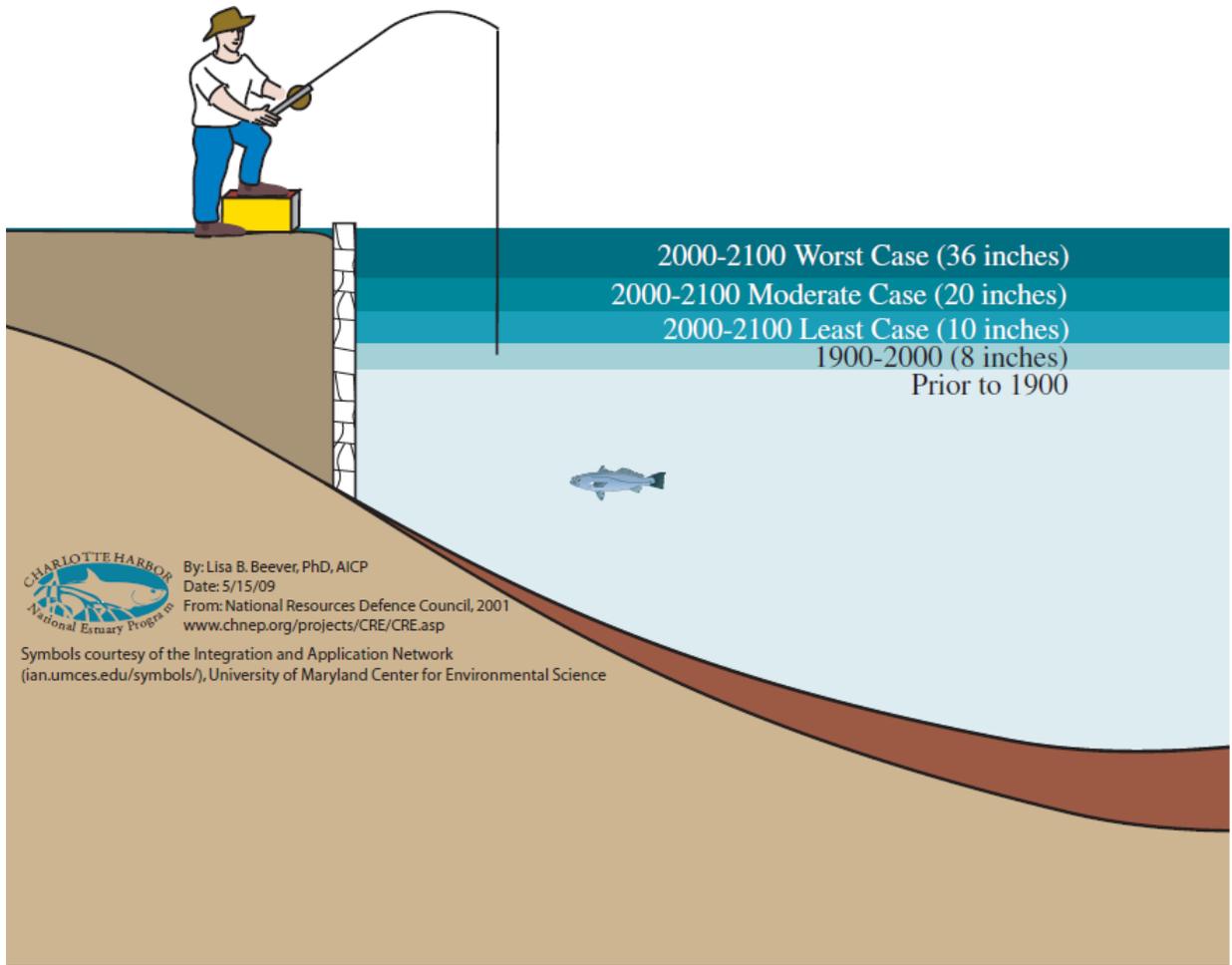
Figure 22: Forecasted Sea Level Rise at Key West, Florida



**Figure 23a: Sea level rise in three different probabilities in the year 2050 for Charlotte Harbor at Punta Gorda.** Least case (90% probable), moderate case (50% probable) and worst case (5% probable)  
*Source: IPCC 2007*



Figure 23b: Estimated Sea Level Rise Year 2050 in Three Probability Scenarios



**Figure 24a: Sea level rise in three different probabilities in the year 2100 for Charlotte Harbor at Punta Gorda.** Least case (90% probable), moderate case (50% probable) and worst case (5% probable)  
 Source: IPCC 2007

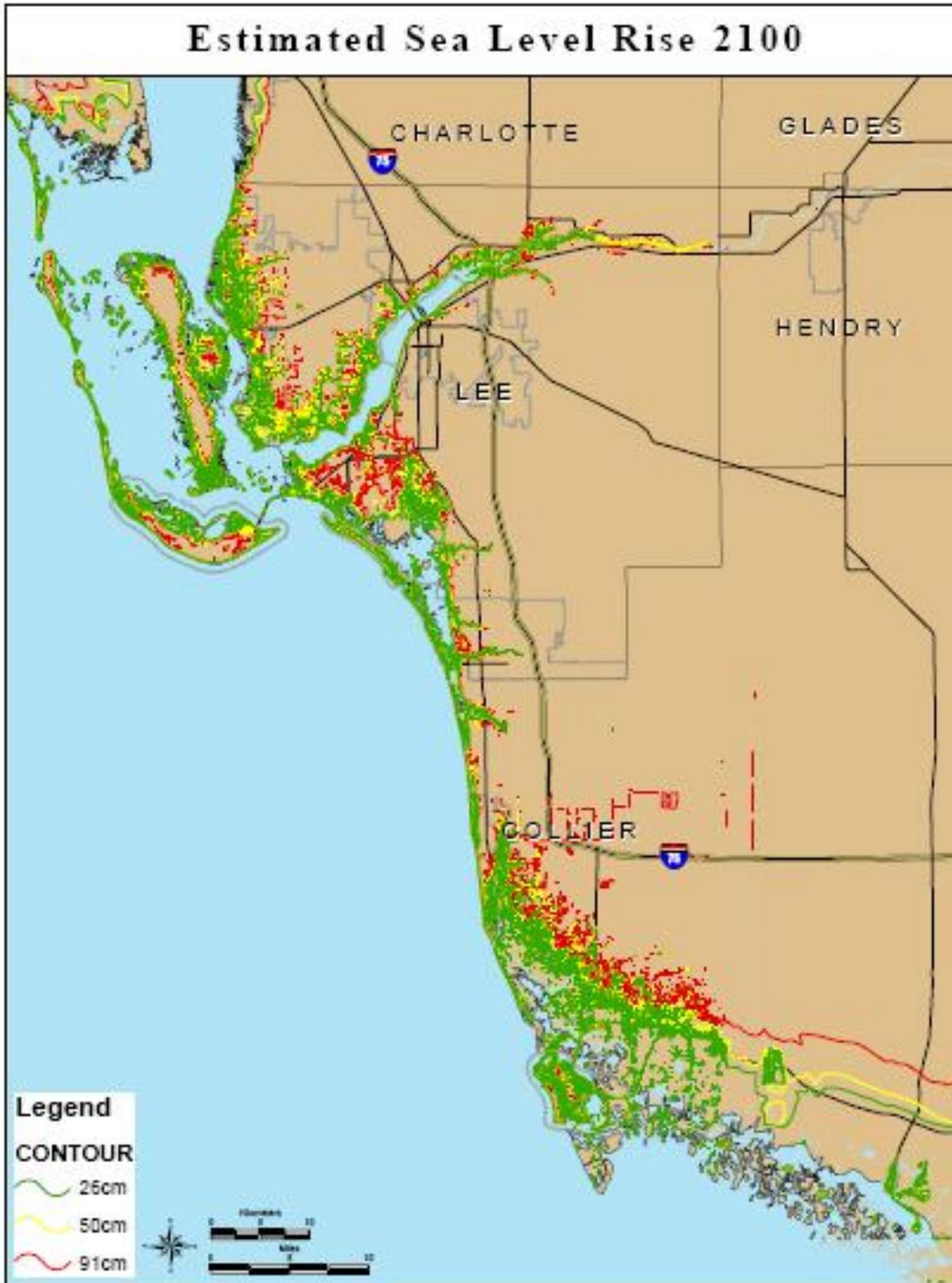
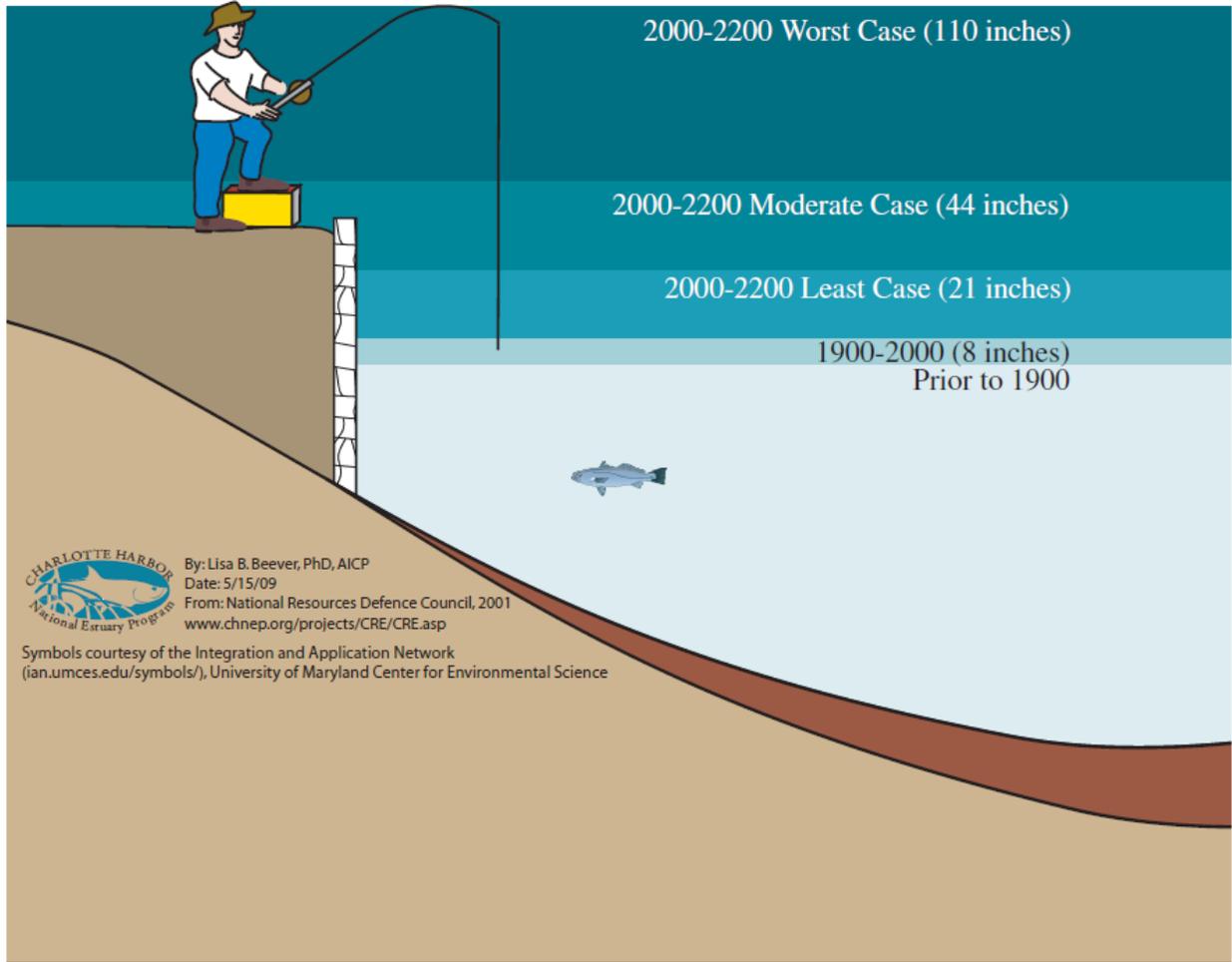


Figure 24b: Estimated Sea Level Rise Year 2100 in Three Probability Scenarios



**Figure 25a: Sea level rise in three different probabilities in the year 2200 for Charlotte Harbor at Punta Gorda.** Least case (90% probable), moderate case (50% probable) and worst case (5% probable)  
*Source: IPCC 2007*

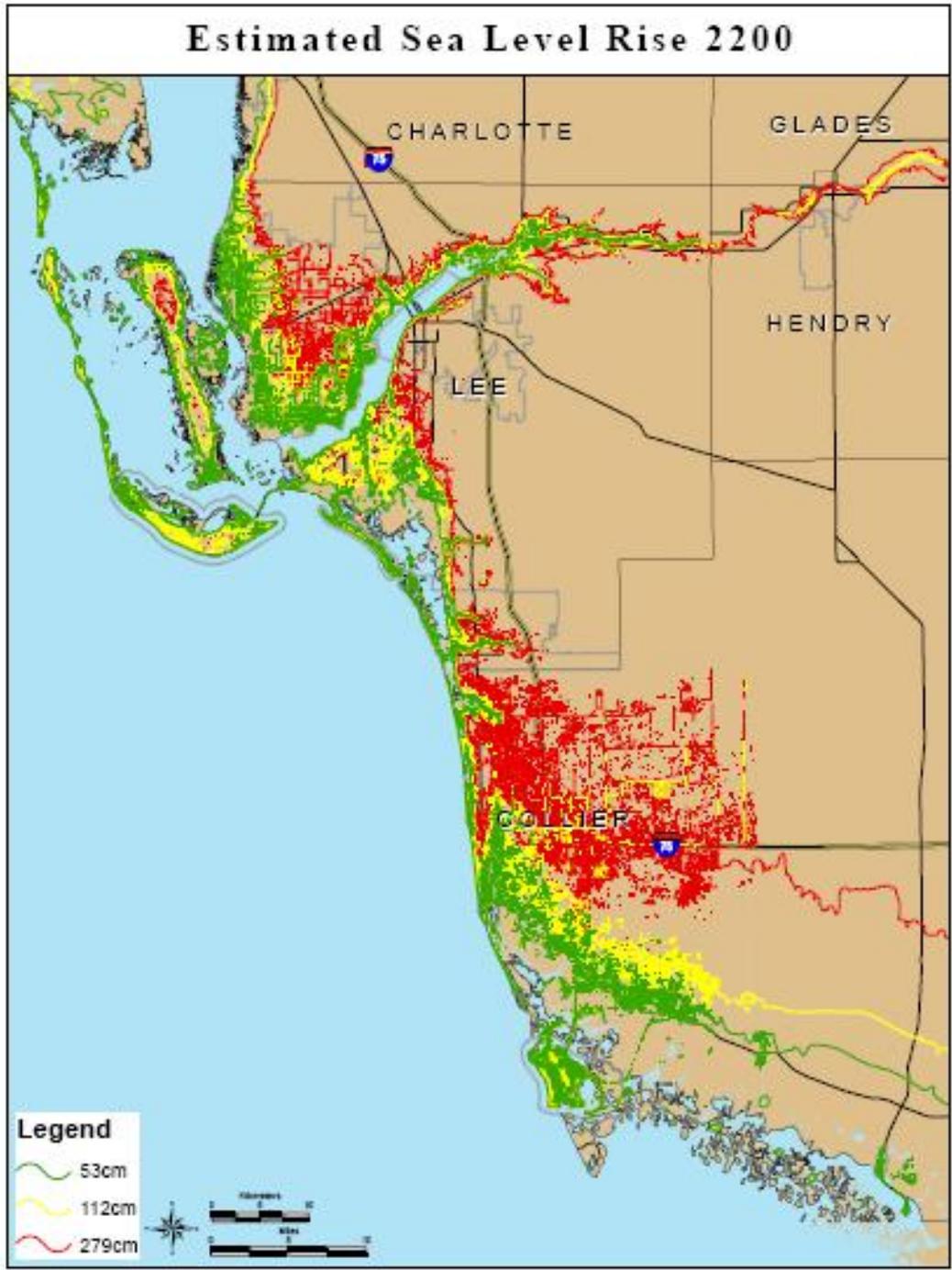
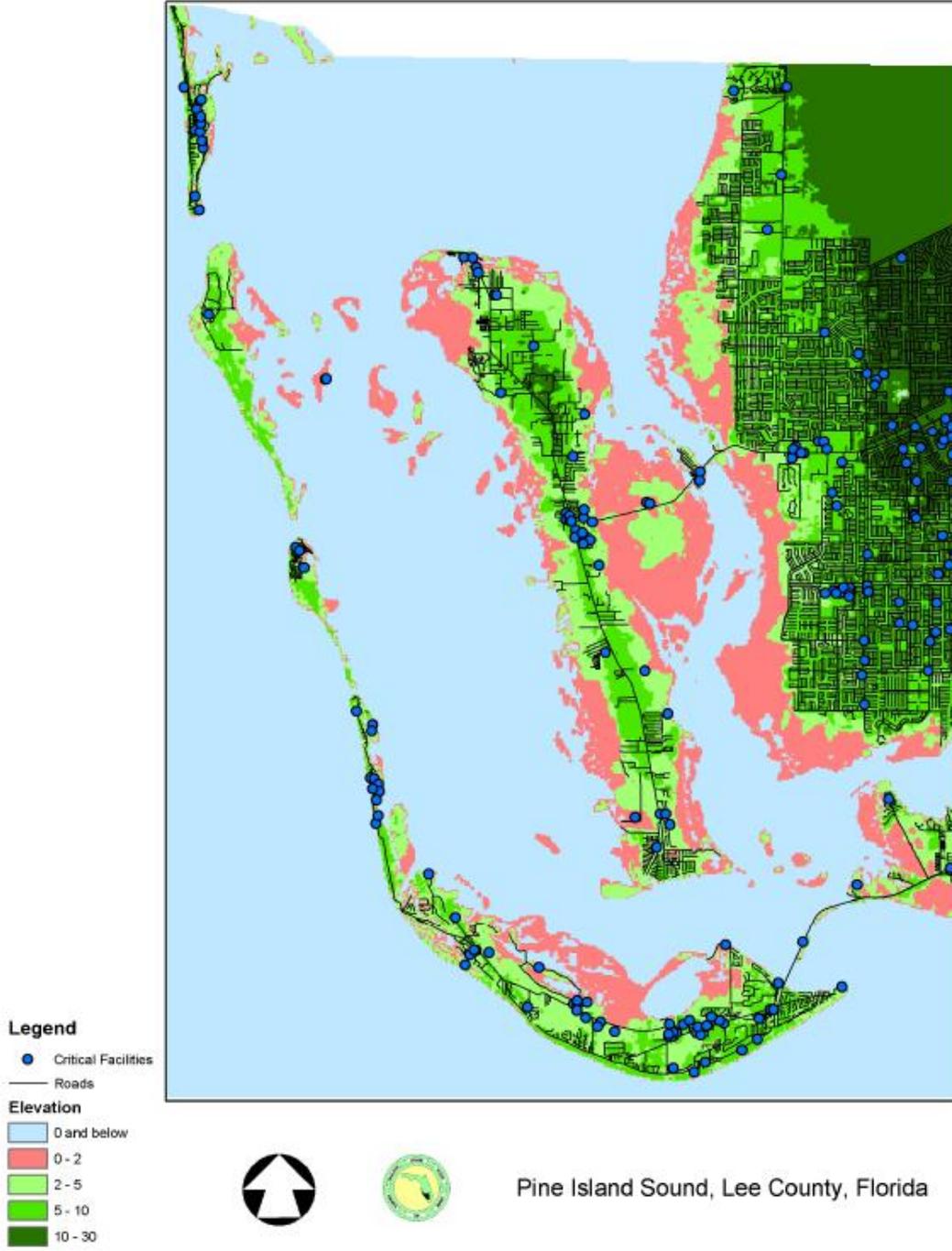
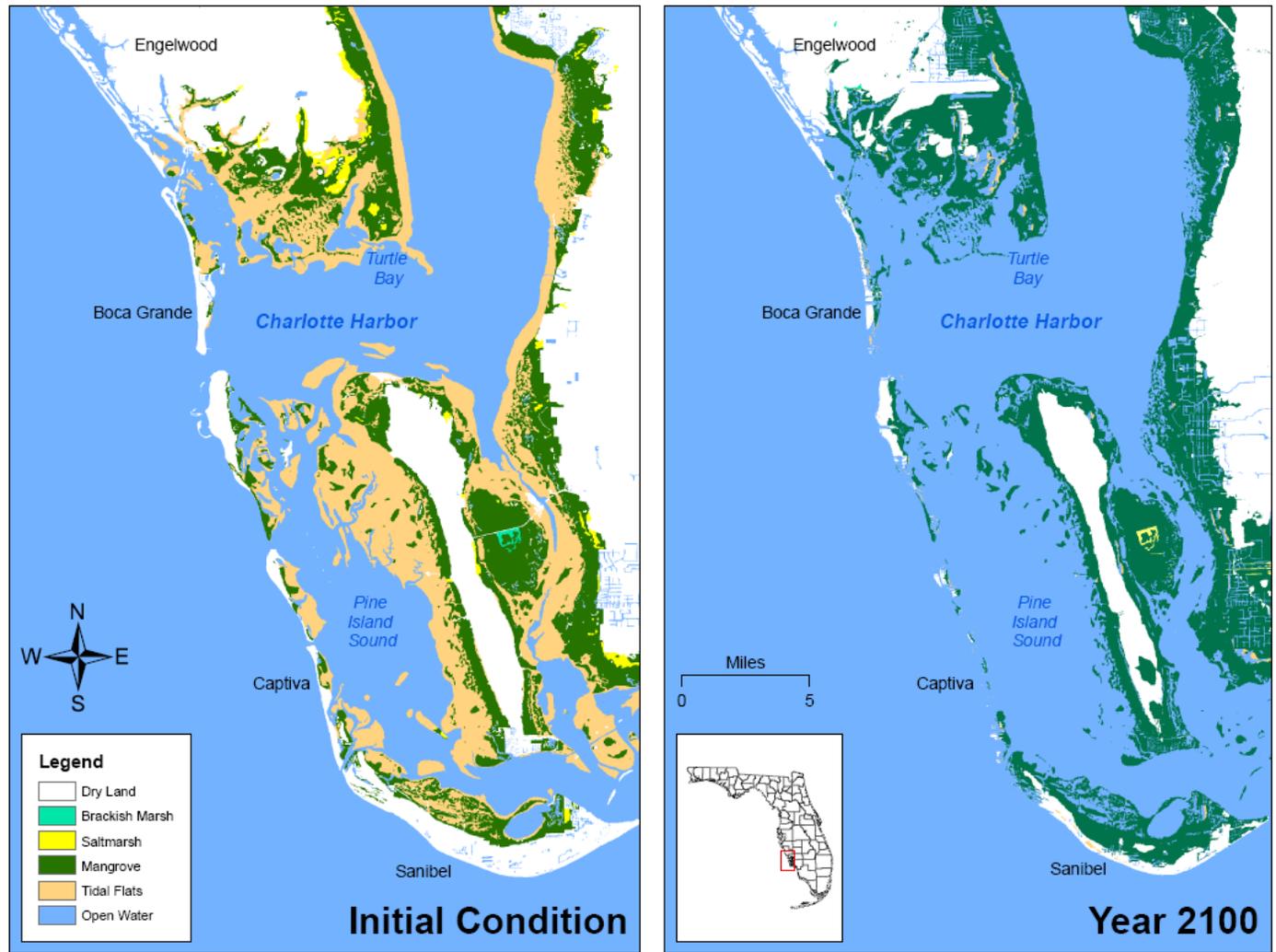


Figure 25b: Estimated Sea Level Rise Year 2200 in Three Probability Scenarios



**Figure 26: Two-foot contour sea level rise for the Pine Island Sound, Matlacha Pass, and San Carlos Bay Area.** This is the prediction of Karl et al. (2007) for the year 2100; approximately equivalent to a 90% probability 2200 prediction (IPCC 2007); a 5% Probability 2075 prediction (IPCC 2007); or the 2050 Business as Usual Worst Case scenario (Stanton and Ackerman 2007).



**Figure 27: Three-foot contour sea level rise Sea Level Rise in Lower Charlotte Harbor Estuary Year 2100.** This is the 5% probability worst case IPCC (2007) scenario.

Some scientists expect more rapid sea level rise than previously predicted by IPCC 2007 (USEPA CRE 2008). One team of researchers has suggested that global sea level could rise far higher than previously forecast because of changes in the polar ice sheets, a meter or more by 2100. They assert that the IPCC projections did not include the potential impact of polar melting and ice breaking off. The IPCC, in its 2007 Fourth Assessment Report, had said that the maximum rise in sea level would be about 59 centimeters. Professor Konrad Steffen from the University of Colorado, speaking at a press conference, highlighted new studies into ice loss in Greenland, showing that it has accelerated over the last decade. Professor Steffen, who has studied the Arctic ice for the past 35 years, has said, "I would predict sea level rise by 2100 in the order of one meter; it could be 1.2 meters or 0.9 meters. But it is one meter or more seeing the current change, which is up to three times more than the average predicted by the IPCC. It is a major change and it actually calls for action." Dr John Church of the Centre for Australian Weather and Climate Research added, "The most recent research showed that sea level is rising by 3 mm a year since 1993, a rate well above the 20th century average." Professor Eric Rignot, a senior research scientist at NASA's Jet Propulsion Laboratory, said that results gathered since the IPCC report showed that melting and ice loss could not be overlooked. "As a result of the acceleration of outlet glaciers over large regions, the ice sheets in Greenland and Antarctica are already contributing more and faster to sea level rise than anticipated," he observed. Professor Stefan Ramstorf of the Potsdam Institute for Climate Impact Research said, "Based on past experience, I expect that sea level rise will accelerate as the planet gets hotter" (Shukman 2009).

Local topography and land use will greatly affect the scope and reach of whatever sea level rise occurs in Florida. The area included in this study is divided into uplands (433 square miles/277,050 acres) and wetlands (915 square miles/585,766 acres) below 10 feet in elevation, which only exist in the four coastal counties (1,348 total square miles/862,816 acres). The areas below 10 feet in elevation, (equivalent to 9.2 feet above mean sea level or subject to daily tidal inundation with 8.2 feet of sea level rise), which are subject to sea level rise impacts, comprise 22.4 percent of the region's total land area. A current population of approximately 607,000 people lives in 357,000 dwelling units (SWFRPC 2001). Millions of square feet of commercial, office and other uses exist within the study area. This area is expected to be essentially built-out in the next 50 years with a population of more than one million people.

Utilizing the most recent available land cover data from the Florida Fish and Wildlife Conservation Commission (FWC) (2003) and currently available Lidar elevations, it is possible to project the amount of habitat that would be subject to future inundation from various levels of sea level rise. The following tables and graphs display the results for Lee and Collier Counties, which are the two counties with complete Lidar data at this time. There are currently gaps in the Lidar data for Charlotte and Sarasota Counties.

The elevations analyzed (0.5, 1.0, 1.5, 2.0, 3.0, 4.0, and 9.0 feet NGVD) correspond to the following climate change scenarios:

Elevation in NGVD	Rapid Stabilization Case	90% (least)	50% (moderate)	5% (worst)	Business as Usual
Half Foot	2084	2059	2030	2014	2011
One Foot	2222	2107	2063	2036	2027
Two Feet	2398	2214	2109	2075	2053
Three Feet	2575	2270	2158	2100	2079
Four Feet	2751	2327	2208	2109	2101
Nine Feet	3633	2610	2338	2174	2153

Table 14: Predicted year of different elevation levels (NGVD) of sea level rise for different future scenarios

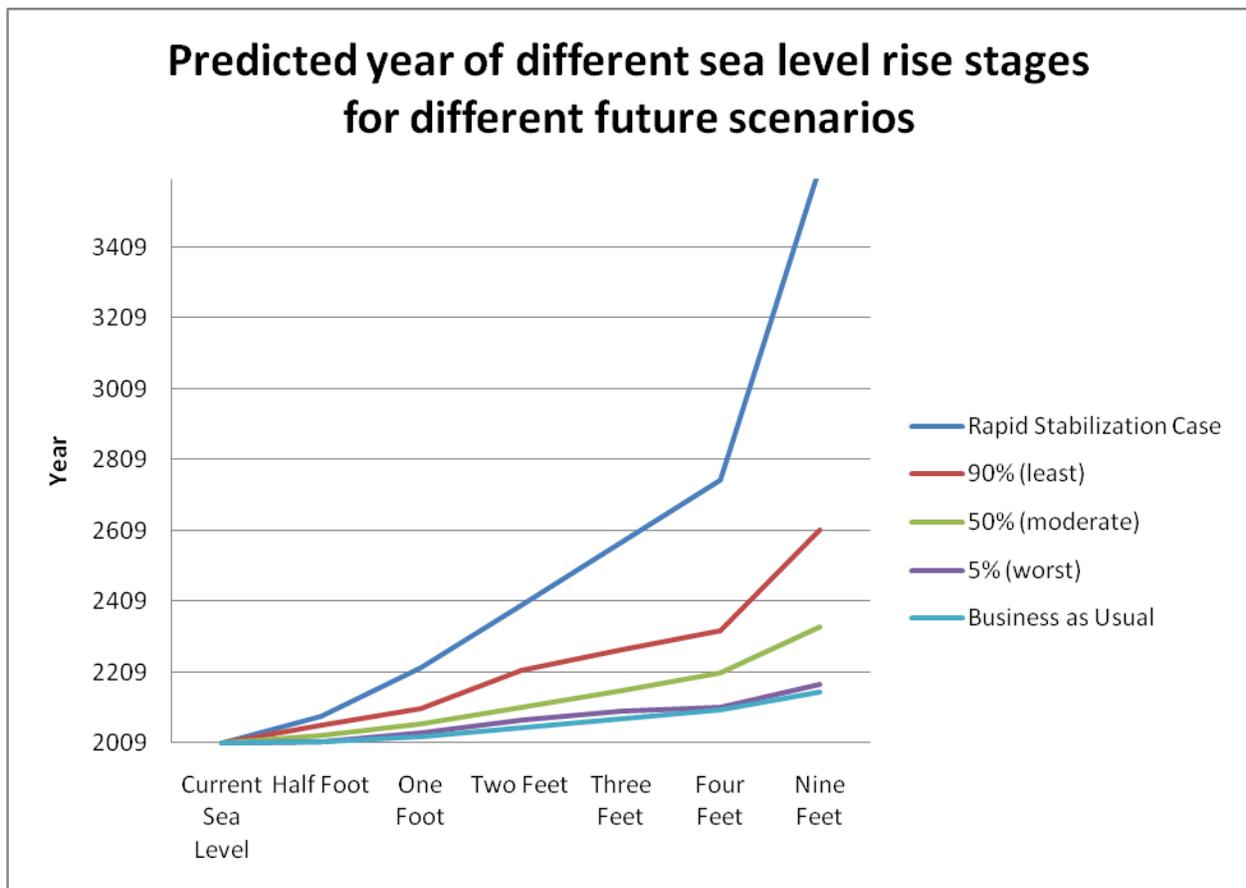


Figure 28: Approximate predicted year of different elevation levels (NGVD) of sea level rise for different future scenarios

Lee County	Half Ft	1 Ft	1.5 Ft	2 Ft	3 Ft	4 Ft	9 Ft
	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Coastal Strand	0.84	2.02	4.76	12.28	29.44	88.74	710.84
Sand/Beach	37.08	72.98	117.21	159.05	219.20	278.08	382.11
Dry Prairie	22.72	58.54	128.26	237.38	648.88	1,230.19	4,452.41
Mixed Pine-Hardwood Forest	12.25	40.49	105.17	193.05	368.66	612.90	1,245.02
Hardwood Hammocks and Forest	52.31	143.99	321.41	538.80	1,126.95	1,894.64	4,474.55
Pinelands	112.08	437.05	1,068.55	2,069.10	4,829.68	7,721.16	16,668.56
Tropical Hardwood Hammock	3.43	11.07	23.66	45.24	87.68	127.68	183.69
Freshwater Marsh and Wet Prairie	20.59	43.32	103.57	175.51	339.80	526.93	1,202.70
Shrub Swamp	18.39	65.29	149.60	248.54	444.25	581.05	970.77
Cypress Swamp	16.70	50.78	111.78	181.62	370.59	513.06	1,091.35
Cypress/Pine/Cabbage Palm	11.44	38.73	84.34	142.28	275.83	361.32	659.74
Mixed Wetland Forest	15.33	64.61	153.84	248.51	440.99	638.06	1,317.61
Hardwood Swamp	30.04	124.97	271.97	419.42	686.73	939.40	1,617.57
Salt Marsh	167.33	576.17	1,516.82	2,403.36	3,921.61	4,332.12	4,679.41
Mangrove Swamp	6,029.46	14,497.23	22,240.81	26,928.51	31,824.22	33,254.71	33,999.58
Open Water	1,788.49	3,605.52	5,421.89	6,741.97	8,557.92	9,972.52	13,660.87
Shrub and Brushland	2.37	6.78	11.71	20.45	51.57	102.02	475.10
Grassland	0.01	0.01	0.12	0.63	1.59	3.43	6.99
Bare Soil/Clear-cut	11.77	25.84	60.24	110.27	222.22	408.39	1,655.42
Improved Pasture	4.35	18.78	25.99	36.02	99.23	226.55	2,132.31
Unimproved Pasture	0.05	0.61	1.29	30.00	101.84	159.12	515.34
Citrus	0.00	2.90	8.73	21.82	77.64	228.40	1,521.45
Row/Field Crops	0.00	0.16	3.78	23.53	93.88	286.54	760.24
Other Agriculture	0.00	0.00	0.39	4.85	18.93	80.62	413.62
Exotic Plants	0.00	0.00	0.00	0.19	1.23	2.35	35.75
High Impact Urban	237.27	681.44	1,437.77	2,543.28	5,938.12	11,800.74	53,005.86
Low Impact Urban	22.07	80.90	183.50	326.60	828.72	1,758.87	7,840.63
Extractive	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	8,616.39	20,650.18	33,557.17	43,862.26	61,607.40	78,129.59	155,679.49

**Table 15a: Acres of habitat or land use at and below different elevations in Lee County 2009.** Note: number includes the prior acreage.

<b>Collier County</b>	<b>Half Ft</b>	<b>One Ft</b>	<b>1.5 Ft</b>	<b>2 Ft</b>	<b>3 Ft</b>	<b>4 Ft</b>	<b>9Ft</b>
	<b>Acres</b>	<b>Acres</b>	<b>Acres</b>	<b>Acres</b>	<b>Acres</b>	<b>Acres</b>	<b>Acres</b>
Sand/Beach	76.0	121.6	172.9	193.8	279.3	332.5	349.5
Xeric Oak Scrub	0.0	0.0	0.0	0.0	3.8	7.6	38.0
Dry Prairie	68.4	161.5	313.5	495.8	1,128.4	1,734.4	6,901.7
Mixed Pine-Hardwood Forest	163.4	528.1	877.7	1,221.5	1,559.7	1,861.7	3,256.1
Hardwood Hammocks and Forest	366.6	906.2	1,802.8	2,634.9	3,822.2	4,661.9	10,646.0
Pinelands	379.9	940.4	1,685.1	2,507.6	3,759.5	5,267.9	24,297.4
Tropical Hardwood Hammock	79.8	146.3	191.9	222.3	277.4	309.7	436.9
Freshwater Marsh and Wet Prairie	1,082.8	2,819.2	4,553.6	6,390.7	12,277.9	20,165.5	106,418.4
Sawgrass Marsh	0.0	0.0	0.0	0.0	0.0	22.8	777.0
Shrub Swamp	617.4	1,269.0	2,169.5	2,959.8	4,280.1	5,864.4	17,819.4
Cypress Swamp	1,274.7	2,351.9	3,940.0	6,291.9	11,309.0	17,783.3	72,852.3
Cypress/Pine/Cabbage Palm	171.0	507.2	1,052.4	1,723.0	3,056.6	4,760.7	27,855.6
Mixed Wetland Forest	989.8	2,336.7	4,403.5	6,668.0	11,421.1	18,220.2	75,760.8
Hardwood Swamp	845.4	2,289.2	4,715.1	7,617.9	12,787.0	17,614.2	48,023.0
Salt Marsh	8,014.9	10,427.6	11,637.7	11,945.4	12,184.8	12,323.5	12,380.5
Mangrove Swamp	21,499.1	28,410.3	30,693.7	31,360.5	31,810.8	31,983.7	32,116.6
Open Water	5,782.7	7,798.3	9,230.7	10,123.6	11,356.5	12,333.0	15,934.8
Shrub and Brushland	11.4	47.5	89.3	152.0	271.7	444.5	1,928.2
Bare Soil/Clear-cut	58.9	96.9	304.0	549.0	1,221.5	2,072.6	3,837.4
Improved Pasture	0.0	0.0	5.7	17.1	85.5	317.3	1,314.6
Unimproved Pasture	0.0	7.6	43.7	53.2	53.2	53.2	95.0
Citrus	0.0	0.0	0.0	0.0	0.0	0.0	112.1
Row/Field Crops	3.8	93.1	332.5	721.9	1,517.9	2,412.6	4,268.7
Other Agriculture	1.9	15.2	43.7	55.1	85.5	114.0	231.8
Exotic Plants	11.4	30.4	43.7	53.2	83.6	93.1	95.0
Australian Pine	0.0	17.1	17.1	17.1	17.1	17.1	17.1
Brazilian Pepper	1.9	15.2	36.1	60.8	106.4	184.3	188.1
High Impact Urban	604.1	1,172.1	1,677.5	2,177.1	3,451.8	5,570.0	14,399.9
Low Impact Urban	218.5	484.4	851.1	1,250.0	2,312.0	4,090.1	12,285.5
Extractive	0.0	0.0	0.0	0.0	19.0	26.6	60.8
<b>Total</b>	<b>42,323.8</b>	<b>62,992.8</b>	<b>80,884.3</b>	<b>97,463.1</b>	<b>130,539.1</b>	<b>170,642.2</b>	<b>494,698.0</b>

**Table 15b: Acres of habitat or land use at and below different elevations in Collier County 2009.** Note: number includes the prior acreage.

Charlotte	Tropical Storm	Cat 1	Cat 2	Cat 3	Cat 4+
Elevation range (in feet)	(3.1' to 5.7')	(4.3' to 6.6')	(8.3' to 12.3')	(11.3'-20.0')	(17.2'-31.7')
Coastal Strand	29.7	46.3	46.3	46.3	46.3
Sand/Beach	147.1	189.7	189.7	189.7	189.7
Xeric Oak Scrub	14.5	40.0	66.2	153.7	221.3
Sand Pine Scrub	0.0	0.0	16.0	18.9	46.0
Dry Prairie	2,163.5	2,729.8	8,531.7	12,463.4	24,453.7
Mixed Pine-Hardwood Forest	539.8	805.6	2,072.8	2,984.1	3,719.6
Hardwood Hammocks and Forest	873.3	1,233.4	3,039.1	4,213.1	5,545.8
Pinelands	3,915.5	4,845.7	9,119.9	11,496.4	28,254.6
Freshwater Marsh and Wet Prairie	1,650.0	1,731.7	2,384.2	2,712.7	13,771.6
Shrub Swamp	647.1	697.0	934.4	1,017.0	2,463.8
Cypress Swamp	432.8	473.0	725.5	792.5	2,279.6
Cypress/Pine/Cabbage Palm	66.5	66.5	72.6	80.7	2,341.2
Mixed Wetland Forest	723.6	761.9	977.8	1,023.0	1,487.6
Hardwood Swamp	948.5	999.8	1,465.6	1,648.2	2,104.3
Salt Marsh	8,171.7	8,303.9	8,891.6	8,894.8	8,894.8
Mangrove Swamp	15,662.0	15,733.4	15,782.7	15,782.7	15,782.7
Tidal Flat	412.2	412.2	412.2	412.2	412.2
Open Water	5,447.9	6,297.0	10,120.0	11,079.0	16,639.5
Shrub and Brushland	145.8	241.5	778.0	1,364.8	2,388.4
Grassland	7.5	16.2	32.1	48.0	125.1
Bare Soil/Clear-cut	101.2	155.5	328.6	640.2	1,563.3
Improved Pasture	171.1	200.7	928.2	2,596.0	15,394.3
Unimproved Pasture	0.0	0.0	0.0	0.0	468.4
Sugar cane	0.0	0.0	0.0	0.0	0.0
Citrus	4.6	20.6	445.7	1,079.4	4,054.3
Row/Field Crops	0.0	0.0	0.0	242.5	2,018.7
Other Agriculture	4.3	6.4	47.7	82.4	1,414.6

Exotic Plants	11.1	11.1	11.1	11.1	11.1
Melaleuca	0.0	0.0	0.0	0.0	1.0
Brazilian Pepper	0.0	0.0	0.0	0.0	176.8
High Impact Urban	4,529.9	8,145.4	26,698.2	37,863.8	48,820.3
Low Impact Urban	1,090.4	1,905.0	10,245.9	15,853.2	20,760.4
Extractive	0.0	0.2	110.6	180.9	543.2
<b>Total</b>	<b>47,911.8</b>	<b>56,069.6</b>	<b>104,474.5</b>	<b>134,971.0</b>	<b>226,394.6</b>

**Table 17c: Acres of habitat or land use at and below different storm surge elevations in Charlotte County 2009.** Note: number includes the prior acreage

Sarasota	Cat 1	Cat 2	Cat 3	Cat 4
	5.1' to 6.3'	8.9' to 10.1'	11.7' to 13.2'	17.5' to 27.5'
Coastal Strand	37.1	37.1	37.1	37.1
Sand/Beach	346.8	356.8	366.3	366.3
Xeric Oak Scrub	12.3	35.2	118.9	130.8
Sand Pine Scrub	6.3	10.0	17.0	26.7
Dry Prairie	308.8	2,706.1	11,135.2	20,995.3
Mixed Pine-Hardwood Forest	357.9	920.3	2,339.2	4,224.3
Hardwood Hammocks and Forest	535.6	1,381.4	3,384.6	5,809.0
Pinelands	1,397.1	3,898.7	8,803.4	16,759.2
Freshwater Marsh and Wet Prairie	159.6	1,121.9	2,870.8	7,705.7
Shrub Swamp	191.2	536.5	1,112.2	2,761.7
Bay Swamp	0.0	0.0	4.4	5.3
Cypress Swamp	153.1	274.8	536.9	1,070.5
Cypress/Pine/Cabbage Palm	0.7	0.7	0.7	0.7
Mixed Wetland Forest	285.4	453.7	780.4	1,255.1
Hardwood Swamp	454.5	1,041.4	2,368.7	4,419.5
Salt Marsh	1,198.7	1,283.3	1,300.1	1,319.9

Mangrove Swamp	665.9	695.2	699.7	701.1
Open Water	2,134.2	2,489.8	3,436.2	6,164.0
Shrub and Brushland	72.9	212.8	614.7	1,478.9
Grassland	3.4	12.1	86.3	239.4
Bare Soil/Clear-cut	100.8	143.0	352.1	685.1
Improved Pasture	6.7	186.2	1,399.9	8,614.8
Citrus	0.0	2.4	64.3	536.6
Row/Field Crops	0.0	0.0	58.4	216.4
Other Agriculture	1.2	7.2	97.8	244.0
High Impact Urban	4,649.6	8,722.6	17,695.0	41,594.7
Low Impact Urban	948.5	2,157.1	5,588.7	13,592.4
Extractive	0.0	0.0	5.9	379.7
<b>Total</b>	<b>14,028.4</b>	<b>28,686.5</b>	<b>65,275.1</b>	<b>141,334.1</b>

**Table 17d: Acres of habitat or land use at and below different storm surge elevations in Sarasota County 2009, Note number includes the prior acreage.**

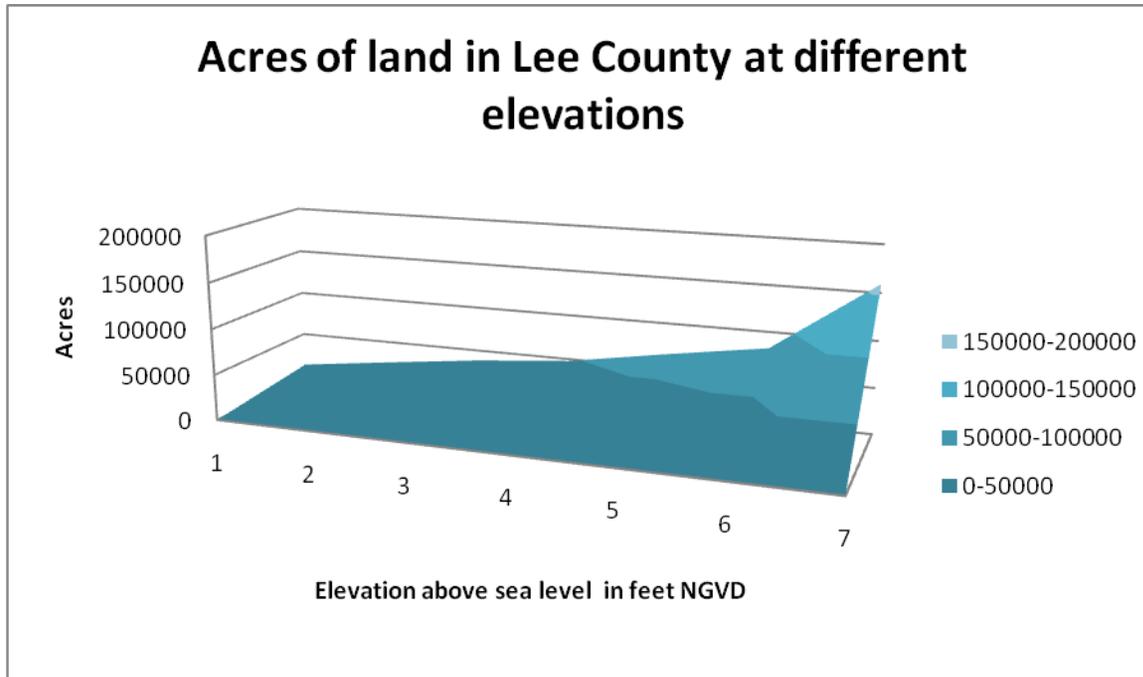


Figure 29a: Acres of habitat or land at and below different elevations in Lee County 2009

### Acres of land innundated in Collier County at different elevations

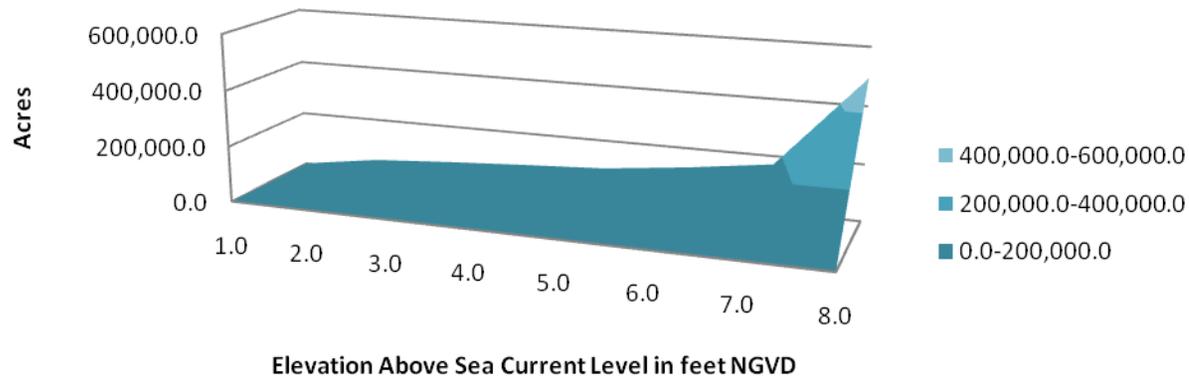


Figure 29b: Acres of habitat or land at and below different elevations in Collier County 2009

## Acres of land in Charlotte County at different storm surge elevations

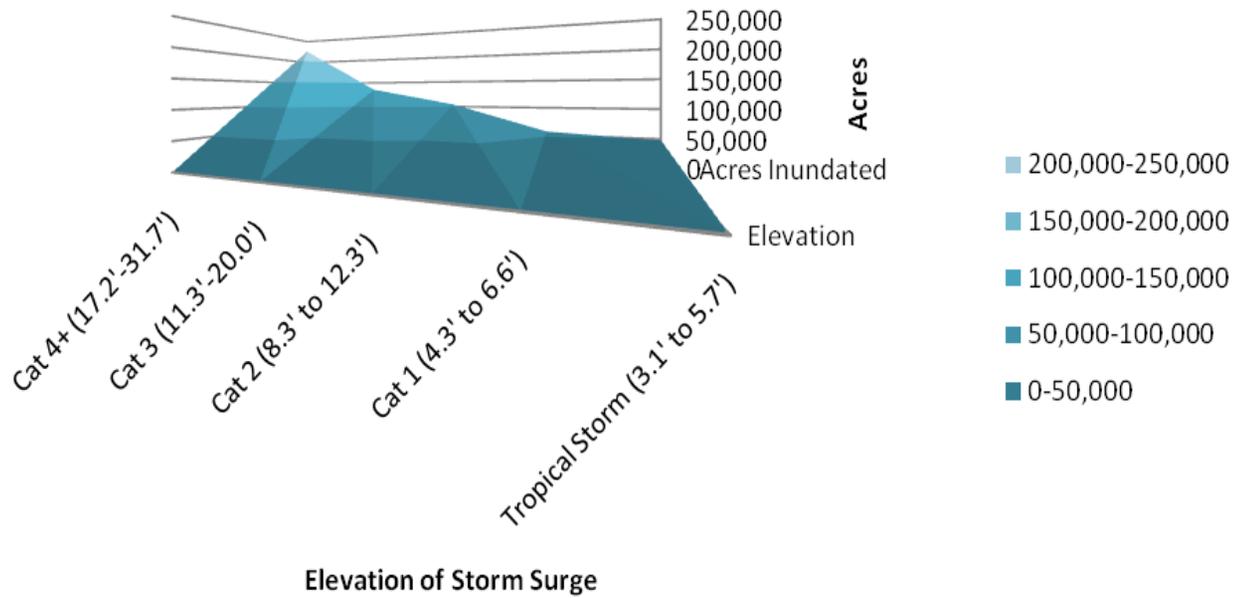
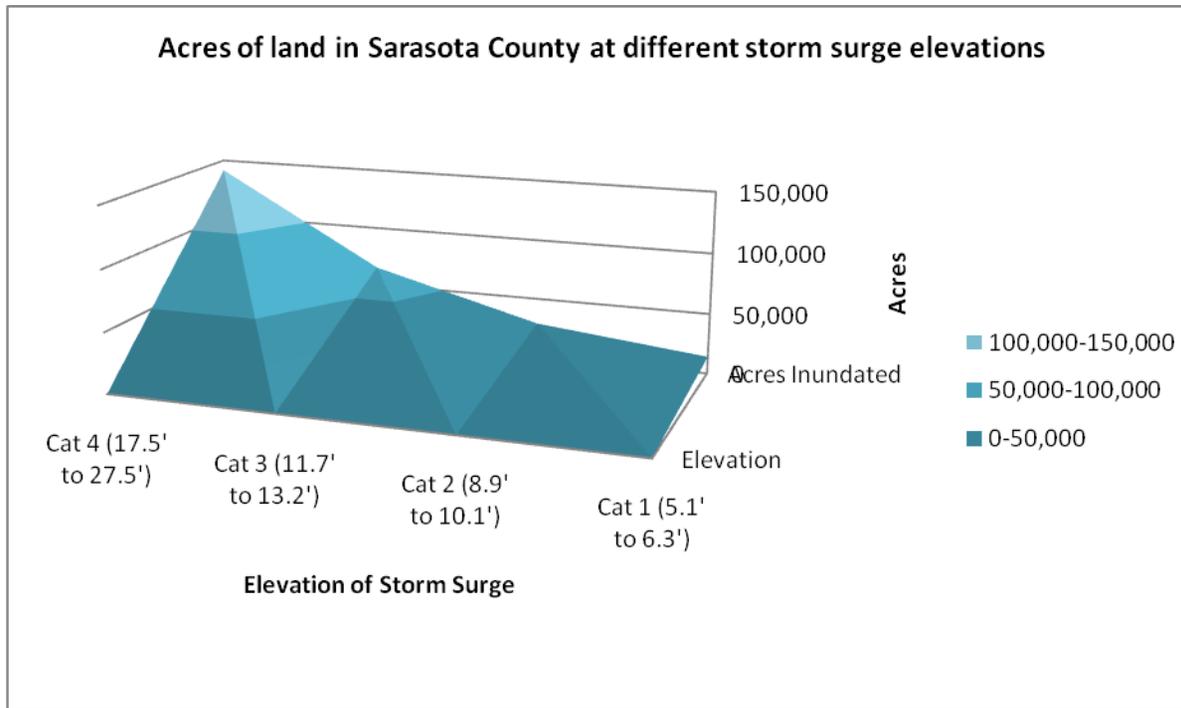
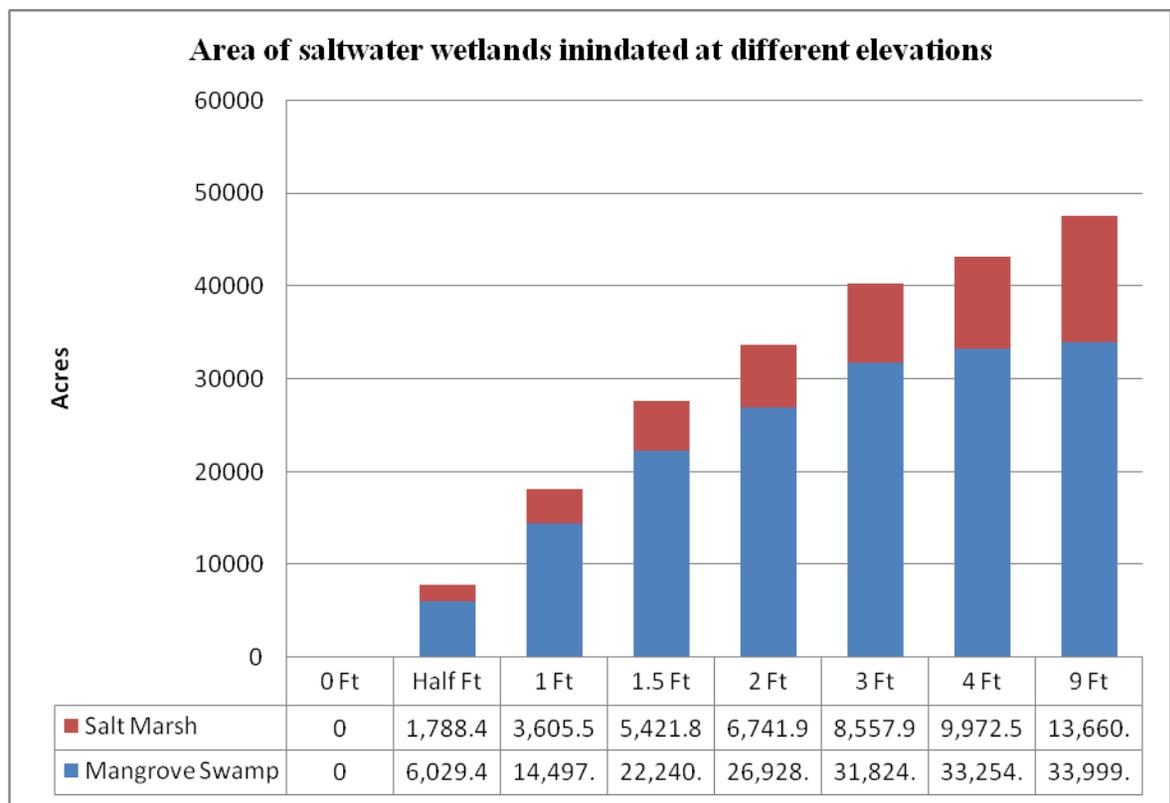


Figure 29c: Acres of habitat or land at and below different storm surge elevations in Charlotte County 2009

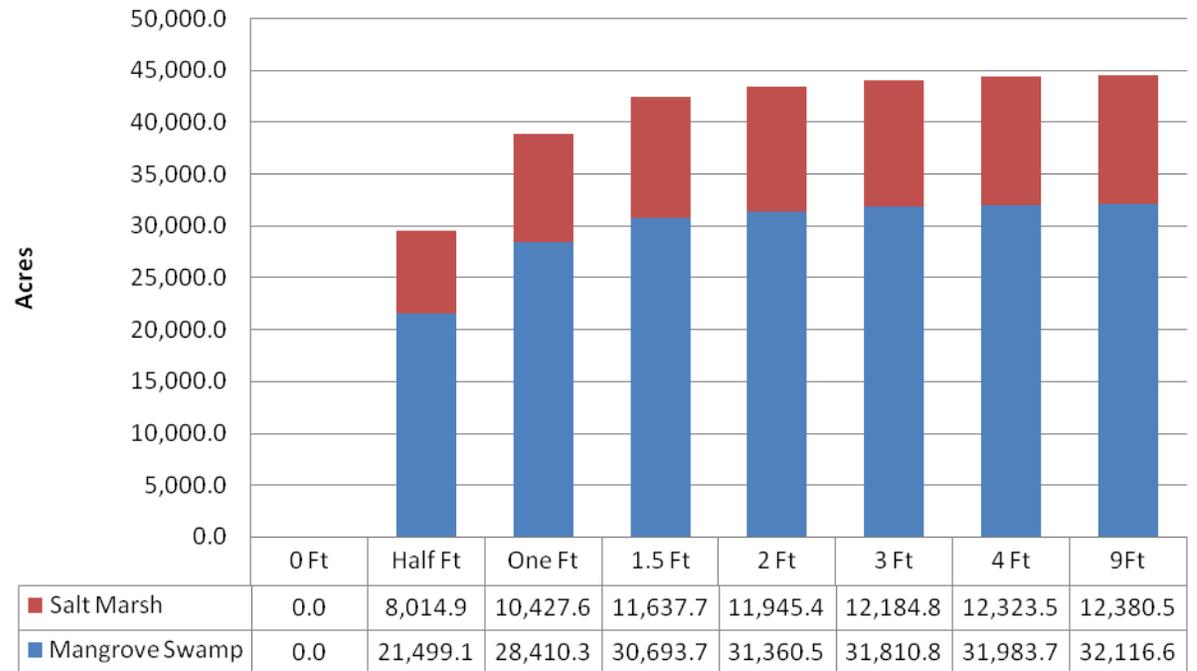


**Figure 29d: Acres of habitat or land at and below different storm surge elevations in Sarasota County 2009**

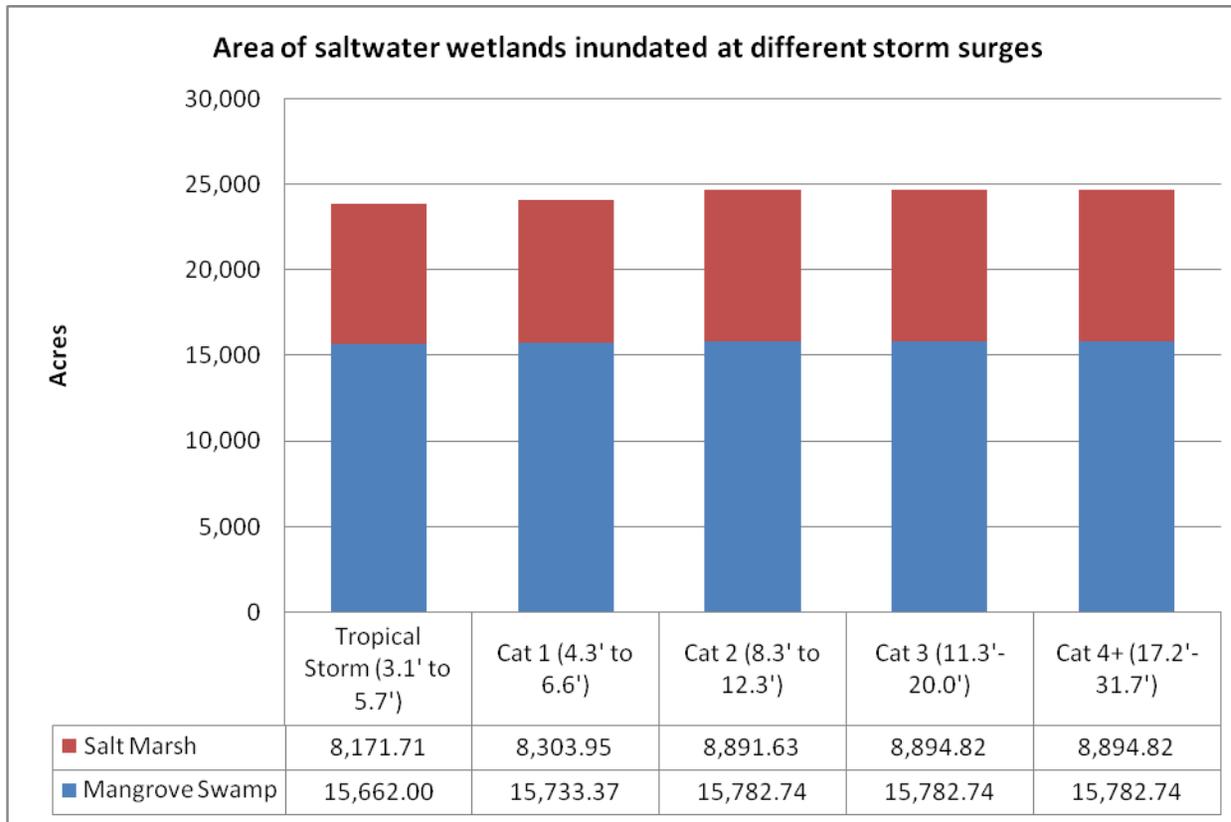


**Figure 30a: Acres of mangrove and salt marsh habitat at and below different elevations in Lee County 2009**

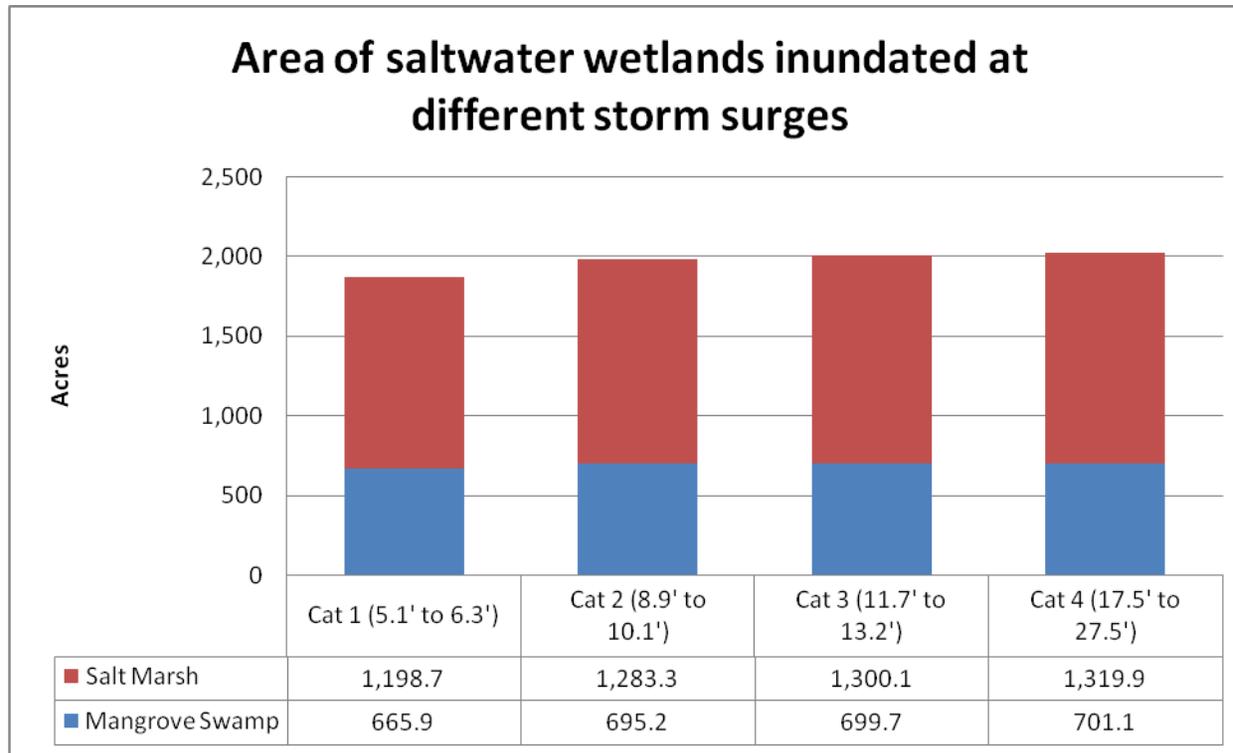
### Area of saltwater wetlands inundated at different elevations



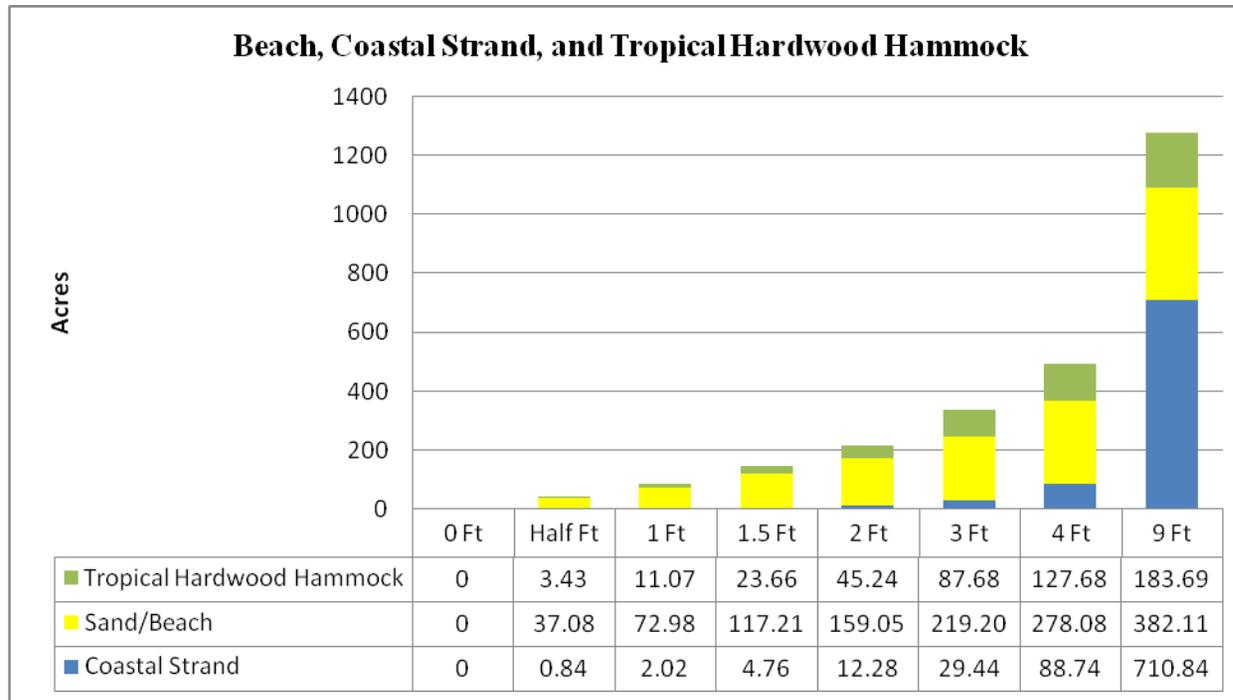
**Figure 30b: Acres of mangrove and salt marsh habitat at and below different elevations in Collier County 2009**



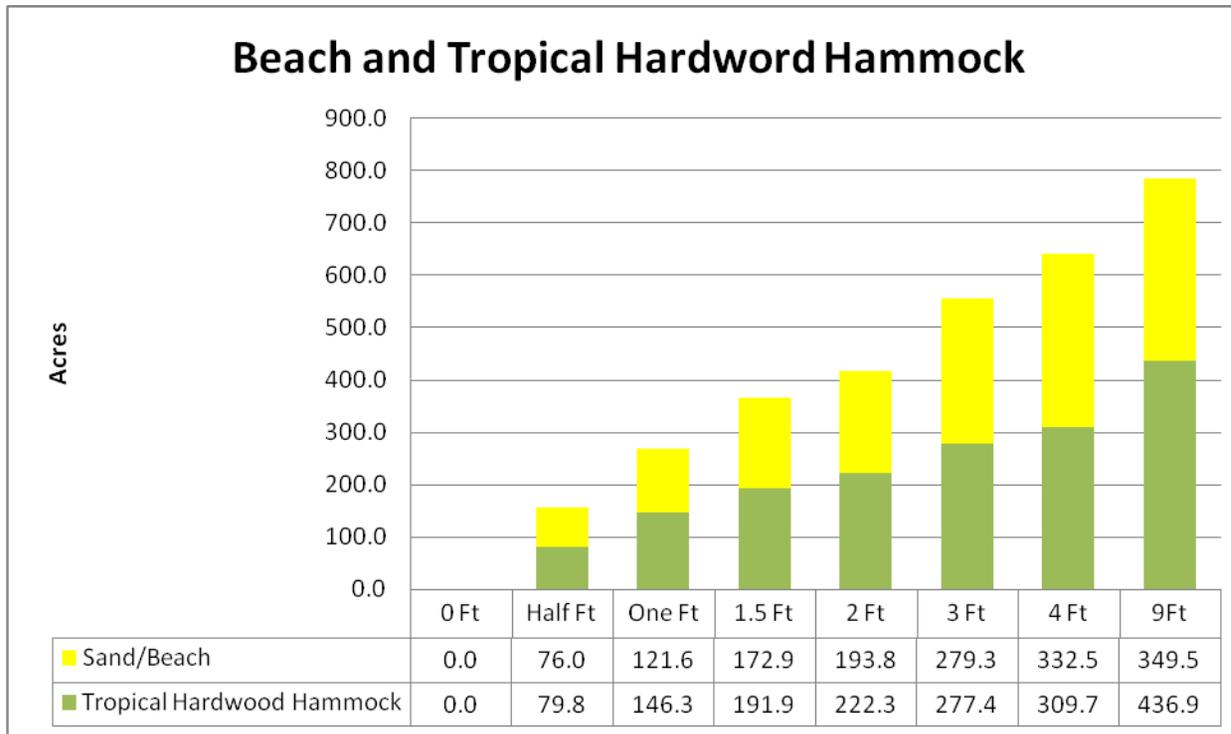
**Figure 31c: Acres of mangrove and salt marsh habitat at and below different storm surge elevations in Charlotte County 2009**



**Figure 31d: Acres of mangrove and salt marsh habitat at and below different storm surge elevations in Sarasota County 2009**



**Figure 31a: Acres of beaches and coastal strand habitat in Lee County at and below different elevations 2009**



**Figure 31b: Acres of beaches and coastal strand habitat in Collier County at and below different elevations 2009**

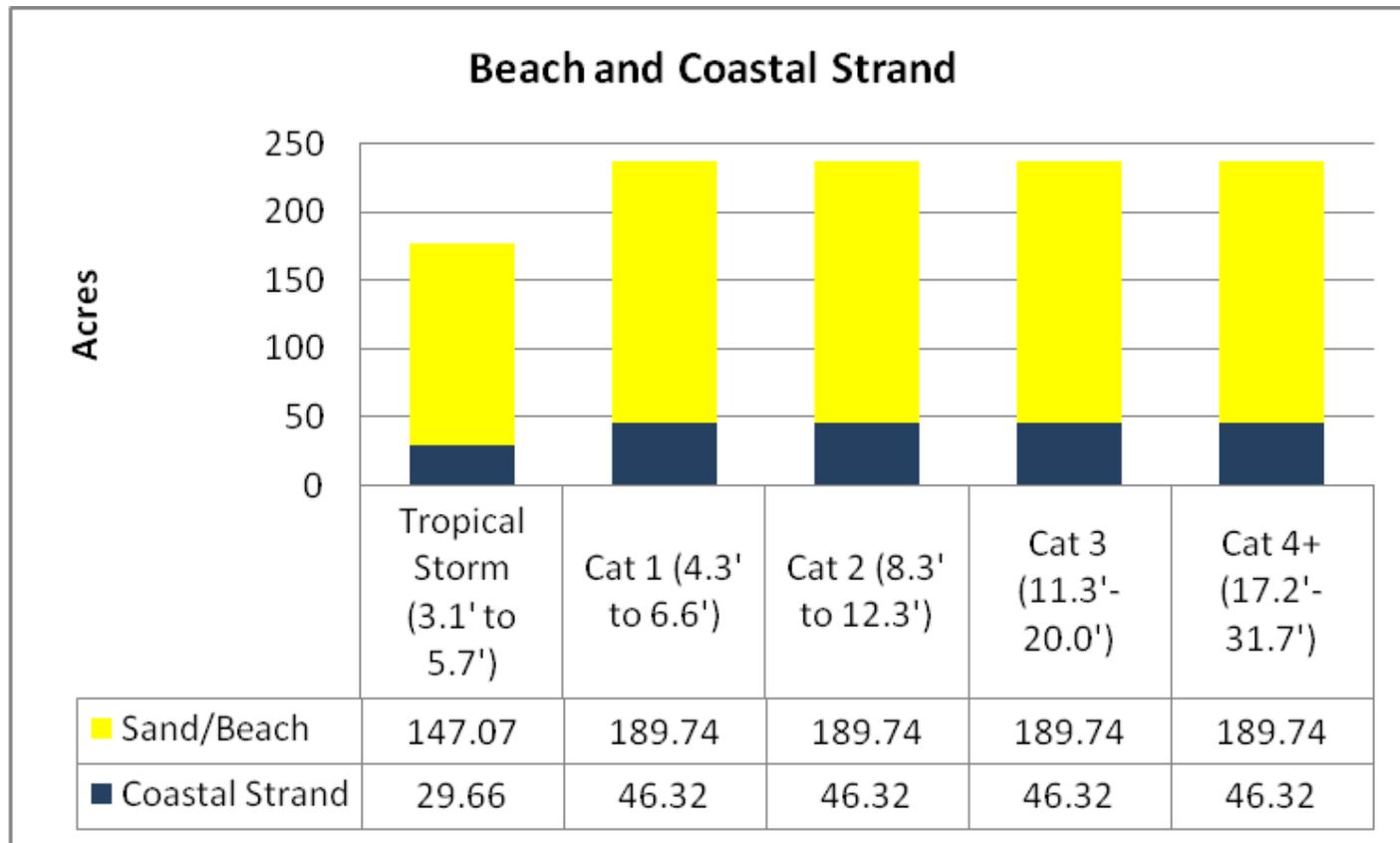
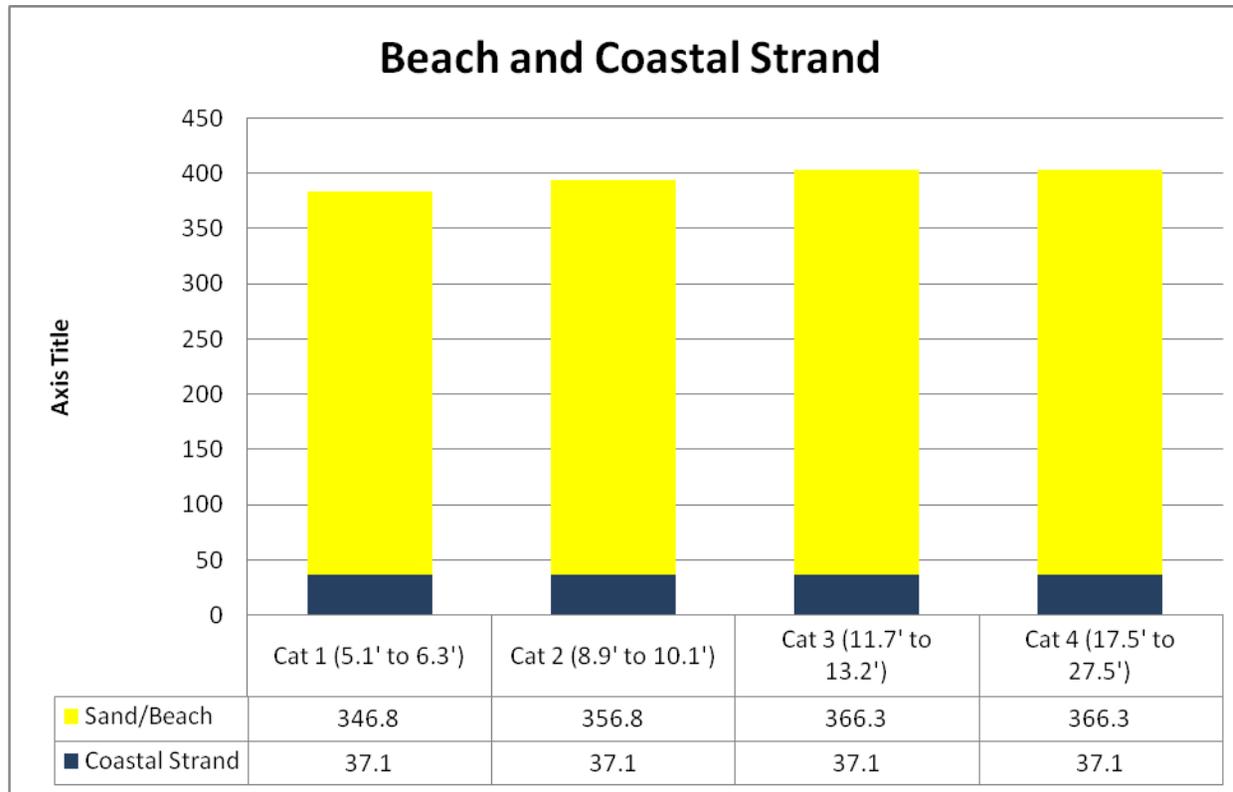
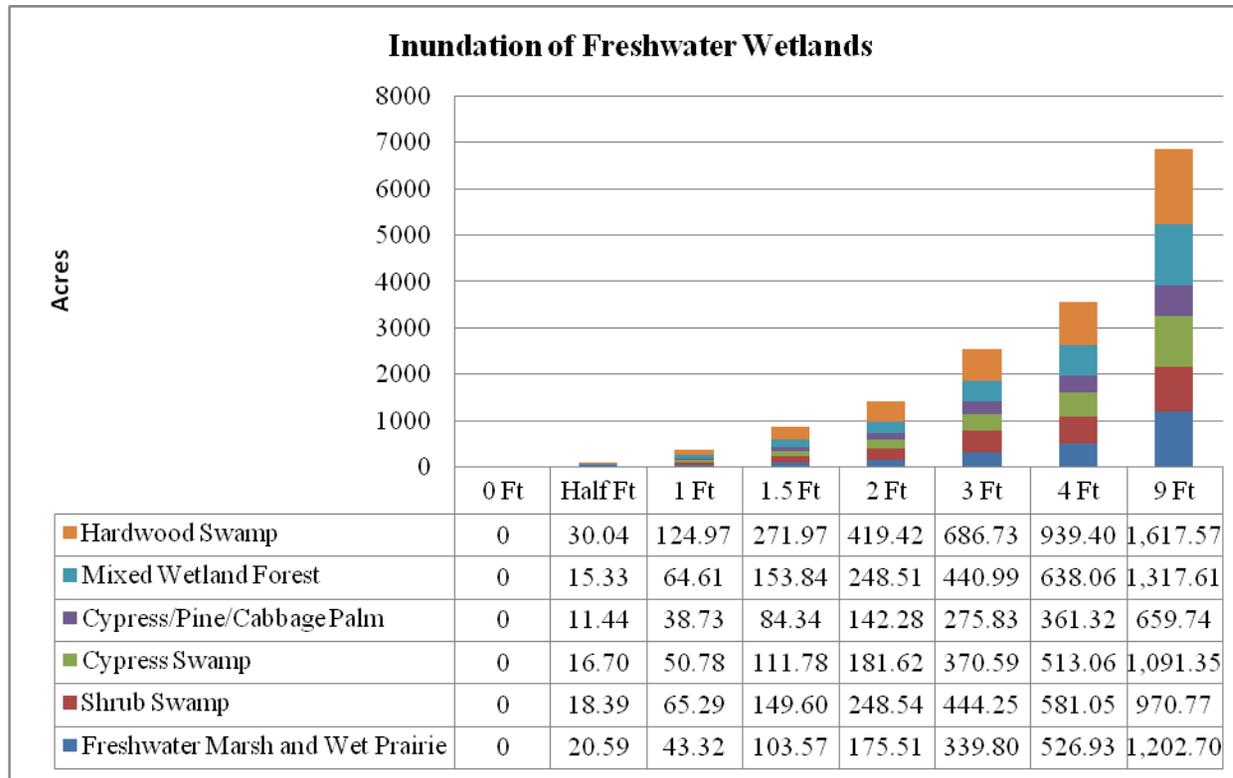


Figure 32c: Acres of beaches and coastal strand habitat in Charlotte County at and below different storm surge elevations 2009

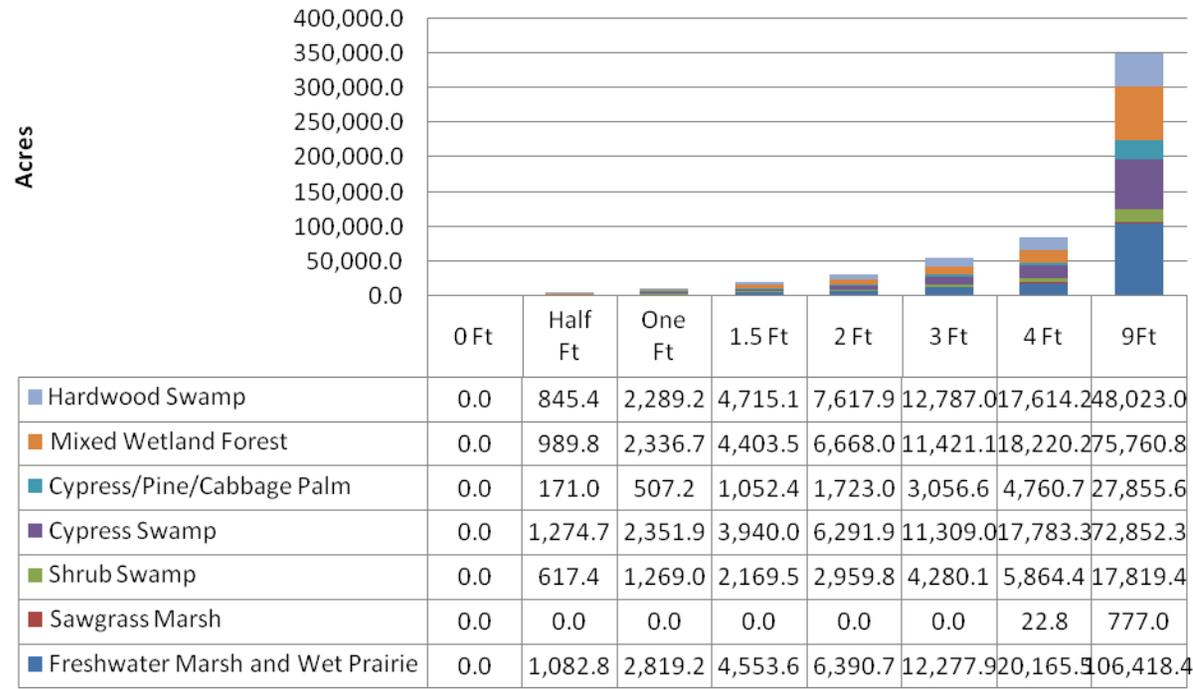


**Figure 32d: Acres of beaches and coastal strand habitat in Sarasota County at and below different storm surge elevations 2009**

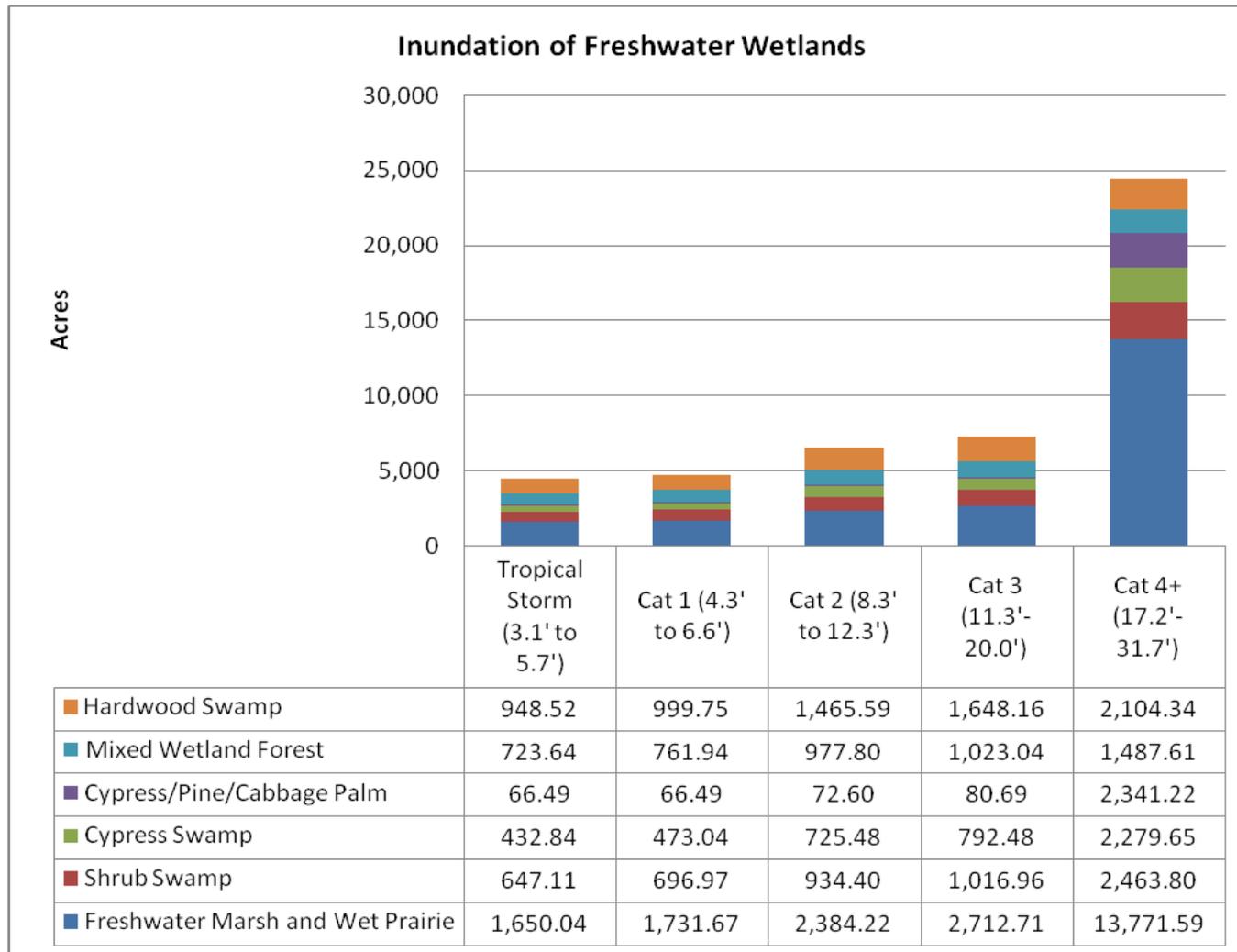


**Figure 32a: Acres of freshwater wetlands habitat in Lee County at and below different elevations 2009**

## Inundation of Freshwater Wetlands



**Figure 32b: Acres of freshwater wetlands habitat in Collier County at and below different elevations 2009**



**Figure 33c: Acres of freshwater wetlands habitat in Charlotte County at and below different storm surge elevations 2009**

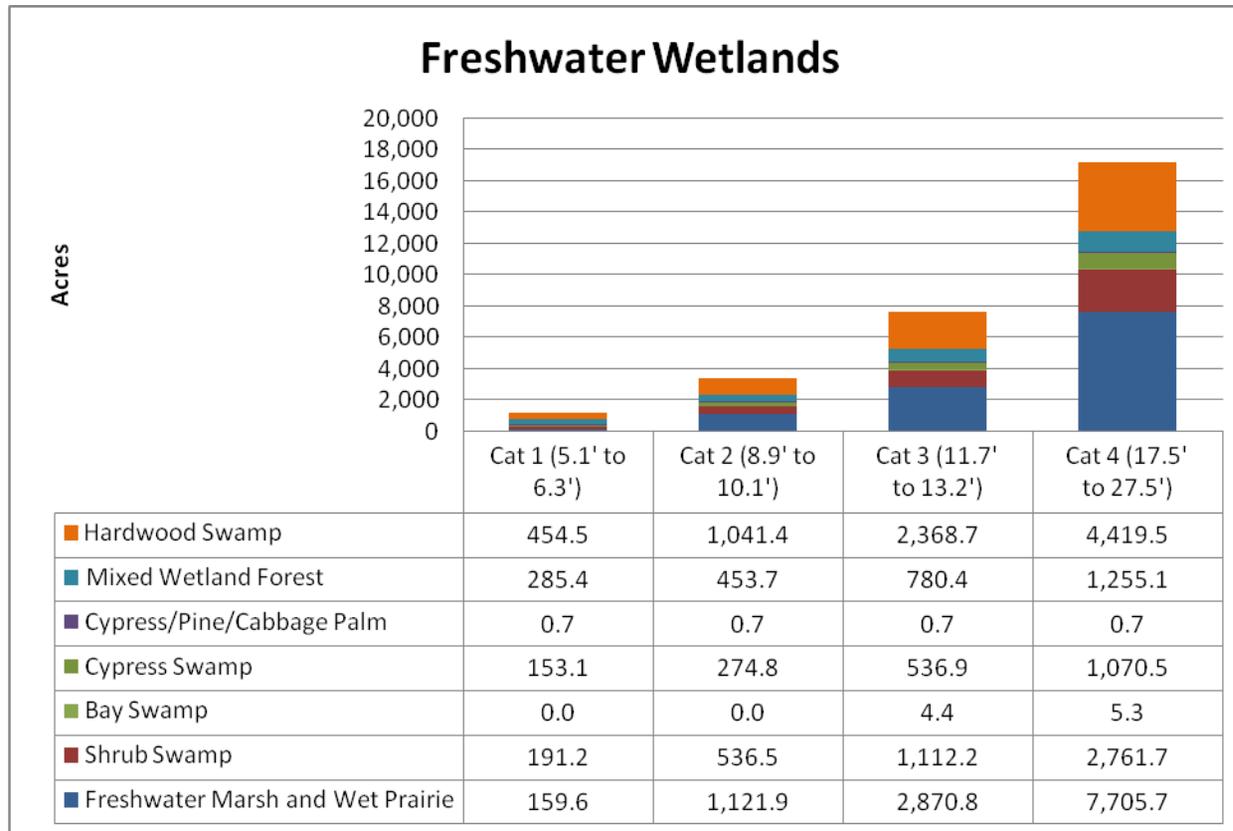
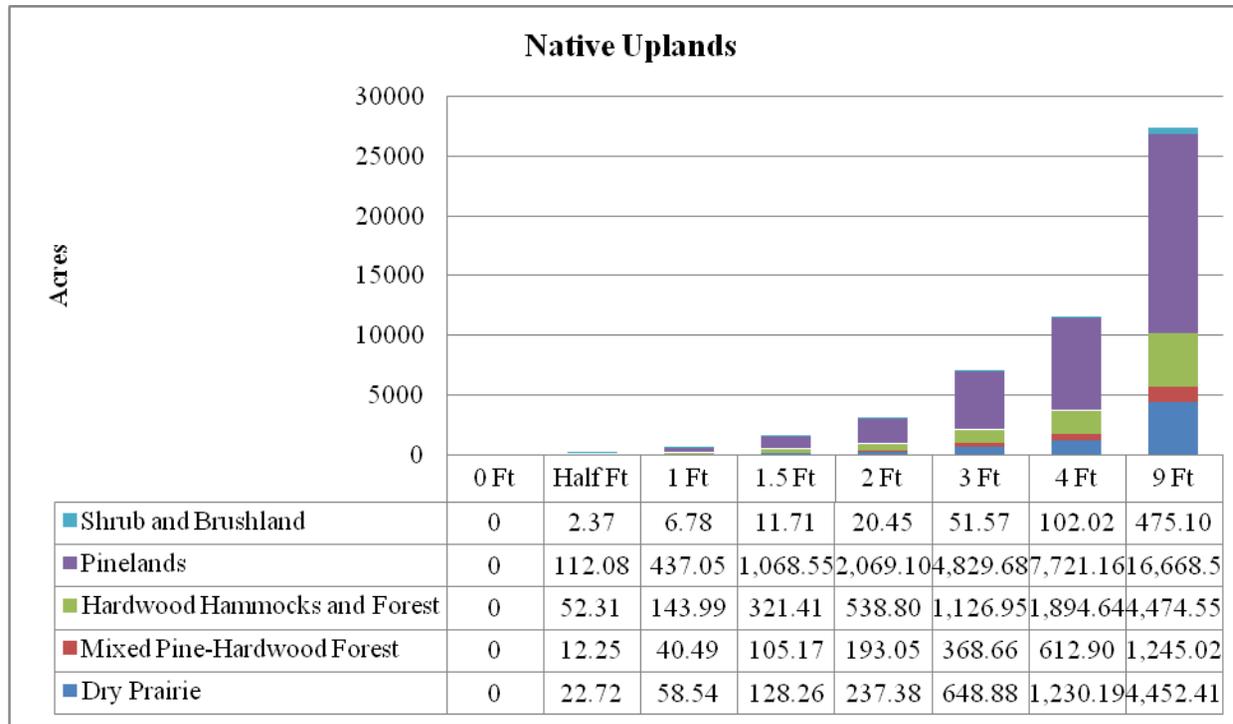
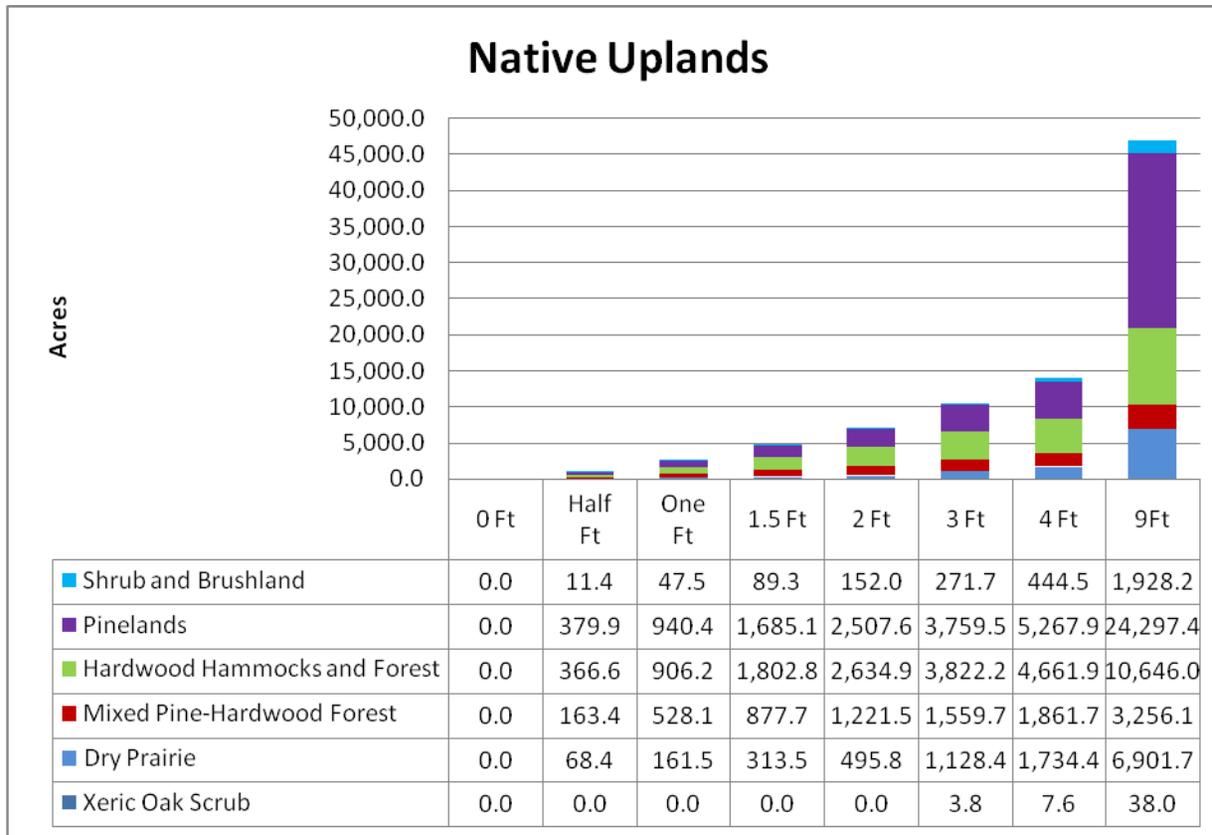


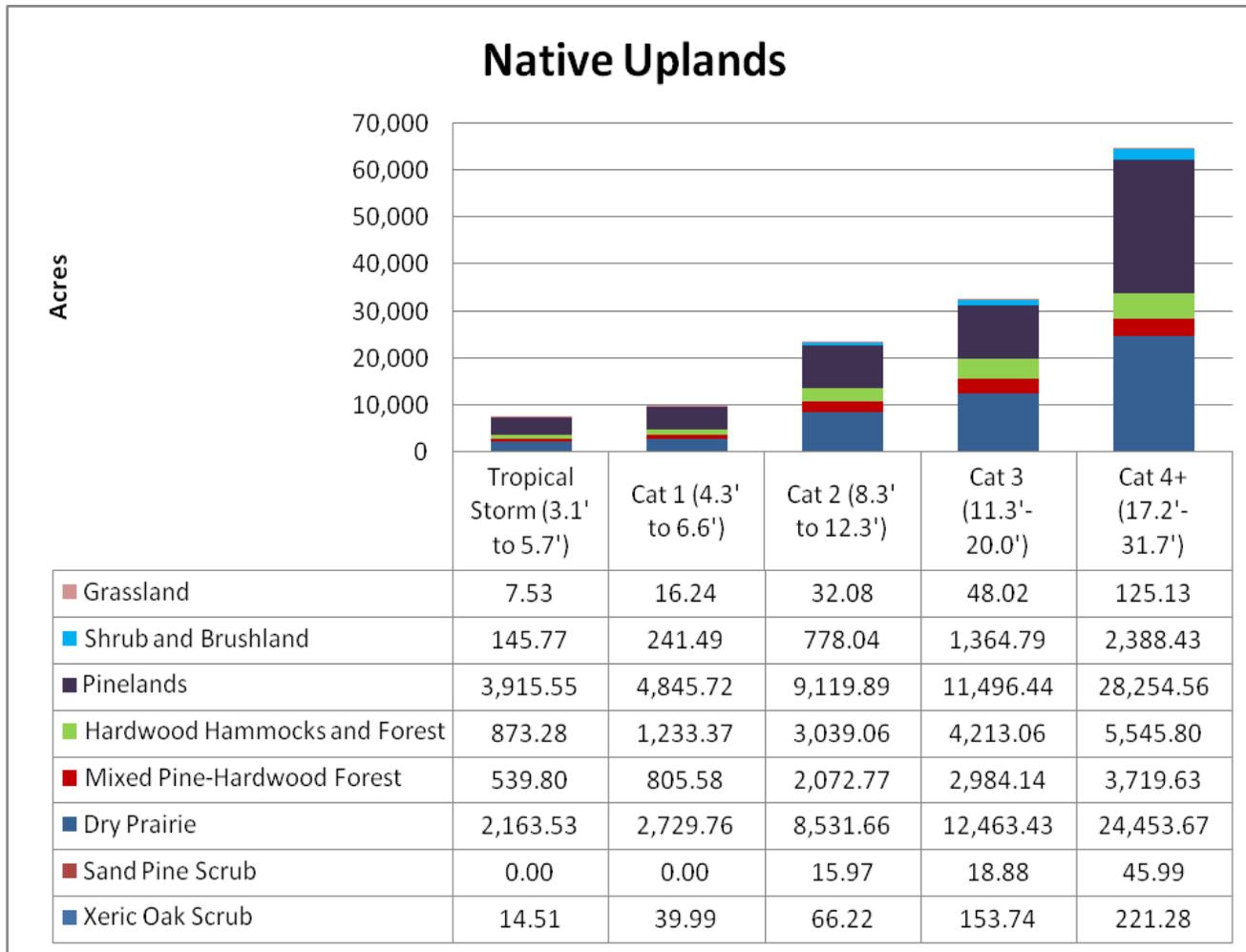
Figure 33d: Acres of freshwater wetlands habitat in Charlotte County at and below different storm surge elevations 2009



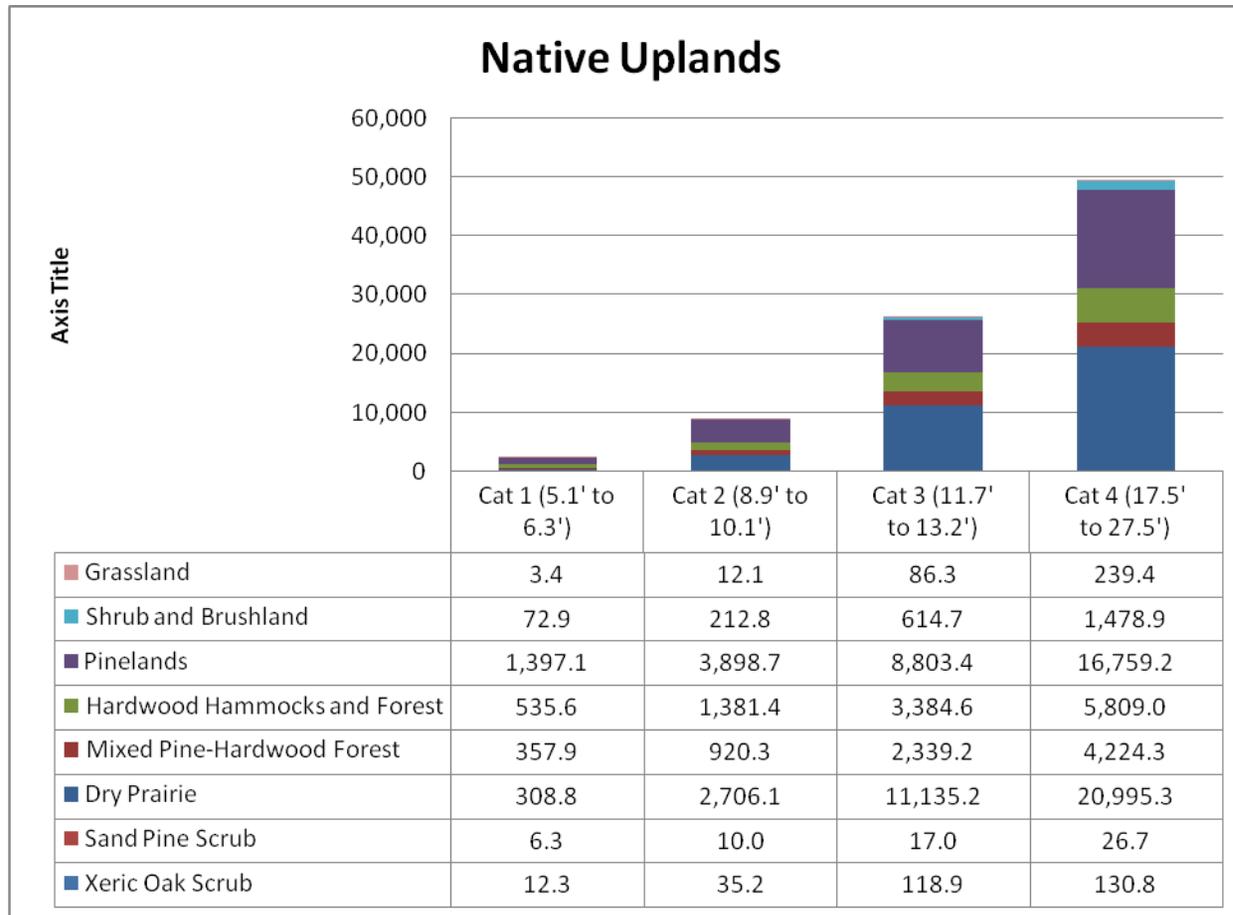
**Figure 33a: Acres of uplands habitat in Lee County at and below different elevations 2009**



**Figure 33b: Acres of uplands habitat in Collier County at and below different elevations 2009**



**Figure 34c: Acres of uplands habitat in Charlotte County at and below different storm surge elevations 2009**



**Figure 34d: Acres of uplands habitat in Charlotte County at and below different storm surge elevations 2009**  
*Note; tropical storm maps are not available from Sarasota County*

<b>Future Land Use</b>	<b>Collier</b>	<b>Lee</b>	<b>Charlotte</b>	<b>Sarasota</b>	<b>Total</b>	<b>Sq. Miles</b>	<b>% of Region</b>
<b>Agriculture</b>	7,766	467	1,247	1,188	10,669	16.7	0.28
<b>Commercial</b>	2,363	9,247	6,260	1,082	18,953	29.6	0.49
<b>Estate</b>	1,005	16,110	107	2,894	20,117	31.4	0.52
<b>Industrial</b>	653	2,597	1,321	382	4,952	7.7	0.13
<b>Multi-Family</b>	2,269	1,937	7,758	3,891	15,855	24.8	0.41
<b>Preserve</b>	615,177	247,286	108,897	22,737	994,098	1,553.3	25.79
<b>Single Family</b>	53,444	89,621	50,668	45,991	239,724	374.6	6.22
<b>Total Acreage</b>	<b>682,677</b>	<b>367,266</b>	<b>176,259</b>	<b>78,165</b>	<b>1,304,368</b>	<b>2,038.1</b>	<b>33.84</b>

**Table 16: Southwest Florida Coastal Region Future Land Use Acreage Subject to 10 Feet NGVD Sea Level Rise (equivalent to 9.2 feet above mean sea level or subject to daily tidal inundation with 8.2 feet of sea level rise)**

<b>Protection Scenarios</b>	<b>Collier</b>	<b>Lee</b>	<b>Charlotte</b>	<b>Sarasota</b>	<b>Total</b>	<b>Sq. Miles</b>	<b>% of Region</b>
<b>0' to 10' NGVD Uplands, Not Protected</b>	37,954	11,797	11,894	16,608	78,253	122.3	2.03
<b>0' to 10' NGVD Uplands, Protection Likely But Wetland Migration Possible</b>	41,887	85,430	49,963	17,979	195,258	305.1	5.07
<b>0' to 5' NGVD Uplands, Protection Not Likely</b>	467	346	796	0	1,609	2.5	0.04
<b>Wetlands</b>	485,074	57,168	34,449	8,807	585,499	914.8	15.19
<b>Total Acreage</b>	<b>565,382</b>	<b>154,741</b>	<b>97,102</b>	<b>43,393</b>	<b>860,619</b>	<b>1,344.7</b>	<b>22.33</b>

**Table 17: Southwest Florida Coastal Region No Protection and Limited Protection Acreage Subject to 10 Feet NGVD Sea Level Rise (equivalent to 9.2 feet above mean sea level or subject to daily tidal inundation with 8.2 feet of sea level rise)**

Wetland Types	Collier	Lee	Charlotte	Sarasota	Total	Sq. Miles	% of Region
Bay Swamps	0	8	8	21	38	0.1	0.001
Cypress	87,594	435	1	81	88,111	137.7	2.29
Cypress - Melaleuca Infested	2,232	131	0	0	2,363	3.7	0.06
Cypress - Pine - Cabbage Palm	72,970	197	0	0	73,167	114.3	1.90
Cypress - with Wet Prairies	56,705	91	0	0	56,797	88.7	1.47
Emergent Aquatic Vegetation	31	0	68	173	273	0.4	0.01
Freshwater Marshes	14,380	775	1,701	2,040	18,896	29.5	0.49
Intermittent ponds	0	0	15	1	16	0.0	0.0004
Gum Swamps	0	11	0	0	11	0.0	0.0003
Inland Ponds and Sloughs	28	3	0	0	31	0.0	0.001
Mangrove Swamps	82,813	42,341	18,162	777	144,093	225.1	3.74
Mixed Wetland Hardwoods	172	2,481	0	0	2,653	4.1	0.07
Mixed Wetland Hardwoods - Mixed Shrubs	30,903	4,613	0	0	35,516	55.5	0.92
Mixed Wetland Hardwoods – Willows	92	0	0	0	92	0.1	0.002
Saltwater Marshes	17,408	3,785	7,378	1,011	29,582	46.2	0.77
Stream and Lake Swamps (Bottomland)	19	71	1,560	2,834	4,484	7.0	0.12
Tidal Flats	736	1,179	0	0	1,914	3.0	0.05
Tidal Flats/Submerged Shallow Platform	0	0	1,207	396	1,603	2.5	0.04
Titi Swamps	0	5	0	0	5	0.0	0.0001
Wet Prairies	60,116	80	312	869	61,376	95.9	1.59
Wet Prairies - with Pine	5,856	65	0	0	5,921	9.3	0.15
Wetland Coniferous Forests	0	0	445	141	586	0.9	0.02
Wetland Forested Mixed	53,022	896	543	459	54,919	85.8	1.42
Wetland Hardwood Forests	0	0	3,049	4	3,053	4.8	0.08
Total Acreage	485,074	57,168	34,449	8,807	585,499	914.8	15.19

Table 18: Southwest Florida Region Wetland Acreage Subject to 10 Feet NGVD Sea Level Rise (equivalent to 9.2 feet above mean sea level) or subject to daily tidal inundation with 8.2 feet of sea level rise)

### Development of Sea Level Response Maps

Current trends and policies regarding land use, conservation and shoreline protection provided a starting point for developing maps of the region’s likely land use response to sea level rise. Nevertheless, because those policies do not precisely correspond to existing land use categories, and because those categories can change over time, some analysis and judgment is necessary to develop the maps. This section explains and documents the procedures used to create the maps.

SWFRPC staff first met with county officials to obtain any necessary data, explain the project, and obtain their understanding given current policies of the areas where shoreline protection is almost certainly precluded by environmental policies or is unlikely because the land will not be developed densely enough to justify shore protection. Originally, all other areas were considered likely candidates for protection measures. Areas where shoreline protection measures, such as seawalls, groins, levees and dikes, are **precluded** or **unlikely** are areas where wetlands present can potentially migrate inland. Areas where protection measures are **likely** or **certain** tend to be urbanized, built environments of human habitation, where wetlands would not be able to migrate.

During this initial phase, no concerted effort was made to distinguish those areas where protection is **likely** from the areas where it is virtually **certain**. Local officials had no trouble identifying conservation areas and those privately owned areas where land values are unlikely to justify protection. But they found it very difficult to specifically identify any areas that were certain to be protected. This preliminary set of maps was approved by the SWFRPC.

One objective of this process was to distinguish the areas where protection was **likely** from those where it is **certain**. USEPA's overall description of the project makes the point that such a distinction is important both for preserving the environment and encouraging efficient coastal investment. Indeed, the USEPA project manager reminded us that our initial decision to combine the likely and certain areas did not necessarily mean that wetland migration might occur across downtown Naples or Ft. Myers. It was just as reasonable to infer that if such areas are called "protection likely", then other areas that were less densely developed were equally likely to be protected. In an area where most of the coastal zone will be developed, the failure to distinguish urban areas that are **certain** to be protected or hardened from developed areas where wetland migration **might** be allowed eventually may imply that the **only** areas where wetlands will be allowed to migrate are the areas deemed to be precluded from or unlikely to be protected. We agreed with USEPA's assumption that part of our job, as planners, was to provide policy makers with options. By identifying those areas where protection is almost certain, the remaining areas where protection is likely would provide policy makers with the contours of an environmental-protection option which would allow more wetland migration than we currently expect. Conversely, hardening the areas where it currently is unlikely is an option that provides less environmental protection and more upland preservation than we currently expect.

This distinction might also be useful for those making long-term investments in the coastal zone. Why should a property owner or a unit of government make a permanent infrastructure investment when there is doubt about whether the land will be abandoned, and if there are similar areas where people are sure to hold back the sea? If in fact, Floridians will ultimately decide not protect all developed areas, it is all the more important to concentrate some types of development in the areas that are certain to be protected. Defining such areas was a first step.

The desirability of distinguishing areas for possible wetland migration from areas that are sure to be hardened, however, does not guarantee that doing so would be easy. Draft

reports from the nationwide USEPA project became available for all of the Atlantic Coast states from Georgia to New York, as well as Rhode Island and parts of Massachusetts. We took a careful look at those reports to see how they made the distinctions and whether those approaches would be applicable to us. Some of the key methodological approaches from those reports included the following:

- Within planning areas where development is expected and protection almost certain due to its low cost relative to land values, the land that was still undeveloped was categorized as likely to be protected in NY, MD, and GA, as well as parts of NC, NJ, and VA. The logic in those states was that as long as the land remains undeveloped, it may still be feasible for conservancies to purchase the land for wetland migration.
- Along estuaries where the economics of protection may be marginal because elevations and land prices are low, development density was often the basis for protection, with the density cutoff tending to be county-specific.
- Along ocean coasts with recreational real estate in jurisdictions that favor beach nourishment, Coastal Barrier Resource Act (CoBRA) areas tended to show up as “protection unlikely”. The distinction between certain and likely protection sometimes hinged on whether the public has access to the shore, the logic being that such areas are currently not eligible for federally funded beach nourishment.
- Large farms and corporate farms in fertile areas were likely to be protected, while smaller farms were converting to wetland.
- A few developed areas were already being abandoned due to flood vulnerability in North Carolina.
- A few New England States already have prohibited shore protection in some areas.
- None of the studies had considered environmental requirements for wetland migration as a basis for distinguishing likely to be protected from certain to be protected; several studies did consider environmental requirements in deciding whether public lands could be allowed to retreat or would likely be protected.
- In a few rural areas in Virginia and Maryland, the existence of infrastructure such as sewer lines makes protection more likely than it would otherwise be.
- The New York and New Jersey studies concluded that protection is almost certain for almost the entire New York metropolitan area. Baltimore,

Washington DC, Wilmington (DE and NC), and Charleston, are also certain to be protected, but they each have land within the suburbs that may not be protected.

- All of the studies except for South Carolina and parts of Virginia had decision-making rules based on planning and land use data, using recommendations of local officials, with site-specific adjustments to the maps as directed by county reviewers.

With the insights from those efforts, we developed decision-making rules as described below. Recognizing, however, that those rules seemed unlikely to identify enough land for wetland migration, we also decided to identify one or more wetland migration corridors within areas that would otherwise be certain to be protected. Our reasoning for identifying such a corridor was twofold. First, as previously mentioned, a key aspect of our mission as planners is to provide policy makers with as wide an array of feasible policy options as possible. Second, the published literature on wetland migration has demonstrated that, given a lead time of 100 years, it would be economically feasible to gradually remove development in a designated corridor to accommodate wetland migration. Our designation of such a corridor in no way implies endorsement for such a corridor—indeed the corridors are still considered “protection likely.” But given the possible environmental requirement for wetland migration, it is most accurate for the maps to acknowledge that we can not characterize all privately owned areas as certain to be protected. We then went back to the counties for their reactions to the revised maps, and made changes accordingly.

Although sea level is very unlikely to rise more than one meter in the next century, the overall study area for this exercise is all land that is either below the 10-foot (NGVD) contour or within 1,000 feet of the shore. Given the likelihood that sea level will only rise two feet in the next century, the 10-foot contour may seem overly inclusive. However, the only complete and comprehensive sets of elevation information in Florida have 5-foot contours, which required a choice between using the 5-foot and 10-foot contours. We chose the latter for several reasons.

First, although the impacts of rising seas in the ‘near term’ are most relevant to current decision-making processes, this study does not focus on a defined time horizon, nor does it address a specific amount of sea level rise. Because the results may be put to a variety of different uses, it is better to be over-inclusive than under-inclusive. The 5-foot contour is only 4.25 feet above the mean tide level and three to four feet above the mean diurnal high tide. The National Ocean Service (NOS) web page reports the following elevations relative to mean low water at Fort Myers, Caloosahatchee River: NGVD (1929) = -0.11 ft; NAVD (1988) = 1.05 ft; mean tide level = 0.63 ft; mean high water = 1.1 feet; mean high high water = 1.3 feet. The diurnal tide range is approximately 2.9 feet along the Gulf at Naples but only 1.3 feet along the Caloosahatchee River at Ft. Myers. (NOS 2003) Tidal wetlands are generally found up to one foot above the diurnal mean high tide, due to the frequent higher tides caused by winds and full and new moons. Thus, the 5-foot contour could become the landward boundary of wetlands if sea level rises two feet, and the 10-foot contour could become the landward boundary with a rise of seven feet.

Clearly, the prospect of a rise greater than two feet is sufficiently plausible that we would constrain the usefulness of the study if we only considered the 5-foot contour.

Second, the 5- and 10-foot contours approximately represent the extents of storm surge from a tropical storm and a category 2 hurricane, respectively, under current conditions. Thus, the entire study area would be affected by even a small rise in sea level. With a five foot rise in sea level over the next two centuries, the land between the 5- and 10-foot contours would become vulnerable to a tropical storm.

Finally, the vertical and horizontal resolution of existing contour data is poor. Not only does the data have a wide contour interval, but under National Mapping Standards, those contours can have a vertical error of 2.5 feet, i.e., the mapped 10-foot contour may really be as low as 7.5 feet in some places. Data that is available does not always have good horizontal accuracy either. Thus, a margin of error is required to ensure that our analysis includes all the lands that might be affected by rising seas.

The source for the five and ten-foot contour lines is the South or Southwest Florida Water Management Districts (SFWMD and SWFWMD) or the U. S. Geological Survey (USGS) Quadrangles. Sarasota County provided us elevation lines using GRID GIS. Additional elevations were determined using the original subdivision construction plans for large, antiquated platted land areas that were dredged and filled below the five-foot elevation level. Examples of this are in Cape Coral, Punta Gorda, Port Charlotte and the Cape Haze Peninsula. The City of Sanibel's elevations were determined using a special elevation study on the island. The latter two-elevation work was previously digitized and then converted into the Geographic Information System (GIS) when the 1991 Southwest Florida Hurricane Storm Tide Atlases were developed. Staff at the Big Cypress National Preserve provided the elevations for the Preserve area in Collier County.

Existing land uses (ELU) as defined in the Florida Land Use Cover Classification System (FLUCCS) were used to determine wetlands, water and uplands. Staff at the Big Cypress Preserve also provided ELU in this area. The FLUCCS maps were also kept current by the SFWMD and SWFWMD and were available in GIS shape file coverage. Once wetlands and water were mapped, everything else was considered uplands.

A determination of future land use was necessary in order to define development rights assumptions for the protection scenarios discussed below. Local government comprehensive plans for the year 2020 were generalized to create a standard format for land uses throughout the region. These generalized land uses are as follows: Agriculture, Residential Estate, Multi-Family, Single Family Residential, Commercial/Office, Mining, Industrial, Water, Military, and Preserve.

Critical facilities, as defined and mapped in the local mitigation strategy plans of the four coastal counties, were used to further assign protection scenario status and to also bring long-term sea level rise response planning into the more current local mitigation strategy planning. The critical facilities considered in this study are as follows:

<b>County</b>	<b>Charlotte</b>	<b>Collier</b>	<b>Lee</b>	<b>Sarasota</b>	<b>Total</b>
Facility					
Airport	1	3	3	0	7
Boat Locks	3	0	2	0	5
Clinic	2	8	2		12
Communication Tower	19	8	9	5	41
Community Centers	14	0	0	0	14
Community College	1	1	1	2	5
Drinking Water Facilities	0	9	13	25	47
Electrical Facilities	15	6	14	0	35
Elementary Schools	6	8	11	0	25
Emergency Medical Services	10	2	3	1	16
Fire Stations	0	12	19	14	45
Government Facilities	18	33	27	14	92
High School	3	2	2	0	7
Hospital	1	0	1	1	3
Hurricane Shelters	0	17	12	0	29
Landfills	0	2	2	1	5
Middle School	1	3	3	0	7
Nursing & Convalescent Facilities	0	0	26	1	27
Police-sheriff Facilities	4	9	3	6	22
Port	0	0	1	0	1
Private College	0	0	1	1	2
Private School	2	3	1	0	6
Sewage Treatment Facilities	0	6	43	21	70
Telephone Remote Building	1	0	0	0	1
Telephone Switching Stations	12	0	0	0	12
U.S. Post Office	0	1	0	0	1
<b>Total</b>	<b>113</b>	<b>133</b>	<b>199</b>	<b>92</b>	<b>537</b>

**Table 19: Critical facilities in the CHNEP/SWFRPC study area vulnerable to tropical storm and hurricane flooding and sea level rise**

For military bases, the USEPA's nationwide convention has been to not speculate on the fate of secured installations, which may involve sensitive security considerations in some cases and is—in any event—outside the planning authority and expertise of local government. USEPA's general convention is therefore to treat secured installations as "likely to protect", except for those installations in urban areas where all the surrounding land is almost certain to be protected. In the latter case, the reasoning is that the land would be protected if it was not a base, and there is no basis for assuming that the military would ever retreat while civilians defended territory against the sea.

Incorporating critical facilities into sea level response planning is probably the best way to begin encouraging local governments to implement the sea level rise protection scenarios. For example, when the SWFRPC approved the maps, staff sensed frustration from elected officials as to what they could do to address this problem in their constituents' short-term outlooks. The SWFRPC concluded that this study would be used to work with local government staffs to consider sea level increases when planning for public facility expansions and reconstruction after hurricane damage or due to old age. Therefore, the intent of the study is being met by facilitating local government decision makers and staffs' efforts to begin considering sea level rise impacts on land uses and the supporting public critical facilities.

Charlotte County contains the following critical facilities in hazard of maximum 5 to 10 foot hurricane storm surge: one airport, two clinics, 19 communication towers, 14 community centers, 15 electrical facilities, 10 fire and emergency medical services (EMS) stations or facilities, 18 government facilities, one hospital, three boat locks, four police/sheriff facilities, six elementary schools, one middle school, three high schools, two private schools, one community college, one telephone remote building, and 12 telephone switching stations.

In Collier County there are three airports, eight clinics, eight communication facilities, six electrical facilities, eight EMS, two Emergency Operations Centers, 12 fire stations, 33 government facilities, one hospital, two landfills, nine police/sheriff facilities, eight elementary schools, three middle schools, two high schools, three private schools, and a community college, six sewage treatment facilities or transfers, 17 hurricane shelters, the main U.S. post office, and nine drinking water facilities in hazard of maximum five-10 foot hurricane storm surge.

In Lee County there are three airports, two clinics, nine communication facilities, 14 electrical facilities, three EMS, 19 fire stations, 27 government facilities, one hospital, two landfills, 26 nursing/convalescent centers, three police- sheriff facilities, one Red Cross center, 11 elementary schools, three middle schools, two high schools, one private college, one community college, 43 sewage treatment facilities or transfers, 12 hurricane shelters, one port, and 13 drinking water facilities in hazard of maximum five-10 foot hurricane storm surge.

In Sarasota County there are five communication facilities, one EMS, 14 fire stations, 14 government facilities, one hospital, landfills, nursing/convalescent centers, six police-

sheriff facilities, a private college, and two community college facilities, 21 sewage treatment facilities or transfers, one hurricane shelter, and 25 drinking water facilities in hazard of maximum five-10 foot hurricane storm surge.

A listing of all identified critical facilities for the coastal counties of the study are is found in Appendix 1 at the end of this document.

Seven colors are used to define the map in each county. First, all water areas in the Gulf of Mexico, bays, rivers, canals or lakes are shown in the color light blue. Second and third, all wetlands either fresh or saltwater are shown in the color dark green with the tidal wetlands shown as purple. Fourth, uplands where no shore protection from sea level rise is assumed are shown in the color light green. Fifth, uplands where shore protection from sea level rise is assumed unlikely are shown in the color blue. Sixth, uplands where shore protection is assumed to be likely are shown in the color red. The seventh color is brown where shore protection is almost certain. Finally, the non-color white is everything above 10' in elevation and is outside the study area.

Assumptions regarding the protection scenarios were made according to elevation and generalized land uses and are defined as follows. The counties agreed with SWFRPC staff that agriculture, mining and upland preserves would not protect their property from sea level rise and therefore would be colored light green. Commercial, estate, industrial, military, multi-family and single family would “almost certainly” protect their property from sea level rise and therefore would be colored brown. Dark blue areas would be land uses between zero and five feet in elevation that is not likely to be protected from sea level rise and might be areas such as unbridged barrier island, low income housing, low value property not on central water and sewer or repetitive flood loss properties. In this phase of the process only critical facilities between the elevation of five and 10 feet were colored brown, but the land itself was colored red. Critical facilities below five feet in elevation were shown as blue and protection was not recommended. Planners from all the counties agreed that we should assume that government owned critical facilities in this area should relocate these facilities to higher ground (see Appendix 1 for critical facilities subject to sea level rise by county).

We completed the maps in GIS shape files or coverage. JPGs and PDFs for each map have been created for easy distribution through the Internet and for display on the SWFRPC website and Environmental Protection Agency website. The SWFRPC provided a readme file on CD for further explanation on the GIS development of these maps to assist the most interested user in this GIS mapping effort.

Once other regional planning councils started to implement the SWFRPC staff initial methodology, it became clear that other data sources were becoming available, such as the Florida Land Use Cover Classification System for existing and future land uses in GIS format, and that even more up-to-date land use information was needed to better determine how to assign the shore protection colors. The table below was subsequently developed.

<b>State-wide approach for identifying the likelihood of human land use protection from the consequences of 10 feet of sea level rise</b>		
<b>Likelihood of Protection<sup>2</sup></b>	<b>Land-Use Category</b>	<b>Source Used to Identify Land Area</b>
Shore Protection Almost Certain (brown)	Existing developed land (FLUCCS Level 1-100 Urban and Built-up) within extensively developed areas and/or designated growth areas.	Developed Lands identified from Water Management Districts (WMD) existing Florida Land Use, Cover and Forms Classification System (FLUCCS) as defined by Florida Department of Transportation Handbook (January 1999); Growth areas identified from planner input and local comprehensive plans.
	Future development within extensively developed areas and/or designated growth areas (residential/office/commercial/industrial).	Generalized Future Land Use Maps from local comprehensive plans, local planner input and Water Management Districts.
	Extensively-used parks operated for purposes other than conservation and have current protection <sup>3</sup> or are surrounded by brown colored land uses.	County-Owned, State-Owned, and Federally-Owned Lands (based on local knowledge) or lands defined as 180 Recreational on the Level 1 FLUCCS, local planner input and Florida Marine Research Info System (FMRIS) for current protection measures.
	Mobile home developments outside of coastal high hazard <sup>4</sup> , expected to gentrify, or connected to central sewer and water.	Local planner input and current regional hurricane evacuation studies.
Shore Protection Likely (red)	Existing development within less densely developed areas, outside of growth areas.	Developed Lands identified from WMD existing FLUCCS; Growth areas identified from local planner input, local comprehensive plans and current regional hurricane evacuation studies.
	Mobile home development neither within a coastal high hazard area that is neither anticipated to gentrify nor on central water and sewer.	Local comprehensive plans and current regional hurricane evacuation studies.
	Projected future development outside of growth areas could be estate land use on Future Land Use Map.	Local planner input
	Moderately-used parks operated for purposes other than conservation and have no current protection or are surrounded by red colored land uses.	County-Owned, State-Owned, and Federally-Owned Lands (based on local knowledge) or lands defined as 180 Recreational on the Level 1 FLUCCS, local planner input and FMRIS.
	Coastal areas that are extensively developed but are ineligible for beach nourishment funding due to CoBRA (or possibly private beaches unless case can be made that they will convert to public)	Flood Insurance Rate Maps for CoBRA, local knowledge for beach nourishment.

	Undeveloped areas where most of the land will be developed, but a park or refuge is also planned, and the boundaries have not yet been defined so we are unable to designate which areas are brown and which are green; so red is a compromise between.	Local planner input
	Agricultural areas where development is not expected, but where there is a history of erecting shore protection structures to protect farmland.	Local planner input
	Dredge Spoil Areas likely to continue to receive spoils or be developed, and hence unlikely to convert to tidal wetland as sea level rises	Local planner input
	Military Lands in areas where protection is not certain.	FLUCCS Level 173
Shore Protection Unlikely (blue)	Undeveloped privately-owned that are in areas expected to remain sparsely developed (i.e., not in a designated growth area and not expected to be developed) and there is no history of erecting shore protection structures to protect farms and forests.	Undeveloped Lands identified from WMD existing FLUCCS Level 1- 160 mining, 200 Agriculture, 300 Rangeland, 400 Upland Forest, 700 barren land ; Non-growth areas identified from planner input, local comprehensive plans, Flood Insurance Rate Maps for CoBRA and current regional hurricane evacuation studies.
	Unbridged barrier island and CoBRA areas or within a coastal high hazard area that are not likely to become developed enough to justify private beach nourishment.	Flood Insurance Rate Maps for CoBRA, local knowledge for beach nourishment and local planner input.
	Minimally-used parks operated partly for conservation, have no current protection or are surrounded by blue colored land uses, but for which we can articulate a reason for expecting that the shore might be protected.	County-Owned, State-Owned, and Federally-Owned Lands (based on local knowledge) or lands defined as preserve on Future Land Use Map, local planner input and FMRIS.
	Undeveloped areas where most of the land will be part of a wildlife reserve, but where some of it will probably be developed; and the boundaries have not yet been defined so we are unable to designate which areas are brown and which are green; so blue is a compromise between red and green.	local planner input

	Dredge Spoil Areas unlikely to continue to receive spoils or be developed, and hence likely to convert to tidal wetland as sea level rises	local planner input
	Conservation Easements (unless they preclude shore protection)	local planner input
No Shore Protection (light green)	Private lands owned by conservation groups (when data available)	Private Conservation Lands
	Conservation Easements that preclude shore protection	local planner input
	Wildlife Refuges, Portions of Parks operated for conservation by agencies with a policy preference for allowing natural processes (e.g. National Park Service)	local planner input
	Publicly-owned natural lands or parks with little or no prospect for access for public use.	County-Owned, State-Owned, and Federally-Owned Lands (based on local knowledge) defined as preserve on the Future Land Use Map and local planner input.
<p>Notes:</p> <ol style="list-style-type: none"> <li>1. These generalized land use categories describe typical decisions applied in the county studies. County-specific differences in these decisions and site-specific departures from this approach are discussed in the county-specific sections of this report.</li> <li>2. Colored line file should be used in areas where less than 10 ft. elevations exist within 1,000 feet of the rising sea or color can't be seen on ledger paper map.</li> <li>3. Current protection may include sea walls, rock revetments, beach renourishment, levees, spreader swales or dikes.</li> <li>4. Coastal High Hazard Area defined in Rule 9J-5 FAC as the Category 1 hurricane evacuation zone and/or storm surge zone.</li> </ol>		

**Table 20: State-wide approach for identifying the likelihood of human land use protection from the consequences of 10 feet of sea level rise**

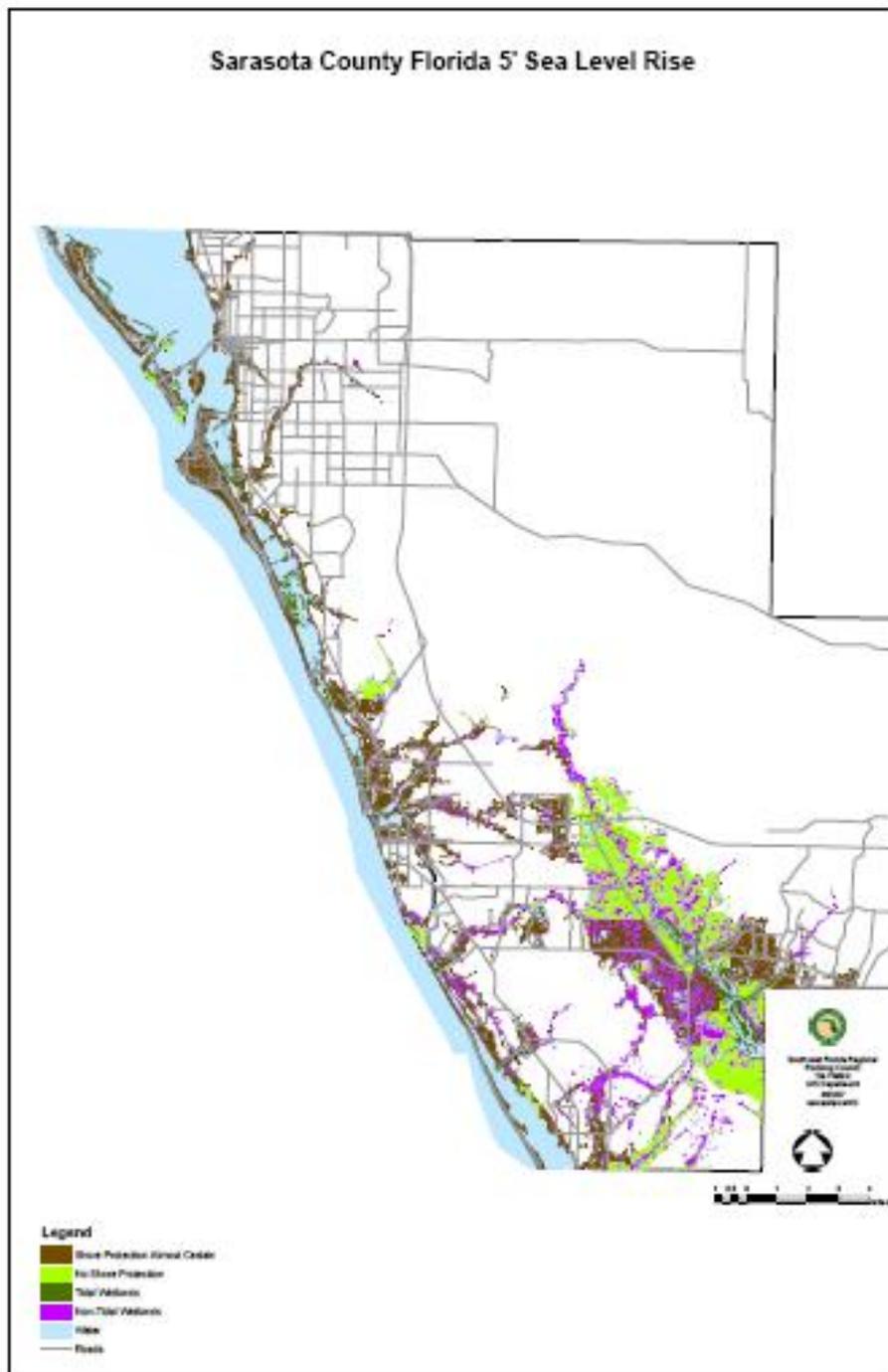


Figure 34: Land use projection map of Sarasota County at 5 foot sea level rise

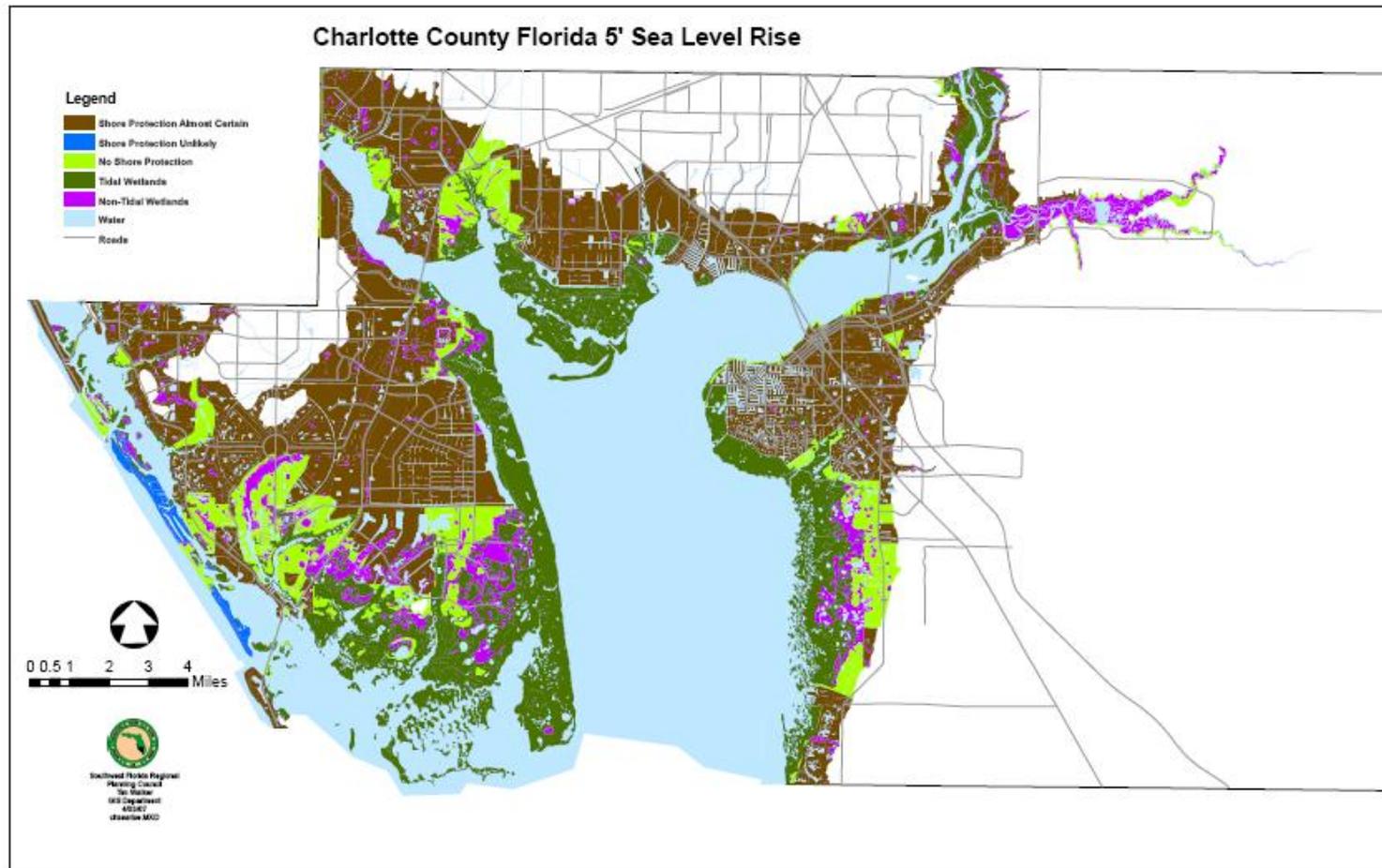


Figure 35: Land use projection map of Charlotte County at 5 foot sea level rise

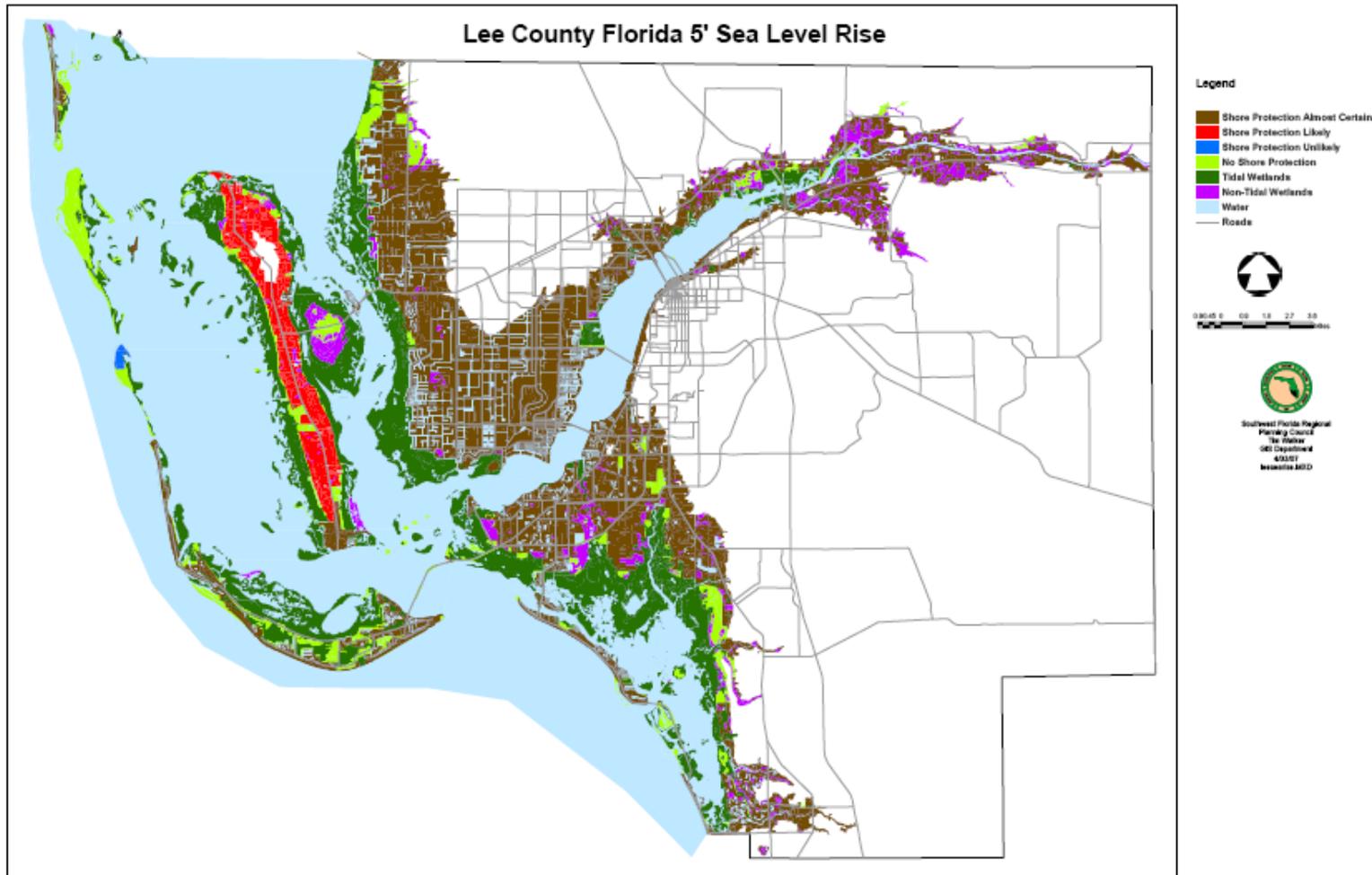


Figure 36: Land use projection map of Lee County at 5 foot sea level rise

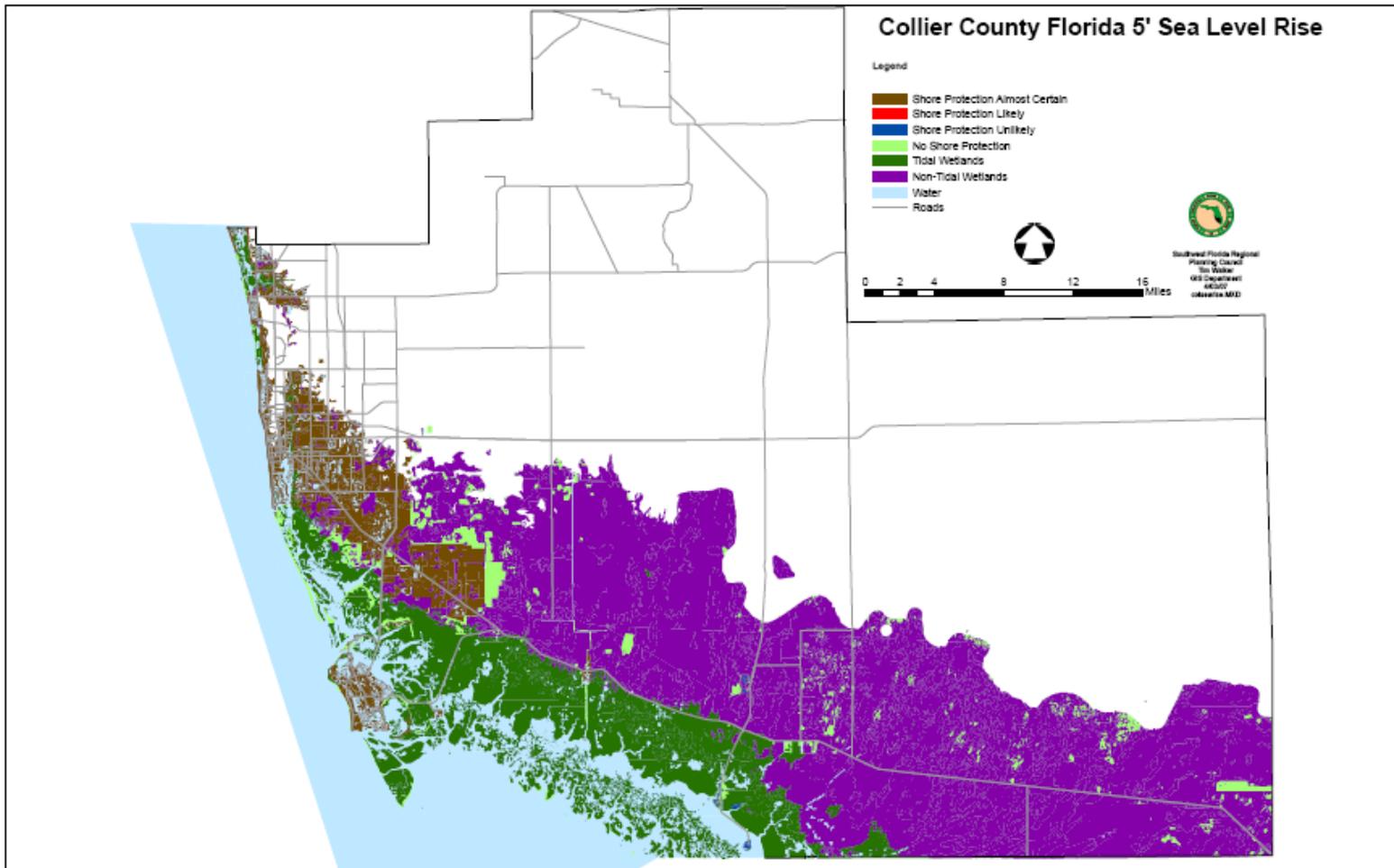


Figure 37 Land use projection map of Collier County at 5 foot sea level rise

## **Altered Hydrology**

### **Known Hydrologic Changes and Events that Have Occurred**

Sea levels in Florida are expected to eventually rise to the degree that saltwater intrusion will threaten the aquifers that currently supply much of Florida's drinking water in low-lying areas. This problem will be exacerbated by increased withdrawals of water for the anticipated increase in Florida's population.

Shallow coastal aquifers are already experiencing saltwater intrusion. The freshwater Everglades recharge Florida's Biscayne aquifer, the primary water supply to the Florida Keys. As rising water levels submerge the land, the low-lying portions of the coastal Everglades will become more saline, decreasing the recharge area and increasing saltwater intrusion (IPCC 2007c). The South Florida Water Management District (SFWMD) already spends millions of dollars per year to prevent Miami's Biscayne aquifer from becoming brackish (Miller et al. 1989).

Gulf Coast ecosystems are linked by the flow of water from the uplands through freshwater lakes, rivers, and wetlands to the coastal and marine systems downstream. Vast wetland areas of the region require periods of flooding to maintain healthy habitats and sustain food webs. While there remains uncertainty about how global warming will affect rainfall, stream flow, soil moisture, and overall water availability, human consumption of water resources is almost certain to increase as a result of the region's population growth.

Water resources are affected by changes in precipitation as well as by temperature, humidity, wind, and sunshine. Thus, changes in streamflow tend not just to reflect, but to magnify changes in precipitation. Water resources in drier climates tend to be more sensitive to climate changes, and, because evaporation is likely to increase with warmer climate, lower river flows and lower lake levels could be expected, particularly in the summer. If streamflow and lake levels drop, groundwater also could be reduced.

A critical factor in Florida's development, especially in southern Florida, has been availability of freshwater. Although south Florida receives an annual average of 54 inches of rain, annual evaporation sometimes can exceed this amount. Rainfall variability from year to year is also high, resulting in periodic droughts and floods. Competing demands for water — for residences, agriculture, industry, and for the Everglades and other natural areas — are placing stress on south Florida's water resources.

### **Potential Future Climate Changes**

Rising air and sea temperatures combined with a rising sea level will change future hydrology. By 2200, the mean sea level is estimated to rise over 177 inches (14.74 feet), inundating most of Monroe County and two-thirds of Miami-Dade County. The Everglades south of I-75, including the Everglades National Park, will no longer be a

freshwater ecosystem, causing a catastrophic environmental change for the species inhabiting that area. The incalculable effects on freshwater flows put surface water supplies throughout southern Florida at risk but three main changes can be expected (Stanton and Ackerman 2007). Flooding will result from changes in the intensity of precipitation and will cause stream bank erosion. Changes in the frequency of precipitation and increases in evaporation will cause drought. The sea level rise, lower water levels in the surface and groundwater result in salt water intrusion.

Increases in precipitation, including heavy and extreme precipitation events, affects all land surfaces and receiving water bodies. Precipitation is expected to increase five to 10% over the levels of the 20<sup>th</sup> century. The altered timing of seasonal hydrologic changes will affect coastlines and wetlands. An increase of freshwater in rivers and estuaries will lead to more severe sediment-loading and flash flooding that results in damage to fish and wildlife resources, human infrastructure, and human safety. Changes in timing of the dry and wet seasons change the flow of pollutants and will affect river discharge balance (University of Washington 2007; USNOAA 2008; SCCP 2005; FOCC 2009; USEPA CRE 2008).

Rising sea temperatures are also expected to increase the frequency of droughts and floods, causing changes to hydroperiod and to water quantity especially during dry periods. The changing timing of seasonal temperature cycles may also disrupt the hydrologic run-off cycle (Peterson et al. 2007). Changes in the volume and intensity of precipitation contribute to erosion, flooding, and run-off at coastlines. Drought from decreased precipitation will cause lower stream flows and result in erosion and subsidence of stream banks (UWCSES 2007; USNOAA 2008; USEPA CRE 2008).

Water constraints are a major threat to the future of Florida's agriculture, by far the biggest user of water. Even the new proposals for sugar cane-based bioethanol will require continuing massive flows of water for irrigation. Changes, even slight ones, in rainfall patterns and amounts may change the agricultural yields of rain-irrigated crops and silviculture directly. Rainfall pattern deviation may alter the spread and severity of plant diseases, pests, and rates of decomposition. Groundwater-irrigated crops are affected as well, due to the variation in water recharge cycles. Changes in rainfall patterns change soil moisture levels which could result in increasing the need for irrigation from groundwater or alternative surface water sources in some areas (Mulkey 2007; Fiedler et al. 2007; USNOAA 2008; FOCC 2009; USEPA CRE 2008).

The agricultural, natural, and cultivated landscape will be negatively affected by the droughts caused by increased atmospheric temperatures. Plant, animal and human communities will suffer from the lowered water tables and deep aquifers. Less water in rivers and reservoirs increases the water supply demands. Subsequent water stress will result in a higher mortality rate for those plant, animal, and human communities from the lack of sufficient water resources (USNOAA 2008; USEPA CRE 2008).

The increased salinity of riverine and estuarine ecosystems is an effect of drought. Increased penetration of saltwater from upstream tidal movement of marine waters will truncate isohaline ecotones. Pollutants from urban runoff are expected to be more

concentrated in freshwater systems due to lower water levels. Increased water temperatures and reduced dissolved oxygen will occur as a result of shallower streams. Marine exotics will spread and some freshwater exotics will be advantaged while native species suffer (University of Washington Center for Science in the Earth System 2007; USNOAA 2008; USEPA CRE 2008).

Rising sea levels will lead to increased saltwater infiltration into aquifers, particularly since water levels in the aquifers are dropping and freshwater recharge is diminishing. Groundwater supplies, which provide most of the state's drinking water, will tend to become brackish. Rising sea levels will also block the traditional water flow through the Everglades ecosystem, which is slowly being reconstructed at great expense. Eventually, if sea levels continue to rise, surficial aquifers throughout the state will be threatened with salt water intrusion into community water supplies (Freed et al. 2005; Dausman and Langevin 2005).

Conservation of water uses measures including grey-water recycling and cistern collection. While these measures may offset some of the future water use demand, they have their own environmental consequences, including discharge of nutrient laden waters for irrigation, increases in breeding loci for *Anopheles* mosquitoes, and more difficult accommodation for future population increase.

New water supplies will increasingly mean new investment in more expensive alternative sources. New reservoirs are being built wherever possible, including underground storage of freshwater in some cases. Wastewater treatment is becoming a growing industry in the state. Many areas have access to brackish groundwater but, while traditional ground and surface water supplies often cost less than \$1 per 1,000 gallons, desalination of brackish water can cost up to \$3 per 1,000 gallons (American Membrane Technology Association 2007). The drawbacks of desalination include creating large volumes of waste water and requiring large amounts of energy. With the reverse osmosis process, used in almost all existing plants, 100 gallons of brackish water is turned into about 75 gallons of useable water and 25 gallons of brine which is often pumped underground (Reeves 2007). The energy requirements of the process are great as well because such high pressure is required to properly force water through thousands of fine-mesh filters. A reliance on desalination would increase the demand for electricity, which in turn would increase the demand for cooling water in power plants, creating a loop. Despite this technology, it's still less expensive to pipe in freshwater from the mainland (Reid 2007).

The state's first large-scale ocean desalination plant was built for Tampa Bay Water, a regional authority in one of the most water-scarce regions. It has been plagued by technical problems, multi-year delays, and financial overruns, reaching a cost of \$158 million by the time it began operation in 2003. The plant hoped to reach its design capacity of 25 MGD of freshwater, with water costs of a little over \$3 per thousand gallon, by the end of 2007 (Barnett 2007; Reid 2007). In view of these problems, no one else in Florida is rushing to build a similar facility.

While the Tampa Bay plant is large compared to previous desalination efforts, it is small compared to Florida's water needs. To meet the growth in the demand for water through 2050 (as projected above), 186 Tampa-sized plants would be needed — more than one new plant coming on line every three months from now through 2050.

In short, there are no feasible supply-side options for providing this much water; most of the gap will have to be filled by conservation and reduction in demand.

Even under the best of circumstances — under the rapid stabilization scenario, with minimal damages due to climate change — Florida's racing economic and demographic growth is headed for a collision with the lack of additional water. The Florida Department of Environmental Protection (FDEP) projects an increase in water requirements of 22 percent by 2025 (FDEP 2007b). Looking farther ahead, if agricultural water use remains constant, since there is little land for agricultural expansion, and if all other water uses grow in proportion to population, then by 2050 the state would need 12,800 million gallons per day (MGD) of freshwater (Stratton and Ackerman 2007). This is a 57 percent increase over water use in 2000, a quantity that appears to be impossible to provide from existing freshwater sources. At the current cost of desalination, \$3 per 1,000 gallons (see above), the additional water needed by 2050 would cost almost \$6 billion per year — if it were available. Groundwater supplies are already encountering limits. The water level in the Floridan Aquifer has been dropping for decades (Marella and Berndt 2005); it can no longer meet the growing needs of many parts of the state. Meanwhile, the state has turned down Miami-Dade County's request for a big increase in its withdrawals from the Biscayne Aquifer, which is also under stress; the county will instead be forced to invest in expensive alternatives such as a high-tech wastewater disinfection plant (Goodnough 2007). Surface water supplies are limited in most areas, and will be further constrained in south Florida by the long-term effort to restore the Everglades ecosystem. Floridians, therefore, can look forward to more intensive conservation efforts, such as strict limits on lawn watering, combined with promotion of alternative vegetation that requires less water than a grassy lawn.

Meeting Florida's water needs will be challenging, even in the absence of climatic change. The business-as-usual climate scenario will make a bad situation much worse, with average temperatures rising by 10°F, rainfall decreasing from 54 to 49 inches per year, and sea levels rising by almost four feet over the course of the twenty-first century. Hotter, drier conditions will increase the demand for water for irrigation and other outdoor uses, while at the same time decreasing supplies. Surface water flows will be diminished by the decreased rainfall and increased evaporation. Groundwater supplies will also gradually diminish, as less rainfall and more evaporation means less water percolating down through the soil to recharge the aquifers. The decreased rainfall will not be uniform and predictable from year to year; rather, there will be more frequent droughts, resembling the conditions of 2001 and 2007. With water levels in Lake Okeechobee and elsewhere dropping under drought conditions, the water supplies for much of south Florida, and much of the state's agriculture, are at risk.

## **Geomorphic Changes**

### **Known Geomorphic Changes and Events that Have Occurred**

Beaches and inlets are regional systems of sediment deposition, erosion, and transport. These processes are profoundly affected by changes in sea level and rates of sea level change, as well as storm events. Scientists and resource managers will be challenged to separate the effects of sea level changes from the effects of storms and the alterations resulting from beach and inlet management actions, such as dredging and beach renourishment.

Shoreline retreat due to erosion and overwash is already occurring (Sallenger et al. 2006, FOCC 2009). There has been an increase in the formation of barrier island inlets and in island dissection events, in which islands are eroded by wind and waves (Sallenger et al. 2006; Sallenger et al. 2005). Normal mangrove accretion in stable estuaries occurs at a rate of 7 mm/year (Cahoon et al. 1999) effectively increasing elevations. Under equilibrium conditions, the processes of erosion and deposition balance, and wetlands are not lost. However, even historic sea level rise coupled with local subsidence has upset coastal equilibrium in many parts of the world (Bird 1985; Bruun 1986).

According to the Florida Department of Environmental Protection (FDEP), beach erosion threatens the very resource that residents and visitors enjoy. In 1989, a first list of erosion areas was developed based upon an abbreviated definition of critical erosion. The list included 217.6 miles of critical erosion and another 114.8 miles of non-critical erosion statewide. Of the state's 825 miles of sandy beaches, the 2006 list includes 385.3 miles of critically eroded beach, 8.6 miles of critically eroded inlet shoreline, 96.8 miles of non-critically eroded beach, and 3.2 miles of non-critically eroded inlet shoreline statewide (FDEP 2006). This data suggests a 20 percent increase in critically eroded beaches within 15 years of records. Over 409 miles, or approximately 50% of the state's beaches, are experiencing erosion. "Critical erosion", is defined as a level of erosion which threatens substantial development, recreational, cultural, or environmental interests.

While some of this erosion is due to natural forces and imprudent coastal development, a significant amount of coastal erosion in Florida is directly attributable to the construction and maintenance of navigation inlets. Florida has over 60 inlets around the state, and many have been artificially deepened to accommodate commercial and recreational vessels and employ jetties to prevent sand from filling in the channels. A by-product of this practice is that the jetties and the inlet channels have interrupted the natural flow of sand along the beach causing an accumulation of sand in the inlet channel and at the jetty on one side of the inlet, and a loss of sand to the beaches on the other side of the inlet (FDEP 2006).

### **Potential Future Climate Changes**

Sea level rise will change coastlines in many ways (USEPA CRE 2008; Volk 2008; Bollman 2007; Titus 1998). There will be erosion with landward migration of coastlines,

barrier island disintegration, saltwater intrusion into surface and subsurface waters, rising surface and groundwater tables. Where retreat is possible, there will be a migration of mangrove and marsh species, altered plant community structural diversity with potential changes in dominant or foundation species, and structural and functional habitat changes. As waters deepen, there will be less sunlight available to submerged aquatic vegetation (SAV) in current locations and light attenuation coefficients will be exceeded (USEPA CRE 2008). The ability of barrier islands to shield coastal areas from higher storm surges and the destructive effects of hurricanes will be reduced by sea level rise (Fiedler et al 2001; Titus 1998; USEPA CRE 2008).



**Photograph 2: Aerial view of Charley Pass, a breach of North Captiva Island created by Hurricane Charley on August 13, 2004**

Continued sea level rise will exacerbate erosion (Sallenger et al. 2009), reducing the elevation of barrier islands (Sallenger et al. 2009) and affecting coastal transportation infrastructure. Increased overwash and breaching of coastal roads will occur (Sallenger et al. 2006). Low barrier islands will vanish, exposing marshes and estuaries to open-coast; high fetch conditions (Sallenger et al. 2009).

A drier climate along the Gulf Coast combined with such activities as dredging, constructing reservoirs, diverting surface water, and pumping groundwater could accelerate local subsidence and sinkhole formation in areas underlain by limestone (Twilley et al. 2001). Carbonate sediment dissolution will accelerate as pH decreases (Orr et al. 2005). There is a potential for terrestrial ground subsidence with loss of terrestrial habitat for wildlife and humans and expansion of aquatic habitats (USCCSP 2008; USNOAA 2008; USEPA CRE 2008; SCCP 2008).

Sea level rise will add to the effects of relative surface elevation subsidence caused by

changes in sediment transport from watersheds to the estuaries and coast. Dams, diversions, reservoirs, shoreline hardening, dredging of channels and passes with deep water or landward spoil disposal can starve the bed load sediment budget preventing the relative elevation of shallow subtidal and intertidal zones to retain a relative position to sea level to allow wetlands to retreat and re-zone. Some structural adaptations to sea level rise, such as vertical sea walls, tidal barriers, fetch barriers, channelization, etc., will restrict sediment transport and reduce the ability of wetlands to migrate inland with sea level rise. The balance between rainfall and evaporation modified by increased human consumption/drawdown of groundwater will reduce supplies for wetlands and estuaries. When wetlands are "squeezed" and can't migrate, they do not create land fast enough to avoid drowning (Ebi et al. 2007; Titus 1998).

Specifically for southwest Florida coastal counties, the following erosion report discusses coastal segments mile-by-mile (FDEP 2006). For illustrative purposes the Lee County Map (Figure 42) is included to show how coastal segments are divided and discussed in the erosion report. This report also includes the segments that have beach restoration projects. Furthermore, Figure 42 is a map and legend that includes locations of shore hardening/armoring along the bases and rivers (FFWI 2006). By examining these two sources, locations of shore armoring can be used to determine where shore protection is almost certain to continue as sea level rises. The following are the areas identified by the FDEP as having critical coastal erosion problems as of 2006

### Sarasota County

There are seven designated critically eroded beach areas (23.1 miles), one noncritically eroded beach area (0.4 mile), and two critically eroded inlet shoreline areas (1.1 miles) in Sarasota County.

The southern half of Longboat Key (R1 - R29) between Manatee County and New Pass has 5.4 miles of critically eroded beach that has threatened development interests in the Town of Longboat Key. This area has a beach restoration project, and terminal groins exist at New Pass.

The north end of Lido Key fronting on New Pass is a critically eroded inlet shoreline area (R31, east 1500 feet) for 0.3 miles. Nearly all of Lido Key (R31 - R44.5) has critically eroded beach that has threatened private development and recreational interests along 2.4 miles. Beach restoration has been conducted along the island and maintenance dredging material has been obtained from the federal navigation channel at New Pass.

The south shoreline of Big Sarasota Pass (R44A - R45) is critically eroded along 0.8 mile of Siesta Key. The threatened private properties along this inlet shoreline have bulkheads and rock revetments.

At the north end of Siesta Key, south of Sarasota Point (R46 - R48.4), is a critically eroded beach area that threatens private development and Beach Road. This 0.4-mile erosion area has rock revetments.

Along the southern half of Siesta Key south of the Point of Rocks headland is a 2.4-mile long critically eroded beach area (R64 - R77) that threatens private development. Some rock revetments exist in this area and a beach restoration project has been constructed. Along the northern half of Casey Key (R81 - R96) is a 2.9-mile long critically eroded beach area that threatens private development and the Casey Key Road. Almost all of this erosion area has rock revetments.

Extending 5.1 miles south of Venice Inlet is a critically eroded beach segment (R116 - R143) that has threatened development and recreational interests in the City of Venice, and to the south a sewage treatment plant, Harbor Drive, and Caspersen Beach. This area has a beach restoration project, and numerous concrete bulkheads exist at the north end of the City of Venice. To the south is a 0.4-mile segment of noncritical erosion (R143-R145).

The south end of Sarasota County (R160-R183.7) is critically eroded for 4.5 miles along Manasota Key threatening private development as well as Manasota Key Road. Some rock revetments have been constructed in this area.

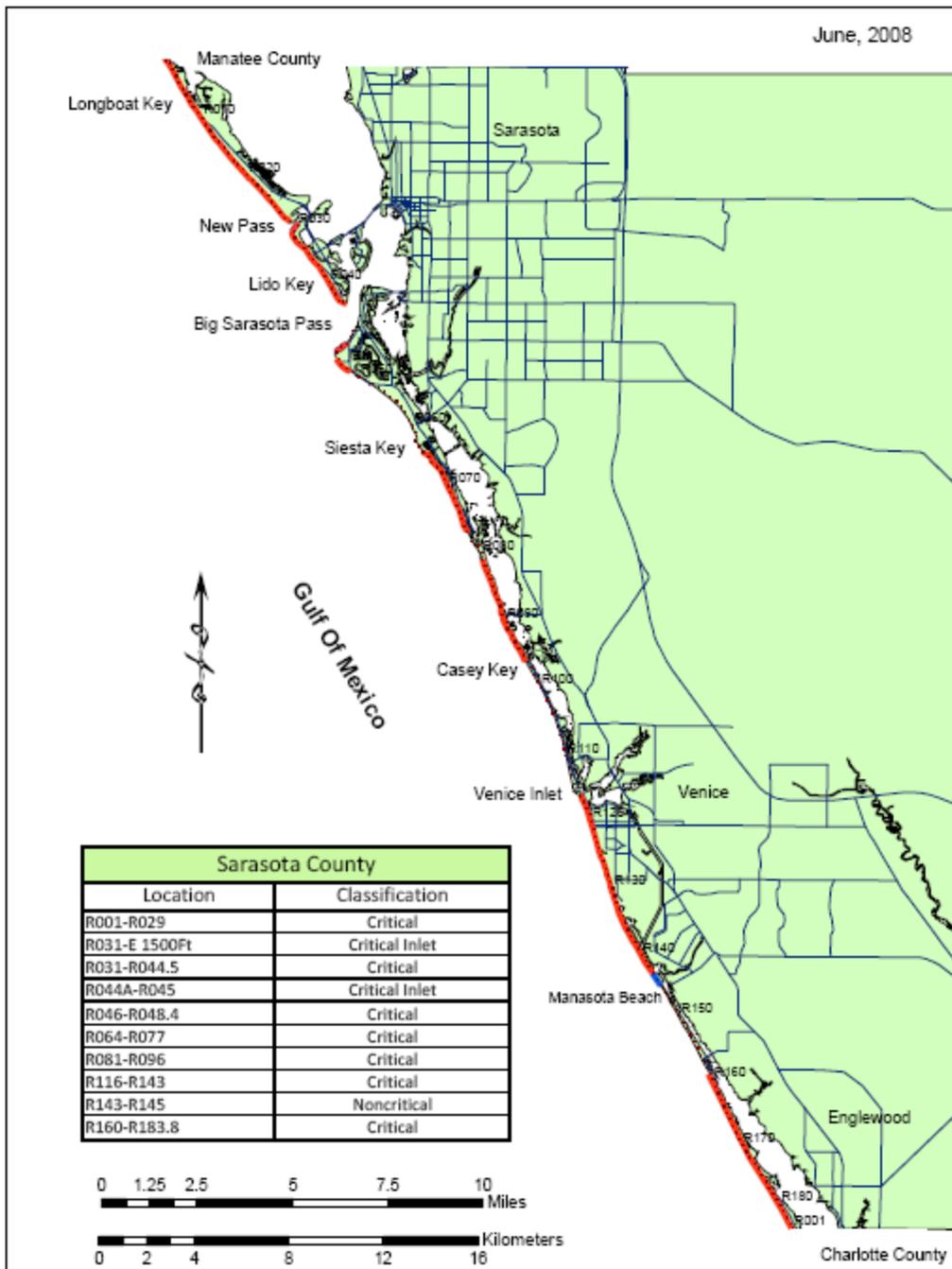


Figure 38: Identified areas of coastal erosion Sarasota County

## Charlotte County

There are three critically eroded areas (5.2 miles) and one noncritically eroded area (0.4 mile) in Charlotte County.

The northern 3.0 miles of Charlotte County (R1 - R17) along southern Manasota Key including Englewood Beach and Stump Pass State Park are critically eroded, threatening private development and public recreational interests. A few retaining walls and bulkheads exist north of Stump Pass State Park. Between R17 and R19 within the state park is 0.4 mile of noncritical erosion. The park has been nourished with Stump Pass maintenance dredge material.

Additional material was placed along Englewood Beach and the state park during the Stump Pass relocation project.

Along Knight Island and Bocilla Island (R28 - R39) are 1.8 miles of critically eroded beach threatening private development. Beach restoration of this area has been conducted with Stump Pass dredge material.

South of Little Gasparilla Pass, which is closed, is a 0.4-mile segment of critically eroded beach on Little Gasparilla Island. This erosion threatens private development.

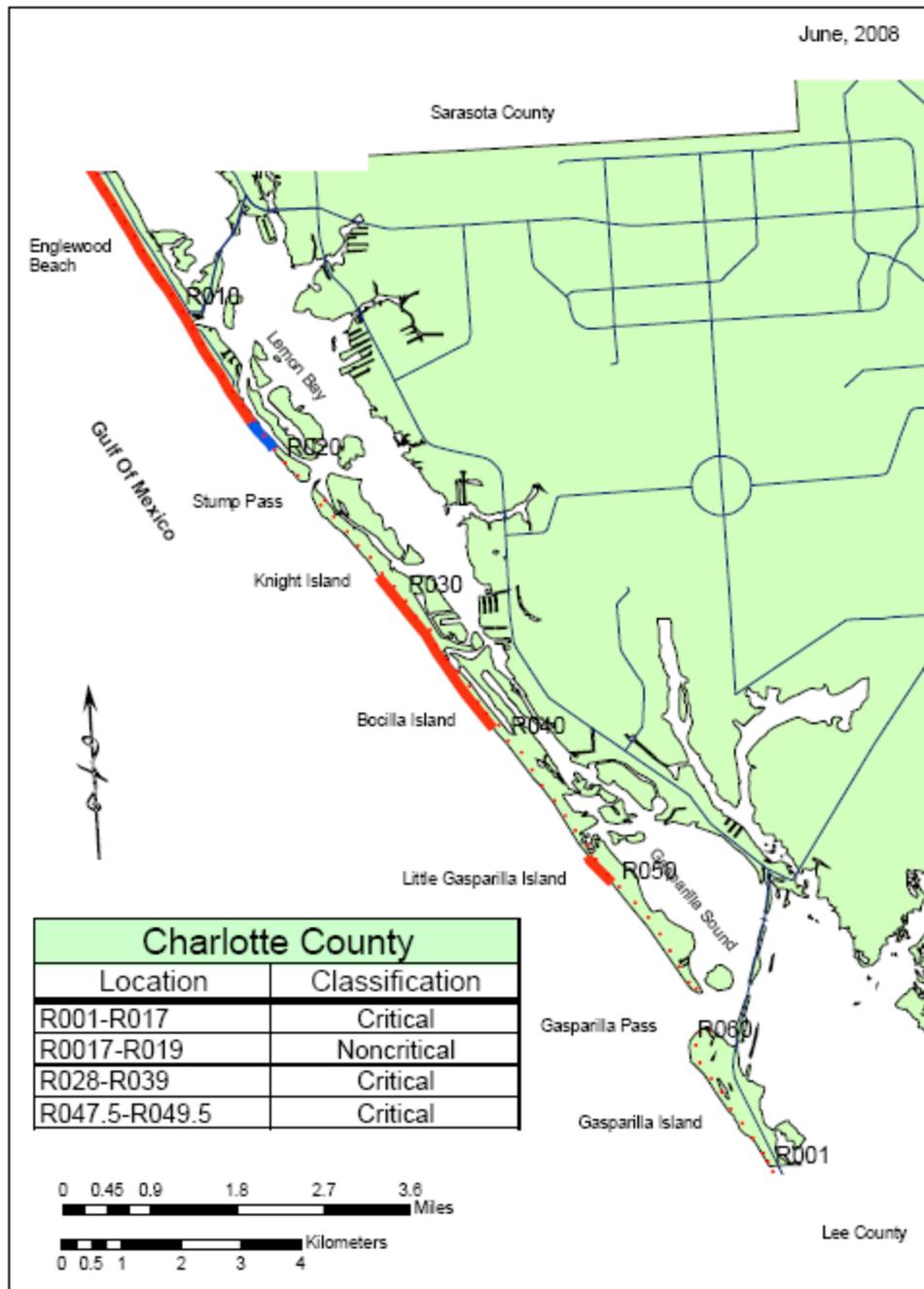


Figure 39: Identified areas of coastal erosion Charlotte County

## Lee County

There are ten critically eroded beach areas (21.6 miles), four noncritically eroded beach areas (5.3 miles), three critically eroded inlet shoreline areas (0.6 mile), and two noncritically eroded inlet shoreline areas (0.4 mile) in Lee County.

The southern 4.0 miles of Gasparilla Island (R7 - R26.7) is critically eroded, threatening development and recreational interests in the town of Boca Grande and the Gasparilla Island State Park. Much of this area has bulkheads, and inlet sand transfer has been conducted using Boca Grande Pass dredge material. The north shoreline of Boca Grande Pass within the Gasparilla Island State Park (0.2 mile) is also critically eroded.

Three areas on Cayo Costa Island are noncritically eroded. The northern segment (R27 - R33) extends for 1.1 miles, the central segment (R46 - R52) extends for 1.2 miles, and the southern segment (R60 - R65) extends for 1.0 mile.

All of North Captiva Island is eroded. The north shore fronting on Captiva Pass (R66, east 1000 feet) has critical inlet shoreline erosion threatening development interests. The northern 1.0 mile of gulf beach (R66 - R71) is critically eroded; threatening development interests, and from R71 through R78 is 2.0 miles of noncritical erosion. The island was breached between R78 and R79 during Hurricane Charley (2004). The truncated southern 0.8 mile of North Captiva Island extending into Redfish Pass (R79-R82.3) is critically eroded threatening development and losing wildlife habitat.

All of Captiva Island is critically eroded. The south shore of Redfish Pass (R83 - R84) has 0.2 mile of critically eroded inlet shoreline. This shoreline has a rock revetment with a terminal groin. The gulf beach from R84 through R109 has five miles that is critically eroded. This entire island segment is a beach restoration project.

Northern Sanibel Island is eroded. From R109 to R118 the beach is critically eroded, extending 1.7 miles south of Blind Pass where the road, development, recreation, and wildlife habitat are threatened. Part of this segment received nourishment from the Captiva Island beach restoration project. Another segment (R129 - R133) on northern Sanibel Island has 0.9 mile that is critically eroded, threatening development interests. This segment in the neighborhoods of Gulf Shores and Gulf Pines has a beach restoration project.

Most of Estero Island is eroded. From R175 (-.4) to R200, Ft. Myers Beach has 5.0 miles that is critically eroded, threatening development and recreational interests. This entire segment is a beach restoration project. Matanzas Pass channel dredge material has been previously placed at the north end on Bowditch Point.

Most of Lover's Key is eroded. The north shore of Lover's Key (R211 - R213) fronting on Big Carlos Pass has 0.3 mile that is noncritically eroded. Most of the Gulf beach extending from R214 to R222 has 1.5 miles that is critically eroded, threatening recreational interests and wildlife habitat in Lover's Key State Park. A beach restoration project was constructed in 2004. The south shore of Lover's Key (R222) fronting on New Pass also has 0.1 mile of noncritically eroded inlet shoreline.

Between New Pass and Big Hickory Pass, Big Hickory Island (R222.7 - R225.9) has 0.8 mile that is critically eroded where wildlife habitat and recreation has been lost. South of Big Hickory Pass, Little Hickory Island (R226 - R230) has 0.9 mile of critically eroded beach threatening development interests in Bonita Beach. This area has a beach restoration project with bulkheads and two terminal groins at the north end.

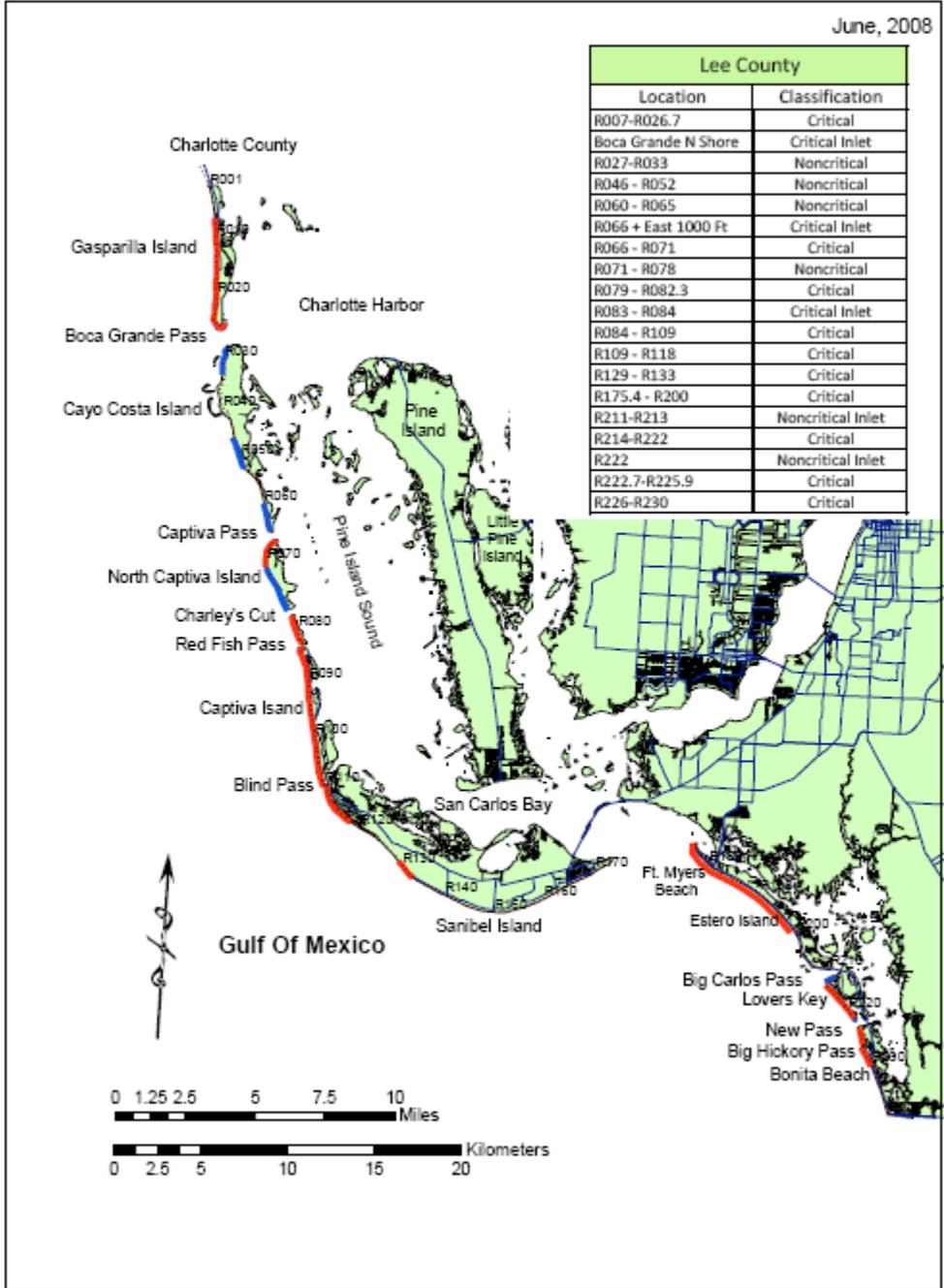


Figure 40: Identified areas of coastal erosion Lee County

## Collier County

There are seven critically eroded beach areas (13.3 miles), five noncritically eroded beach areas (5.3 miles), and one critically eroded inlet shoreline area (0.8 mile) in Collier County.

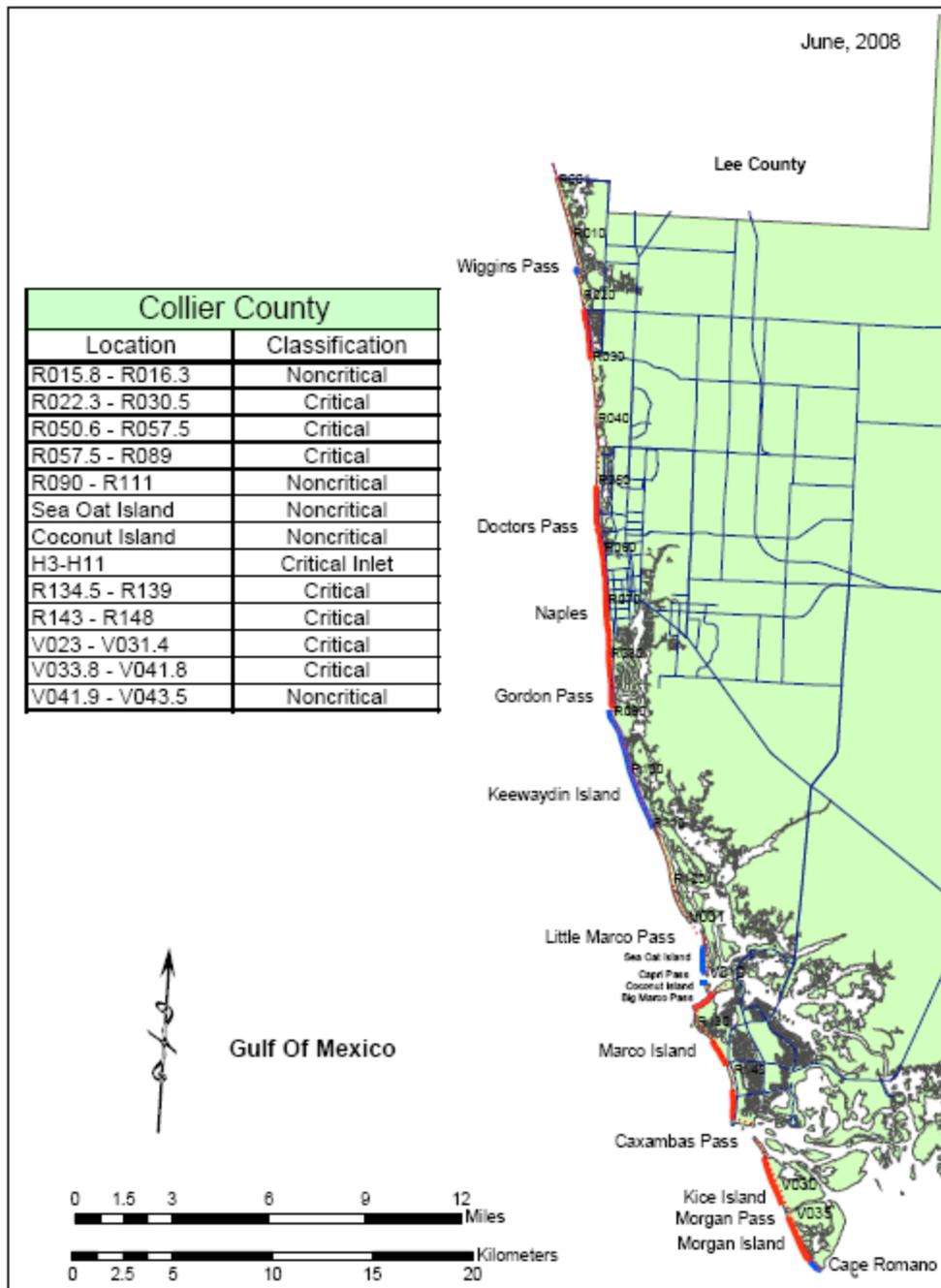
In northern Collier County, a 0.1-mile beach segment north of Wiggins Pass (R15.8 - R16.3) is noncritically eroded. A 1.6-mile beach segment (R22.3 - R30.5) is critically eroded, threatening development interests in Vanderbilt Beach. This area has a beach restoration project and numerous bulkheads.

The City of Naples has two segments that are critically eroded, threatening development interests north and south of Doctors Pass. North of Doctors Pass (R50.65 - R57.5) is a 1.3-mile critically eroded segment, and between Doctors Pass and Gordon Pass (R57.8 - R89) is a 5.6-mile critically eroded segment. These areas of Naples have a continuous beach restoration project. Numerous bulkheads and revetments also exist throughout Naples. Groins exist north of Gordon Pass.

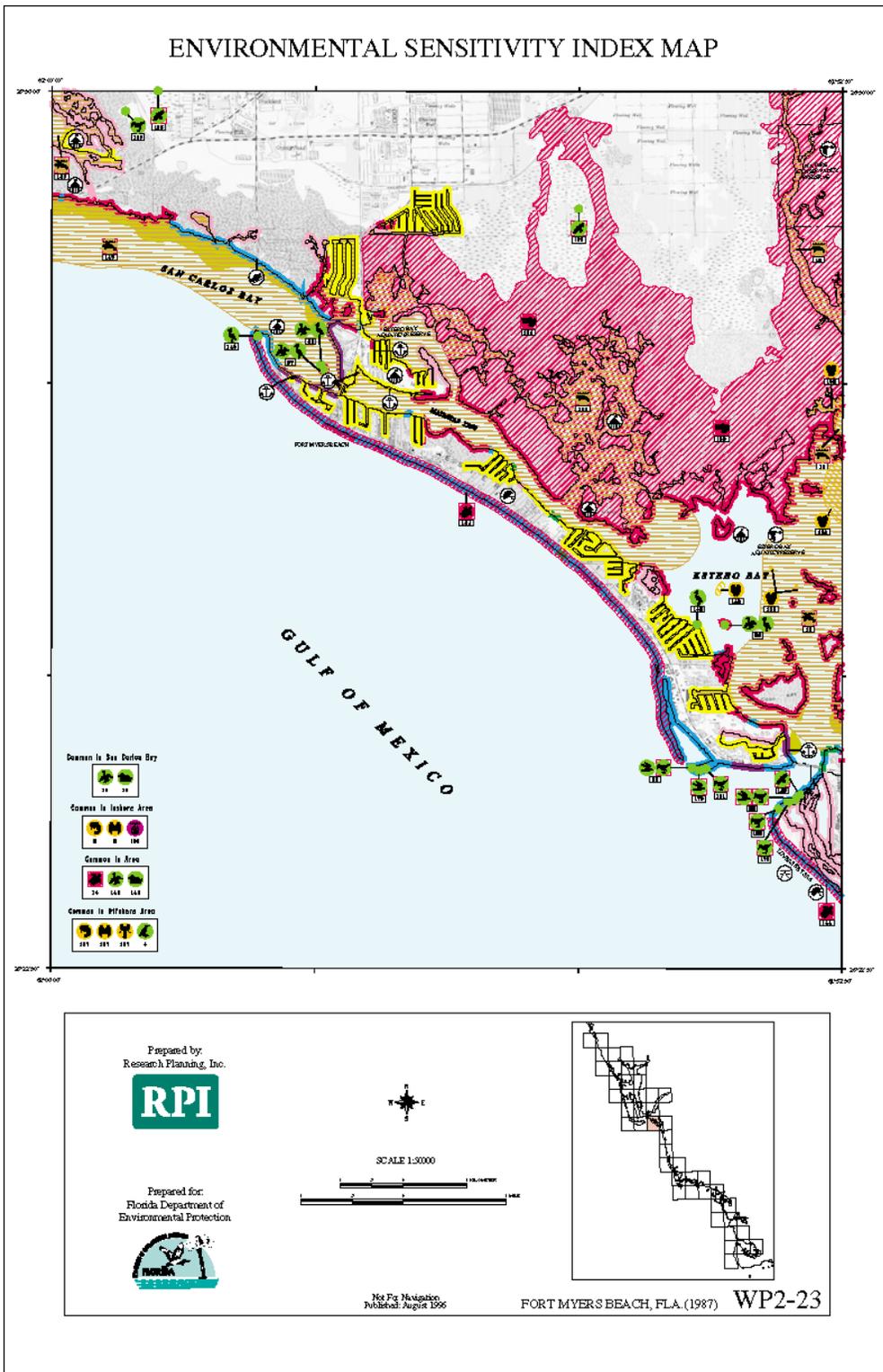
South of Gordon Pass (R90 - R111) is a 3.9-mile stretch that is noncritically eroded along the northern half of Keewaydin Island. Between Little Marco Pass and Capri Pass, Sea Oat Island has 0.9 mile of beach that is noncritically eroded. Also, Coconut Island (M1 - M2) has 0.1 mile that is noncritically eroded off the north shore of Marco Island; however, little remains of this island that was severely impacted by Hurricane Wilma (2005).

Marco Island has three areas that are critically eroded, threatening development interests. Along Hideaway Beach, the north shore of Marco Island (H3 - H11) fronting on Big Marco Pass has 0.8 mile of inlet shoreline that is critically eroded. The central gulf beach of Marco Island (R134.5 - R139) has 0.8 mile that is critically eroded and the southern stretch of beach (R143 - R148) has 0.9 mile that is critically eroded. All three critically eroded areas on Marco Island have beach restoration projects, and the northern segment also has a rock groin field along Hideaway Beach.

Erosion on the two southern barrier islands in Collier County has progressed into the backshore mangrove forest resulting in the loss of beach wildlife habitat. Following Hurricane Wilma (2005), a 1.6-mile segment of Kice Island (V23 - V31.4) is critically eroded. South of Morgan Pass, Morgan Island has a 1.5-mile segment (V33.8 - V41.8) that is critically eroded and a 0.3-mile segment (V41.8 - V43.5) that is noncritically eroded.



**Figure 41: Identified areas of coastal erosion Collier County**



# WEST PENINSULAR FLORIDA 1

## SHORELINE HABITAT RANKINGS

- 1 EXPOSED VERTICAL ROCKY SHORES  
EXPOSED SEAWALLS
- 2 EXPOSED ROCKY PLATFORMS
- 3 FINE-GRAINED SAND BEACHES
- 4 COARSE-GRAINED SAND BEACHES
- 5 MIXED SAND AND GRAVEL (SHELL) BEACHES/FILL
- 6 GRAVEL BEACHES/RIPRAP
- 7 EXPOSED TIDAL FLATS
- 8 SHELTERED ROCKY SHORES/SEAWALLS/  
VEGETATED BANKS, SOLID MAN-MADE STRUCTURES
- 9 SHELTERED TIDAL FLATS
- 10A EXPOSED MARSHES AND/OR MANGROVES
- 10E SHELTERED MARSHES AND/OR MANGROVES

## HUMAN-USE FEATURES

- |                                |                                      |
|--------------------------------|--------------------------------------|
| AIRPORT                        | MARINE SANCTUARY                     |
| AQUACULTURE                    | NATIONAL PARK                        |
| ARCHAEOLOGICAL/HISTORICAL SITE | STATE PARK                           |
| BOAT RAMP                      | RECREATIONAL BEACH                   |
| COAST GUARD                    | WATER INTAKE                         |
| DIVE SITE                      | WILDLIFE REFUGE                      |
| MARINA                         | ID NUMBER                            |
| STATE BOUNDARY                 | AQUACULTURE BOUNDARY<br>MANAGED AREA |

## SENSITIVE BIOLOGICAL RESOURCES

- |                    |                                 |                       |
|--------------------|---------------------------------|-----------------------|
| BIRDS              | MARINE MAMMALS                  | SHELLFISH             |
| DIVING BIRDS       | MANATEES                        | BIVALVES              |
| GULLS AND TERNS    | TERRESTRIAL MAMMALS             | CRABS                 |
| PASSERINE BIRDS    | SMALL MAMMALS                   | LOBSTERS              |
| PELAGIC BIRDS      | CONCENTRATION SITE              | SHRIMP                |
| RAPTORS            | SUBMERGED AQUATIC<br>VEGETATION | MULTI-GROUP           |
| SHOREBIRDS         | SAV                             | ID NUMBER             |
| WADING BIRDS       | REPTILES                        | THREATENED/ENDANGERED |
| WATERFOWL          | TURTLES                         |                       |
| CONCENTRATION SITE |                                 |                       |

Figure 43: Key to Environmental Sensitivity Index Map for the Estero Bay Area

## Habitat and Species Changes

### Known Habitat and Species Changes and Events that Have Occurred

#### *Corals and Coralline Ecosystems*

In Florida, corals are tropical animals already living close to their upper water temperature limits. Corals have a close association with single-celled plants that live inside their cells and that provide energy to the coral by photosynthesis. Corals are said to bleach, or whiten, when those plant cells die. Bleaching events are correlated with local or regional increases in seawater temperature. In the early 1980s, during the first massive coral bleaching event in the Florida Keys, observations of increased coral diseases also began to be reported (Wilkinson and Souter 2008).

Reef-building corals of Florida now are one to 1.5 degrees Celsius closer to their upper temperature limits than they were 100 years ago. Corals that are stressed by high water temperature have displayed higher rates of disease and coral bleaching (Wilkinson and Souter 2008; FOCC 2009). Corals stressed by temperature and bleaching are more vulnerable to pathogens on their outer surface, resulting in increases in coral disease (Ritchie 2006; Harvell et al. 2002; Eakin et al. 2005). Coral diseases have increased substantially in the Florida Keys due to an increase in sea surface temperatures (Wilkinson and Souter 2008).

Increased sea-surface temperatures in coastal and marine environments, especially during slick, calm periods in shallow and semi-enclosed embayments, lead to episodic die-offs of sponges, seagrasses, and other important components of coastal and marine communities (FOCC 2009; USEPA CRE 2008). Massive die-offs of tropical reef fish, caused by infections of the organism *Brookynella*, a marine disease caused by a protozoan, or single-celled animal, that infects reef fish under stress, occurred in 1980 in the Florida Keys and from 1997 to 1998 in the Florida Keys and the Caribbean (Wilkinson and Souter 2008). Massive die-offs of sponges and blooms of cyanobacteria, a form of blue-green algae that can produce biological toxins, have also been documented during extended periods of elevated sea-surface temperatures (Wilkinson and Souter 2008) from Miami to the Dry Tortugas, and in Florida Bay during recent periods that coincided with elevated sea-surface temperatures and doldrum weather periods (Wilkinson and Souter 2008). An epidemic die-off of the long spine sea urchin (*Diadema antillarum*) began on the Caribbean side of Panama in 1983 (Lessios et al. 1984). A massive die-off of seagrasses occurred in Florida Bay in 1987, at the same time that a massive coral bleaching event was occurring throughout the Keys and around the Caribbean (Wilkinson and Souter 2008). Recent changes in the distribution and productivity of a number of fish species can, with high confidence, be ascribed to regional climate variability, such as the El Niño–Southern Oscillation warming phenomenon in the Pacific Ocean (Lessios et al. 1984).

Along with increasing sea temperatures, staghorn and elkhorn coral are now re-expanding their ranges northward along the Florida peninsula and into the northern Gulf of Mexico (Brander 2007). Abundant fossil evidence demonstrates that marine animals shifted towards the poles as sea surface temperatures rose—for example, during the Pleistocene–Holocene transition, which occurred about 11,000 years ago (Precht and Aronson 2004.). In addition to allowing natural range expansions, warming temperatures can facilitate the establishment and spread of deliberately or accidentally introduced animal and plant species (Carlton 2001; Stachowicz et al. 2002).

The metabolism of marine and coastal ecosystems is affected by water temperature, nutrient supply, and volume of freshwater inputs. How efficiently or inefficiently nutrients move through the food web can affect the diversity, number, and economic value of living marine resources (FOCC 2008).

Estuarine circulation, salinity, and faunal use patterns are changing (Peterson et al. 2008). Many tidal wetlands are keeping pace with sea level changes (Estevez 1988). Some are accreting vertically, migrating up-slope, or both (Williams et al. 1999; Raabe et al. 2004; Desantis et al. 2007). The rate of sea level rise will be critical for the continued presence of tidal wetlands.

### *Seagrass*

The seagrass beds of Charlotte Harbor consist predominantly of shoal grass (*Halodule wrightii*) and turtle grass (*Thalassia testudinum*). Some manatee grass (*Syringodium filiforme*) is distributed in patches within beds of the dominants. Primary feeders on seagrasses include sea turtles, manatees, sea urchins, blue crabs, fiddler crabs, and many fishes. The amount of direct grazing varies with location. In Lemon Bay many seagrass grazing fishes are at their northern limit. Many feeders, such as conch, scrape the seagrass blades for epiphytic algae and animals. If roots are undisturbed, seagrass beds respond well to grazing, regenerating easily. With optimal depths, water clarity, and temperature, seagrasses can grow as fast as 2.3 inches per day. In concert with mangroves, macrophytic algae, phytoplankton, benthic micro-algae and emergent marshes, the seagrass meadows provide the primary productive food base of the estuarine system.

The complex structure of seagrass bottoms provides living spaces for numerous periphytic and epifaunal organisms, topological structures for a rich invertebrate fauna, and cover from predation for large populations of small fishes, nektonic and benthic crustaceans, annelids, mollusks, and echinoderms. This combination of shelter and food source makes the seagrass bed a rich nursery and feeding ground for the juvenile and adult forms of many commercially and ecologically significant species of fish and other vertebrates. Many animals associated with mangroves, oyster bars and open unvegetated waters by day, such as pomadaspid fishes, forage in grassbeds at night. Many estuarine fishes spend their entire life cycle feeding in seagrass habitats while others are resident only during critical developmental periods (Ogden and Zieman 1977).

### *Macro-Algal Beds*

The primary types of macro-algal growth of Charlotte Harbor include: those that grow on the soft sediments; epiphytic species that utilize seagrasses, mangroves, or emergent marsh grasses; the algae that require a hard substrate to anchor such as oyster bars; and the unattached drift algae.

The only algae able to remain in the soft sand and mud substrates utilized by seagrass are mat-forming algae and the *Siphonales* green algae that have creeping rhizoid anchors, including *Halimeda*, *Penicillus*, *Caluerpa*, *Rhizocephalus* and *Udotea*. These algae have limited substrate stabilization capability when compared to seagrasses. They are able to survive in more shifting sediments, however, and are often considered as an early successional stage for seagrass establishment. These algae provide primary food production and deposit large quantities of calcium carbonate, or lime mud, from their skeletons upon seasonal die-back. Many of these species are also common in seagrass, mangrove, soft bottom, and hard substrate communities as well.

The epiphytic algae are a diverse assemblage. Red algae (*Rhodophyta*) make up approximately 45% of the common species of epiphytes. Blue-green (*Cyanophyta*) and green algae (*Chlorophyta*) constitute 21% each of this total and brown algae (*Phaeophyta*) represent the remaining 12%. At least 113 species of epiphytic algae are recorded from turtle grass alone. Sixty-six species are common and the others facultative. The turnover of the epiphytic community is rapid since a seagrass blade's lifetime is 30 to 60 days. The epiphytes increase the primary productivity of seagrass beds and can account for 18 to 33% of community metabolism. They are able to fix molecular nitrogen which is utilized by seagrass. Many animals feed directly on these epiphytes. Heavy growth of encrusting coralline algae, however, can damage seagrass blades by reducing photosynthesis (Goering and Parker 1972).

Hard substrate algae consist of hundreds of species from all of the major macroalgal phyla. Natural bottoms of the Lemon Bay Aquatic Preserve provide few hard abiotic surfaces. Old exposed shells (oysters, clams and whelks) and some areas of exposed bedrock constitute the principal natural areas of hard bottom. Mixed abundances of these plants occur where water quality and clarity is good.

The drift algae species begin growth attached to a firm substrate, plant or inorganic, and subsequently become detached by wave action, grazing, or mechanical disturbance. Large masses travel on the tides and currents like organic tumbleweeds, providing shelter and food for many small invertebrates and fishes, often where no other cover would be available. The drift algae of the Lemon Bay Aquatic Preserve are commonly the red algae, *Gracilaria* and *Laurencia* that seasonally peak in abundance and concentration from July to December.

The contribution of microalgae to estuarine productivity and the food chain is often overlooked because of their microscopic size and seasonality. Diatoms and armored flagellates, which comprise the major abundance and diversity of phytoplankton and benthic, epiphytic, and epifaunal microalgae, are essential to zooplankton, the larval life stages of crustaceans and fish species, and filter-feeding mollusks including clams and

oysters. Productivity of the phytoplankton community is seasonal, with different species assemblages resulting from changes in temperature, day length, water quality and clarity, nutrient balance, and grazing pressures. Imbalances in these factors result in algal blooms, including the notorious red tide. Although phytoplankton productivity is, on the average, only one sixth of the system-wide macrophytic production, this productivity is directly available, often at critical periods in consumer life cycles. In combination with bacteria and saprophytes, the epiphytic microflora mediates the productivity of mangroves, seagrass, and salt marsh plants by converting their detrital biomass to nutritive forms digestible by animals.

### *Mud Flats and Sandbars*

Regardless of their barren appearance, naturally occurring, undisturbed, unvegetated bottoms are rich in animal biomass and can display high diversities of invertebrates and fishes. The principal sand and mudflat community is buried beneath and within the unvegetated substrates. This includes a diverse assemblage of bivalve mollusks: hard shelled clams, angel wings, surf clams, razor clams, stout tagelus, donax clams, semele clams, macoma clams, tellins, Venus clams, cockels, lucines, and many others. Burrowing segmented worms, filter feeding segmented tube worms, burrowing flatworms, ribbon worms, burrowing crustaceans, brittle starfish, sand dollars, acorn worms, and lancelets filter feed, deposit feed, scavenge, and hunt within the unvegetated substrate. Numerous species of gastropods are also associated with seagrass and algal beds, living on and within sand and mudflats, often in amazing abundance, including Florida crown conchs, whelks, nassa mud snails, horse conchs, tulip conchs, moon snails, horn shells, and ceriths. Predatory, bottom-feeding fishes flourish in these areas of naturally diverse, often patchy bottom habitats. Many mobile invertebrates and fishes which avoid open, unvegetated areas during the day forage across these flats nocturnally.

The intertidal flats support abundant burrowing crab colonies that forage in coordination with tidal cycles. Wading and shore birds, including sandpipers, dowitchers, willets, plovers, egrets, herons, and ibis hunt the denizens of the flats by probing the substrates and snatching the exposed invertebrates.

Benthic microalgae are often present in more consolidated substrates providing a pale pink, green, brown, or black hue to surface sand/mud layers. The natural unvegetated bottom observed today is often the seagrass bed, algal bed, or oyster bar of tomorrow, given the proper conditions and freedom from disturbance. Frequently, when areas are observed in mid-winter, the vegetation component is not apparent. The same site examined in mid-summer can be a lush seagrass bed.

### *Oyster Bars*

The oyster bars and reefs of Charlotte Harbor are located in the lagoonal estuaries near the confluence of estuarine streams with the bay. The intertidal oyster reefs range in size from small scattered clumps to large mounds of living oysters atop dead shells. Reefs are limited to the middle intertidal zone, where minimum inundation time determines the maximum reef height. Predation and siltation limit oyster populations in the subtidal

zone to scattered individuals. During ebb tide exposure to the air, the living reefs are greenish-brown from a thin film of associated algae. In typical reefs the upper surface is level. Sides slope steeply at the edges, with the living portion of the reef thickest at the perimeter. Central areas tend to trap mud from sedimentation and biodeposition, which can smother the live oyster.

At least 50 species of macroinvertebrates are associated with oyster bars, including sponges, insects, barnacles, mud crabs, stone crabs, commensal crabs, clams, mussels, anemones, polychaetes, amphipods, and mollusks including oyster drills. Several bird species, many fishes, and an occasional raccoon hunt the oyster bars at appropriate tides for the reef dwellers and the oysters themselves. Many fish and swimming invertebrates take shelter in the rough topography of the reef to escape predators.

The filter feeding oysters, clams, mussels, sponges, and fan-worm polychaetes directly consume the plankton and suspended particulate material from the water column. In the process of concentrating biomass from this food source, filter feeders can also concentrate metals, red tide toxins, certain harvesting human pathogens, and exotic anthropogenic chemicals. For this reason shellfish harvesting is allowed only in areas with safe water quality. Most Charlotte Harbor oyster bars are in prohibited areas due to the pollution of the adjacent tributaries.

Oyster bars fill a major trophic role in the conversion of carbon and nutrients from phytoplankton and detritus to animal biomass available to higher order consumers, including blue crab, black drum, American oystercatchers, oyster drill, stone crab, and Herbst's mud crab. Concurrent with their metabolism, the oysters, their associated fauna, and aerobic bacteria mineralize organic carbon and release nitrogen and phosphorus in forms usable by primary producers such as phytoplankton, benthic algae, seagrasses, mangroves, and marsh grasses. Oyster reef communities have among the highest measured metabolic rate of any benthic community.

Oysters in reefs live close to their stress tolerance threshold. Further perturbation of conditions by man can easily destroy the entire reef community. Turbidity from dredging, man-made chemicals, heavy metals, artificial hydraulic changes, oxygen depletion by over nitrification, and sediment disturbance, all contribute to the continual loss of live oyster reefs in southwest Florida.

### *Mangroves*

The mangrove forests of south Florida are a vital component of the estuarine and marine environment, providing a major detrital base to organic food chains, significant habitat for arboreal, intertidal and subtidal organisms, nesting sites, cover and foraging grounds for birds, and habitat for some reptiles and mammals. The relationship between mangroves and their associated marine life cannot be overemphasized. The mangrove forest provides protected nursery areas for fishes, crustaceans, and shellfish that are important to both commercial and sport fisheries. The value and central role of mangroves in the ecology of south Florida has been well established by numerous scientific investigations directed at primary productivity, food web interactions, listed

species, and support of sport and commercial fisheries. Mangroves are important in recycling nutrients and maintaining the nutrient mass balance of the estuarine ecosystem. They are one of the most productive ecosystems in the world, in terms of primary or associated secondary biological productivity. Mangroves provide one of the basic food chain resources for arboreal life and nearshore marine life through their leaves, wood, roots, and detrital materials. This primary production forms a significant part of the base of the arboreal, estuarine, and marine food web. Mangroves have a significant ecological role as physical habitat and nursery grounds for a wide variety of marine/estuarine vertebrates and invertebrates. Many of these species have significant sport fishery and/or commercial fishery value. Approximately 554,515 acres (224,579 hectares) of mangroves remain in central and south Florida. This tropical ecosystem is a habitat unique in the continental United States. It deserves special protection because of this uniqueness and because of the multiple ecological functions it provides. Mangroves have a significant ecological role as habitat for endangered and threatened species, and many species of special concern. For several of these species, the habitat is critical and vital to their continued survival.

Mangroves also serve as storm buffers by functioning as wind breaks and by baffling wave action with prop roots. Mangrove roots stabilize shorelines and fine substrates, reducing turbidity, and enhancing water clarity. Mangroves improve water quality and clarity by filtering upland runoff and trapping waterborne sediments and debris. Unaltered mangroves contribute to the overall natural setting and visual aesthetics of Florida's estuarine waterbodies. Through a combination of the above functions, mangroves contribute significantly to the economy of the coastal counties of south Florida and the state as a whole.

Mangroves are tropical species restricted by frost and vegetative competition to intertidal regions in tropical and subtropical sheltered waterbodies. Mangroves in the subtropical regions of south Florida represent the northern limits of tropical species that have been able to colonize because of the warm ocean waters and warm currents along the Florida coastline and dependably warm winters (Tomlinson 1986). The distribution of mangroves in North America has changed through geologic time. When the red mangrove (*Rhizophora mangle*) evolved in the Cretaceous, Florida was a great coral reef in shallow seas. There may have been a few mangroves surrounding small islands and on the coastline in what is currently Georgia. In the Eocene, when black (*Avicennia germinans*) and white (*Laguncularia racemosa*) mangroves evolved, mangroves extended as far north as South Carolina. During the Pleistocene Ice Ages, mangroves were absent from the Florida coastline and *Spartina* marshes dominated the estuarine intertidal zones. During the past few centuries mangrove distribution has changed in response to short- and long-term climatic fluctuations.

Red and white mangroves have been reported as far north as Cedar Key on the west coast of Florida. Black mangroves occur further north than reds and whites and have been reported as far north as 30° N latitude on the east coast of Florida (Odum 1982). They are distributed as a shrub elsewhere around the Gulf of Mexico where vegetated shorelines have survived development. Over 90 percent of the mangroves in Florida occur in the four southern counties of Lee, Collier, Dade, and Monroe.

The availability of fresh water and nutrients influences the location, size, structure, and productivity of mangrove communities in south Florida. Mangroves reach their greatest abundance in southwest Florida where the positive interaction of fresh water and nutrient inputs with lower wave energy shorelines occurs. In southeast Florida, mangrove development has historically been limited by the lack of fresh water and nutrients combined with narrow intertidal zones and high wave energy. Along the central east coast (Indian River Lagoon) (IRLCCMP 1996) and parts of the west coast (Charlotte Harbor and Sarasota Bay), mangrove communities support the continued existence of barrier islands against tidal and wave forces (CHNEP CCMP 2008). The Everglades system changes from fresh water to an extensive mangrove community at its seaward margin of Florida Bay. Fluctuations in sea level rise along the Florida peninsula can limit the distribution of mangroves, particularly if the rate of sea level rise exceeds the rate of mangrove forest growth and substrate accretion, and if the landward slopes provide no suitable habitat for forest retreat as sea level rises (Wanless 1998). Areas with seawalls behind mangrove habitat prevent such shoreline adjustment. The local distribution of mangroves is affected primarily by a variety of interacting factors that include microclimate, substrate type, tidal fluctuation, terrestrial nutrients, wave energy, and salt water. Sea level rise, shore erosion, interspecific competition, and seed dispersal also affect local distribution to a lesser degree. The interrelations of these factors can alter the intertidal distribution of mangrove species. Mangroves are unique in that their morphological specialization, such as aerial roots, vivipary, and salt excretion or excluding abilities allows them to adapt to these different rigorous environmental factors.

Mangrove ecosystems are a mosaic of different types of forest, with each type providing different physical habitats, topology, niches, microclimates, and food sources for a diverse assemblage of animals. Mangroves have important structural properties including: the trapping and stabilization of intertidal sediments; the formation of organic soils and mucks; providing protection from wave and wind erosion; providing a dendritic vegetative reef surface in the subtidal and intertidal zones; and forming a structural complex of a multi-branched forest with a wide variety of surface habitats (Savage 1972).

Mangrove associates include up to 30 species of vascular plants occurring in transitional areas with mangroves, but are not restricted to mangrove communities. Several saltmarsh grasses (*Juncus*, *Sporobolus*, *Monanthachloe*, and *Distichlis*) and succulent herbs (*Salicornia*, *Sesuvium*, and *Batis*) occur with mangroves along transition zones of saline marshes. Smooth cordgrass (*Spartina alterniflora*) communities often colonize bare emergent areas near mangrove forests, but are eventually displaced by mangroves shading them.

Mangrove ecosystems are important habitat for at least 1,300 species of animals including 628 species of mammals, birds, reptiles, fish, and amphibians. They provide areas for breeding, nesting, foraging, and shelter (Odum *et al.* 1982, Beever 1989, Beever 1996, Day *et al.* 1989, Odum and McIvor 1990). The mangrove forest provides a multitude of habitats for resident, seasonal, and transient organisms from adjacent terrestrial and marine habitats. Many of the larger motile species are not restricted to mangroves, but are seasonal or opportunistic visitors. However, most invertebrate and

some resident vertebrate species are totally dependent upon mangroves to survive and complete important life cycle functions (Tomlinson 1986). Fish and invertebrates from the marine environment are frequent visitors to mangrove communities, as are birds and mammals from nearby terrestrial systems.

The prop roots of red mangroves support a specific microhabitat for resident species (*e.g.*, tunicates, crustaceans, mollusks, fishes) that spend their entire life cycle either on or among the root systems. Transient species are not dependent upon prop roots, but use them intermittently for shelter, feeding, and/or breeding. The prop root system also provides an important nursery for organisms (*e.g.*, crustaceans, mollusks, fishes) that develop here and spend their adult lives elsewhere (Odum and McIvor 1990).

Mangrove canopies provide habitat for some species of songbirds that occur only in this habitat type, such as the black-whiskered vireo (*Vireo altiloquus*), mangrove cuckoo (*Coccyzus minor*), yellow warbler (*Dendroica petechia*), and Florida prairie warbler (*D. discolor*). The black-whiskered vireo nests primarily in red mangroves up to 5 m (15 ft) above the ground. Considered a rare bird species by the Florida Committee on Rare and Endangered Plants and Animals (FCREPA), the mangrove cuckoo requires large expanses of undisturbed forested mangrove and hardwood hammock habitat found primarily in the southernmost parts of Florida, from Charlotte Harbor to the Florida Keys (Smith 1996). The mangrove cuckoo nests on horizontal branches of mature mangrove trees. The yellow and Florida prairie warblers nest 3 to 6 m (10 to 20 ft) high in mangroves.

In addition to these mangrove endemic species, many estuarine birds utilize fringing mangrove forest as loafing areas and foraging perches. Included in this group are osprey (*Pandion haliaetus*), northern harrier (*Circus cyaneus*), sharp-shinned hawk (*Accipiter striatus*), Cooper's hawk (*Accipiter cooperii*), red-shouldered hawk (*Buteo lineatus*), broad-winged hawk (*Buteo platypterus*), short-tailed hawk (*Buteo brachyurus*), red-tailed hawk (*Buteo jamaicensis*), American kestrel (*Falco sparverius*), peregrine falcon (*Falco peregrinus tundrius*), bald eagle (*Haliaeetus leucocephalus*), merlin (*Falco columbarius*), kingfisher (*Megaceryle alcyon*), eastern brown pelican (*Pelecanus occidentalis*), double-crested cormorant (*Phalacrocorax auritus*), anhinga (*Anhinga anhinga*), and a variety of wading birds. As loafing areas, this habitat provides resting areas near their food supplies. This allows the use of foraging habitat distant from nighttime roosts or nesting areas without the added energy cost of flight. For other species in this group, the height of the mangroves offers a better view of prey. This area is also an important foraging area during periods of low water because organisms become concentrated in small pools of water, making it easy for predators to capture prey. Juvenile endangered wood storks (*Mycteria americana*) are especially dependent on these conditions.

Twenty-four taxa of reptiles utilize the aquatic and arboreal habitats of the mangroves. Resident species include the mangrove water snake (*Nerodia fasciata compressicauda*), the threatened Atlantic salt marsh snake (*Nerodia fasciata taeniata*), rough green snake (*Ophedryx aestivus*), the threatened eastern indigo snake (*Drymarchon corais couperi*), yellow rat snake (*Elaphe obsoleta quadrivittata*), green anole (*Anolis carolinensis*), mangrove terrapin (*Malaclemys terrapin rhizophorarum*), American alligator (*Alligator*

*mississippiensis*), and the endangered American crocodile (*Crocodylus acutus*). The threatened loggerhead sea turtle (*Caretta caretta*) and the endangered green sea turtle (*Chelonia mydas*) are found in association with mangrove-lined shorelines along tidal passes and within estuarine embayments.

Five amphibian species utilize the mangrove habitat for feeding and/or breeding. The most frequently encountered and abundant amphibians are treefrogs (*Hyla* spp.) and, unfortunately, the exotic marine toad (*Bufo marinus*). No state listed amphibians are found in mangrove habitats. The amphibian life cycle is poorly adapted to the saline environment required by mangroves.

The value of the red mangrove as the basis of the detrital food chain of estuarine waters is well documented (Odum *et al.* 1982, Seaman 1985, Hutchings and Saenger 1987). It is recognized that over 90 percent of commercial fishery species and at least 70 percent of sport fishery species depend upon the natural mangrove forest for food and habitat as a critical part of their life cycles (Lewis *et al.* 1985). In concert with seagrass beds, macrophytic algae, phytoplankton, benthic microalgae, and emergent marshes, the mangroves provide the primary productive food base of the estuarine system. The detritus provided by decomposition of seasonally shed mangrove leaves is the food base for microcrustaceans and other detrital processors that are consumed by macrocrustaceans, small fishes, and other first order predators. These animals, in turn, are the prey of larger fish species such as snooks (*Centropomus* spp.), snappers (*Lutjanus* spp.), jacks (*Caranx* spp.), tarpon (*Megalops atlantica*), sheepshead (*Archosargus probatocephalus*), spotted seatrout (*Cynoscion nebulosus*), and redfish (*Sciaenops ocellatus*). Based on surveys performed during the preparation of the Charlotte Harbor Aquatic Preserve Management Plan, at least 230 species of fish utilize the mangrove ecosystem of Charlotte Harbor for food, shelter, breeding and/or nursery grounds (Beever 1988).

The dominant fish species of the basin mangrove forests are poeciliids, mosquitofish (*Gambusia* spp.), the least killifish (*Heterandria formosa*), and the sailfin molly (*Mollienesia latipinna*). These cyprinodont fish are a fundamental link between primary producers and higher trophic level fish and wildlife species. The typical cyprinodont diet consists of plant and animal tissue, including periphyton, insect larvae, and vascular plant detritus. They subsequently are food for sport fish and wading bird species. Fourteen of the 54 freshwater fish species found in south Florida (Kushlan and Lodge 1974) utilize the mangrove wetlands during the wet season, high-runoff flow events (Odum *et al.* 1982).

Most of the 350 species of marine invertebrates in Charlotte Harbor are found in or depend on mangroves for habitat or food. The arboreal canopy provides habitat to both aquatic and amphibious resident and transient species (Simberloff and Wilson 1969, Beever *et al.* 1979, Odum and McIvor 1990). Approximately 264 species of arboreal arthropods inhabit the mangrove canopy, branches, and wood (Beever *et al.* 1979). Aquatic organisms, such as crabs and snails, spend part of their time in the water, but can also migrate up into the canopy of mangroves.

The mangrove tree crab (*Aratus pisonii*) is found only in estuarine areas from the Indian River Lagoon and Tampa Bay south to the Florida Keys (Gore1994a). This species is restricted to mangroves for its adult life cycle, especially red mangroves. It is one of the few crabs that also use the arboreal canopy and can climb to the uppermost branches which it forages upon (Beever *et al.* 1979). The mangrove crab (*Goniopsis cruentata*) is restricted to mangrove forests in central and southern Florida mangrove areas (Gore1994b).

Landward from the shoreline, the mangrove forest intermixes with saltmarsh species and provides habitat to organisms that can withstand changing water levels. As water levels change with daily tides and seasonal influences, the organisms here migrate to adjacent permanent aquatic habitats.

Further inland, the mangrove forest mixes with tropical hardwood hammock species. Organisms rely on the arboreal and terrestrial components of this transition community. Commonly associated hardwood species include cabbage palms (*Sabal palmetto*), Jamaica dogwood (*Piscidia piscipula*), West Indian mahogany (*Swietenia mahogani*), stopper (*Myrtus verrucosa*), poisonwood (*Metopium toxiferum*), black bead (*Pithecellobium keyense*), and gumbo limbo (*Bursera simaruba*) (Schomer and Drew 1982). The transition between these two adjacent communities provides an important ecotone, where species can take advantage of resources from both communities. Mammals and reptiles move from the hardwood forests to feed in the mangrove community.

### *Salt Marshes*

The salt marsh community of southwest Florida is perhaps one of the most unique and rare salt marsh systems in the United States. The mild subtropical climate of Florida supports a combination of temperate salt marsh vegetation and tropical mangroves that intermix to form an important transitional ecotone between land and sea. The salt marsh offers numerous ecosystem services including recreational, commercial, and aesthetic values to man. It provides the foundation of life to a variety of resident and transient organisms, especially the six federally-listed and 23 state-listed animal species found there. Although almost 66 percent of the remaining salt marsh habitat is protected in southwest Florida, this habitat continues to be lost to human-induced impacts such as dredge and fill operations, alterations of hydrology, and pollution.

Over 50 percent of the salt marsh habitat adjoining the Charlotte Harbor system has been destroyed since 1945 (Charlotte Harbor NEP 1995). Recent mapping of the CHNEP watershed found approximately 2,463 miles of coastal shoreline encompassing approximately 220,000 acres from the Dona and Roberts Bays in Sarasota County to southern Estero Bay in Lee County. Within this area, there are 9,218 acres of salt marsh (CHNEP 2008). Currently, over 41 percent or 1,020 miles of coastal wetland shorelines have been lost or significantly altered in the CHNEP watershed. The most significant coastal wetland losses have been on estuarine rivers and creeks and on barrier islands and include substantial losses of salt marsh.

Mangroves primarily dominate the CHNEP open tidal shoreline, although there are patches of transitional salt marsh habitat. Within these zones, dominant species include cordgrass (*Spartina spp.*), saltgrass (*Distichlis spp.*), glasswort (*Salicornia spp.*), and sea purslane (*Sesuvium spp.*) (Drew and Schomer 1984). Monotypic stands of black needlerush (*Juncus roemerianus*) are more common in slightly elevated areas with lower tidal inundation. Cordgrass and needlerush dominate salt marsh communities around the mouths of rivers (e.g., Myakka and Peace Rivers). The interior wetland habitat of Sanibel Island has expanses of salt marsh dominated by Baker's cordgrass (*Spartina bakerii*) and leather fern (*Acrostichum spp.*).

Salt marshes in Charlotte Harbor Estuary have been destroyed or directly impacted by construction activities for residential and commercial purposes including seawalls, drainage ditches for agriculture and mosquito control, boat facilities, and navigation channels. Man-made hydrological alterations have reduced the amount of freshwater flow from some rivers (e.g., Peace River), while artificially increasing the flow through others (e.g., Caloosahatchee). Approximately 400 linear miles of man-made canals were built in the 1950s to 1970s, resulting in a significant loss of salt marsh habitat (Charlotte Harbor SWIM 1993). The interior salt marshes of Sanibel Island were heavily altered from human construction activities, hydrologic changes, and exotic vegetation invasion (Clark 1976).

Limited data are available for determining the long-term trends in the areal extent of salt marshes. All existing estimates lump the five types of southwest Florida salt marsh into a single unified number. It is estimated that Florida contained approximately 399,152 acres (163,652 ha) of salt marsh coverage prior to European colonization (Cox et al. 1994). Since that time, an estimated 111,940 acres (45,895 ha) or 28 percent of salt marsh habitat has been lost (Kautz et al. 1993). Of the current 287,212 acres (117,757 ha) of salt marsh habitat in Florida, over 66 percent, or 189,597 acres (77,735 ha), are located in existing conservation areas (Kautz et al. 1993, Cox et al. 1994). Twenty percent of all Florida saltmarsh is found in south Florida (Montague and Wiegert 1990), including the CHNEP study area.

Southwest Florida salt marshes were not significantly modified by human activities until the early 20th century when many areas were permanently altered to accommodate the speculative real estate development that led to a rapidly growing human population. The common practice of constructing bulkheads and filling salt marsh areas for residential and commercial development destroyed many salt marshes and also altered the natural hydrology. As a result, many salt marsh communities experienced changes in water and soil salinities, water levels, and tidal flushing regimes. Contaminants and pollutants have also been introduced into salt marshes. Exotics are conveyed by a variety of means, including water transport, birds, illegal dumping of vegetation and land clearing. Many exotics initially colonize along roadways or similarly cleared areas. Disturbed or denuded areas are often invaded by exotics such as Australian pine (*Casuarina equisetifolia*) and Brazilian pepper (*Schinus terebinthifolius*) before native salt marsh seedlings can establish themselves.

Unregulated dredging and filling occurred in southwest Florida until the early 1970s when Federal and state governmental policies were implemented to minimize impacts on

salt marshes. Current Federal and state regulations normally require some degree of mitigation to offset the alterations or losses of wetland habitat; however, salt marsh habitat continues to be destroyed or altered today as coastal development continues in South Florida.

Efforts to control mosquitoes in southwest Florida began in the early 1930s with the use of ditching, impoundments, and pesticide spraying (Montague and Wiegert 1990, David 1992). Salt marsh plants were killed from the semi-permanent flooding and salinity changes caused by impoundments. Management efforts to control the population of mosquitoes continue today, although substantial progress has been made to minimize negative impacts on salt marshes.

Natural disturbances on salt marshes include fires, storms and hurricanes, drought, and floods. These events usually have a short-term, localized effect on salt marsh habitat and the community is generally able to recover fairly quickly. However, when these disturbances occur closely together, or are coupled with human-induced impacts, the effects can be catastrophic to the salt marsh community. Fires usually do not permanently affect salt marshes but may temporarily affect soil composition, species composition and biomass (Schmalzer et al. 1991, Schmalzer and Hinkle 1992). Most salt marshes are affected by the storm surge more than the flooding or strong winds caused by tropical storms. One of the most significant impacts to salt marshes from hurricanes is the potential for rapid invasion of exotic vegetation into disturbed areas.

### *Creek Wetlands*

The low tidal creek reaches display a mixture of mangrove and saltmarsh vegetation. Further upstream the less saline mixture of upland watershed drainage with bay waters provides a euryhaline zone which can support up to 29 species of halophytic plants. In this ecotone between mangroves/salt marsh and the freshwater wetlands, the dominant plant species change in response to seasonal variations in salinity, water volume, air and water temperature, nutrient loading, and grazing pressures. Diversion of fresh water by unnatural water control projects and activities shifts plant species composition in favor of more salt tolerant plants.

The gross productivity of riverine wetlands increases when surface freshwater input increases, however net production decreases because of osmoregulatory stress: thus productivity is optimal at medial salinity. In these moderate to low salinity waters, a wide variety of plant communities can develop, depending on sediment, elevation, and season.

Widgeon grass, a submerged grass tolerant of wide salinity changes, vegetates sandy shallow channels, providing habitat for fishes and invertebrates in similar fashion to seagrasses. Creek banks support a variety of emergents, including three-squares (*Scirpus spp.*), bulrushes (*Scirpus spp.*), fringerushes (*Fimbristylis spp.*), *Juncus* rushes, spikerushes (*Eleocharis spp.*), cattails (*Typha spp.*), giant reed (*Arundo donax*), leather fern, saltgrass, knotgrass (*Paspalum distichum*), cordgrasses, asters (*Aster spp.*), pinks (*Sabatia spp.*), coast water hyssop (*Bacopa spp.*), and many of the salt marsh herbs.

The health of the estuary depends upon the health of its tributaries. If the riverine wetlands are destroyed, the creeks channelized, and the water quality degraded in the watershed external of the below the tide boundaries of water bodies, it will not be possible for those water bodies to retain fishery and wildlife habitat values.

### *Coastal Strand*

A narrow band of coastal strand habitat is located between areas of fringing red mangrove forest and immediately adjacent natural grade uplands or spoil-created uplands. The coastal strand community is a combination of tropical and temperate flora that display a level of salt tolerance, such as sea grape (*Coccoloba uvifera*), grey nicker (*Caesalpinia bonduc*), buttonwood (*Conocarpus erectus*), and strangler fig (*Ficus aurea*). These species benefit from the temperature-regulating influence of adjacent estuarine waters. The historic extent of the coastal stand has been abbreviated by the past placement of fill for development in areas of coastal strand and wetlands, including salt marsh, high marsh, and mangrove. This is the area that probably also had southern red cedar (*Juniperus silicicola*) historically. Coastal strand is an important habitat for listed plant species, neotropical migratory birds, butterfly species, and wide-ranging animals such as river otter and raccoon that use the habitat during seasonal food abundance.

### *Pine Flatwoods*

South Florida slash pine is the dominant tree of the pine flatwoods canopy of southwest Florida. The South Florida slash pine is more flood- and drought-tolerant than is the North Florida slash pine. Squillace (1966) concluded that the phenotypic plasticity that allows the South Florida slash pine to accommodate both upland and wetland conditions, fire, and flood, is the result of its evolution under the severe environmental factors of south Florida floods and droughts that vary from year to year and fluctuate widely over longer time courses.

While tree densities in pine flatwoods are typically sparse, with canopy coverage typically ranging from 10 to 25%, pines are abundant enough to dominate the apparent landscape view and canopy, but are not close enough to touch each other. Ground cover receives nearly full sunlight (Wade et al. 1980). Mature south Florida slash pine can attain a height of 110 feet, with a diameter at breast height (dbh) of 16 inches (Duever et al. 1976). Mature trees typically attained 10 to 12 inches dbh with 60 to 75 feet of height. Growing season is from February to November, with maximum growth rates attained at the spring and autumnal equinoxes (Langdon 1963).

The type of south Florida pine flatwoods varies with hydrology, elevation, and topography. Xeric pine flatwoods have approximately three feet of well-drained, dry soil above the typical groundwater level, and the water table only attains the surface during unusual precipitation events such as hurricanes. The xeric pine flatwoods have an open understory with bunchgrasses and wiregrass, short clumps of saw palmetto (*Serenoa repens*), and xeric shrub species such as fetterbush (*Leucothoe racemosa*), tarflower

(*Bejaria racemosa*), rusty lyonia (*Lyonia ferruginea*), pennyroyal (*Piloblephis rigida*), pawpaws (*Asimina spp.*), and prickly pear cactus (*Opuntia spp.*).

Mesic pine flatwoods are less well-drained and are infrequently and briefly inundated by water only during extremely high levels of precipitation during the rainy season. The mesic pine flatwoods have a relatively closed understory dominated by medium height to tall saw palmetto and occasional shrubs such as wax myrtle (*Myrica cerifera*), fetterbush, pawpaw, cabbage palms, and winged sumac (*Rhus copallinum*).

In contrast, water stands on the surface, inundating hydric pine flatwoods for one or more months per year during the rainy season. The naturally occurring hydric pine flatwoods have standing water for at least one month (30 days) of the year. The hydric pine flatwoods habitat becomes saturated and attains standing water in the middle wet season. The hydric pine flatwoods habitat is dominated by a slash pine upperstory with a wetland plant understory. The wetland understory of hydric pine flatwoods is a combination of freshwater slough, freshwater seasonal pond, and high marsh vegetative components. Mid-story plants of hydric pine flatwoods include cabbage palm, wax myrtle, strangler fig, Brazilian pepper, red maple (*Acer rubrum*), dahoon holly (*Ilex cassine*), and buttonbush (*Cephalanthus occidentalis*). The hydric pine flatwoods of southwest Florida is a distinct habitat in dynamic equilibrium between drought and flood that is regularly and predictably perturbed by fire and water (Beever and Dryden 1992).

Nearly all plants and animals of the pine flatwoods are adapted to periodic fires (FNAI 1989). South Florida slash pine is extremely fire tolerant (Ketcham and Bethune 1963). South Florida slash pine seedlings have a grass stage that greatly increases their resistance to fire damage. Fire stimulates slash pine seedlings to sprout, promoting their growth as pioneers of burned land. The herbaceous plant community of the pine flatwoods survives fire by seeding and resprouting from root stock. In natural pine flatwoods communities, the dried herbaceous growth of several prior growing seasons forms the principal fuel for natural fires.

In pre-Columbian times, fires probably occurred in the xeric pine flatwoods every five to seven years, mesic pine flatwoods every two to five years, and hydric pine flatwoods every three to 10 years. While natural fires were numerous, the areal extent of any given fire was probably small (25 acres or less). Most natural fires occurred at the end of the dry season. This pattern of patch fires creates a mosaic of plant and habitat diversity, as opposed to a monopyric, even-aged plant community.

Much of the variation in community structure within a pine flatwoods is probably associated with fire frequency. The longer the period since the last fire, the more developed the understory shrub layer. If the understory is allowed to grow too long without fire, the accumulated needle bed and the height of flammable understory shrubs increases the probability of catastrophic canopy fires (FNAI 1989). If fires are very frequent, slash pine seedling regeneration will not occur, and the pine flatwoods will tend to be dominated by an herbaceous understory with clusters of cabbage palms forming a cabbage palm prairie (Wade et al. 1980).

Less fire tolerant plant community components have refugia in deep water found in hydric pineland. With overdrainage, fire refugia are lost. This typically results in decreases in the midstory, tropical components of south Florida pine flatwoods with subsequent losses in plant species diversity. If overdrainage is coupled with too-frequent fire, and a melaleuca (*Melaleuca quinquenervia*) seed source is nearby, the pine flatwoods will become dominated by melaleuca monocultures (Wade et al. 1980).

Without regular fires, the pine flatwoods can be expected to succeed into shrub-dominated forests with a closed canopy, eliminating groundcover herbs and shrubs (Alexander 1967, FNAI 1989). After approximately six to 10 years of fire absence, perennial plants that are normally set back by fire attain larger sizes. An increased ground cover results from the presence of fewer, but larger, individual plants. These individual plants are subsequently shaded out by other plant species that would normally be killed by fire. This results in an increase in cover, but a decrease in plant species diversity. In general, fire exclusion from pine flatwoods results in species loss; decreased forage quantity and quality for herbivorous species, and subsequently for their predators; increased danger from wildfires; and decreased pine regeneration (Wade et al. 1980).

Pine flatwoods are an important habitat for a number of vertebrate species, including the pine woods tree frog (*Hyla femoralis*), oak toad (*Bufo quercicus*), box turtle (*Terrapene carolina bauri*), eastern diamondback rattlesnake (*Crotalus adamanteus*), black racer (*Coluber constrictor priapus*), brown-headed nuthatch (*Sitta pusilla*), Bachman's sparrow (*Aimophila aestivalis*), pine warbler (*Vermivora bachmanii*), great horned owl (*Bubo virginianus*), least shrew (*Cryptotis parva*), cotton mouse (*Peromyscus gossypinus*), cotton rat (*Sigmodon hispidus*), and gray fox (*Urocyon cinereoargenteus*) (Layne 1974). Burning to increase habitat value for wildlife is a well-established practice in pine flatwoods. It has been documented to increase habitat values and wildlife habitat (Komarek 1963, Stoddard 1963, Lewis 1964, Moore 1972, Hughs 1975). Different burn regimes favor different wildlife species. For example, quail (*Colinus virginianus*) are favored by 2-year rotational burns (Moore 1972) and turkeys (*Meleagris gallopavo*) are favored by 3- to 4-year cycles (Stoddard 1963). A diverse pattern of burning, similar to the natural burn conditions for pine flatwoods, can produce the highest species diversity, but fire is often suppressed due to proximity of pine flatwoods to development.

### *Xeric Oak Scrub*

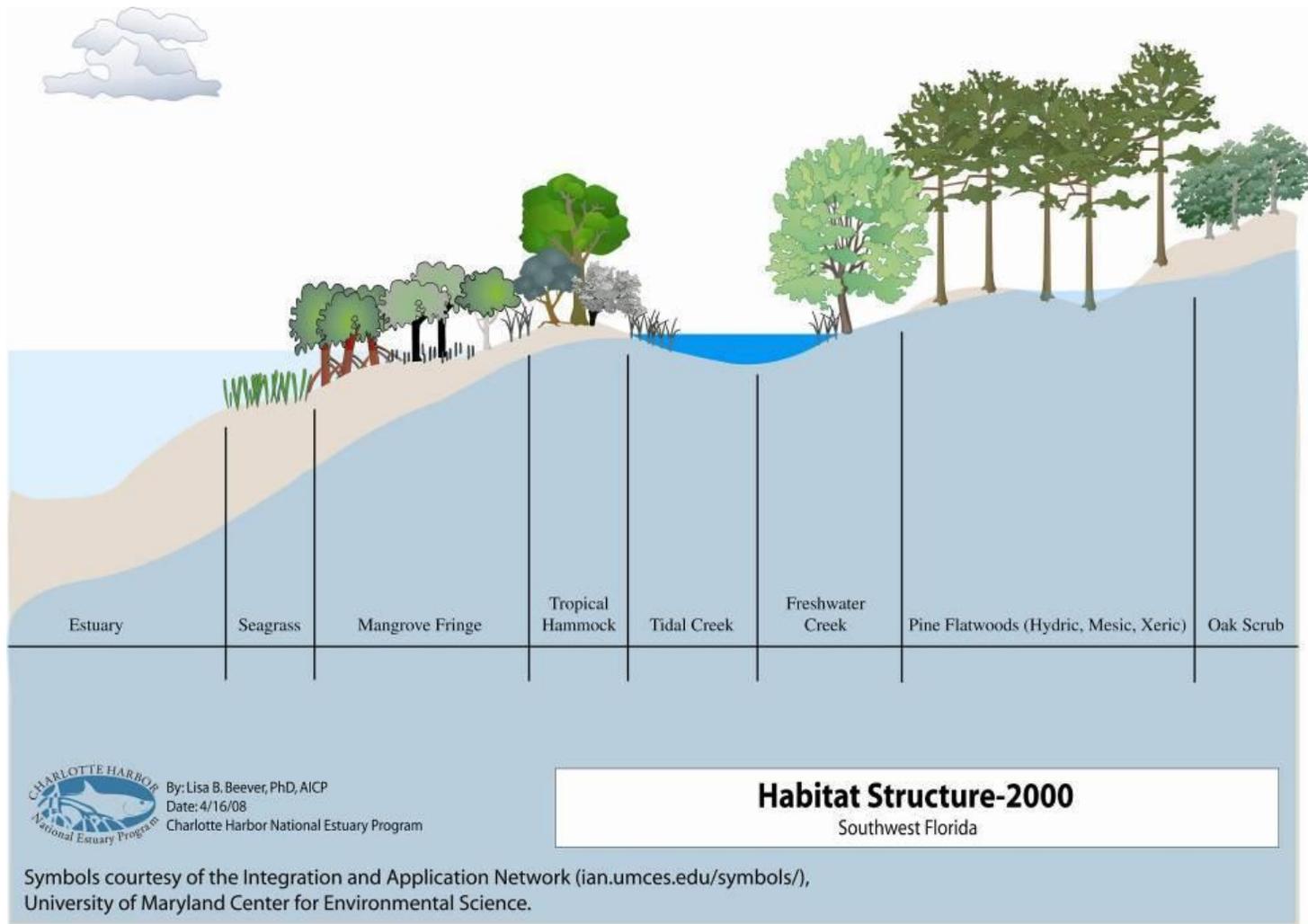
Scrub communities drain rapidly because of their soils. Their typically higher elevation and soil type are suited for development. As such, they are the most endangered of Florida's native upland communities. Scrub communities are ranked by the Florida Natural Areas Inventory (FNAI 1989) as G2 and S2. The G2 designation indicates global imperilment while the S2 designation indicates statewide imperilment. The oak scrub system is a unique habitat of special value to listed species. Scrub habitats contain many uniquely Florida species, including Florida scrub jay (*Aphelocoma coerulescens*), gopher frog (*Rana capito*), Florida mouse (*Podomys floridanus*), invertebrates commensal with gopher tortoise (*Gopherus polyphemus*) burrows, and many endemic plant species.

The scrub habitat of southwest Florida tends to be a coastal or riverine scrub (Mulvania 1931) with a canopy dominated by scrub live oak (*Quercus inopina*) and a midstory of xeric shrubs and shorter oaks. The open understory is vegetated with dwarf saw palmetto, wiregrasses, and a sparse herbaceous groundcover. Most of the oldest developed areas of southwest Florida located adjacent to the creeks and rivers were historically oak scrub or an oak scrub flatwoods mixture.

### **Coastal Zonation**

The standard zonation of Charlotte Harbor and southwest Florida consists of red mangroves in the lower and middle intertidal zone, black mangroves in the upper intertidal areas that are occasionally flooded and white mangroves in patches on higher elevations that is less frequently flooded. Buttonwoods are located further inland in areas that are within the limits of the highest tides (Tomlinson 1986).

Mangrove forests are different than other vegetative communities in that there is an absence of traditional plant succession. Instead, mangrove communities experience replacement succession primarily as a function of sea level rise, where mangroves must either keep up with the rise in sea level or retreat from rising water levels. On shorter time scales, the mangrove community can experience fluctuations in habitat type and species composition as a result of changes in such factors as hydrologic patterns. A typical zonation with adjacent uplands is shown in Figure 44:



**Figure 44: Typical coastal habitat zonation for Charlotte Harbor, Year 2000**

## Potential Future Climate Changes

Climate-related changes in freshwater runoff to coastal marine systems, coupled with changes in stratification (or layering) patterns linked to warming and altered salinity, will change the quantity and availability of nutrients in estuarine systems (Boyd and Doney 2002). Changes in the absolute and relative availability of nutrients will lead to changes in microscopic plants (phytoplankton) and microbial activity in the marine food web (Arrigo 2005). Induced changes may result in food webs that are less efficient in transferring energy to higher levels, thus affecting the productivity of economically important fish and other plant and animal life (Arrigo 2005).

Increased runoff in some areas, coupled with human population increases in Florida, will lead to the increased transport of nutrients to coastal waters, contributing to hypoxia (IPPC 2007b) and leading to adverse impacts on bottom-feeding fish and sessile (attached to the bottom) organisms (IPPC 2007b). Locations that have experienced hypoxia may experience longer hypoxic episodes or more frequent recurrence of hypoxia (Osterman et al. 2007). Increased density stratification within estuaries could also occur with increased precipitation and runoff. New locations with hypoxia may develop in coastal areas where they previously have not appeared (Osterman et al. 2007).

As sea-surface temperatures continue to rise, die-offs of marine fauna incapable of moving to cooler water are likely to become more frequent. Other factors, such as low levels of dissolved oxygen, the addition of nutrients and other land-based sources of pollution, and harmful algal blooms, will exacerbate these die-offs. The conditions that have contributed to fish diseases and various die-offs in the Florida Keys may move to more northern latitudes. As sea-surface temperatures continue to increase, the impacts may begin to affect more northerly coastal and marine environments that have thus far escaped these problems (FOCC 2009).

Marine thermal stratification will change dissolved oxygen levels at different water depths. This will result in changes to zonation for animal and plant life and increase the probability of fish and other marine life kills (Coastal States Organization Climate Change Work Group 2007; Holman 2008; FOCC 2009; USEPA CRE 2008)

The range of potential impacts on species and ecosystems include the following:

### *Corals and Calcifying Organisms*

Increased atmospheric concentrations of carbon dioxide are expected to contribute to increased acidity (lower pH) of sea water. Marine organisms with calcium carbonate shells or skeletons, such as corals, clams, and plankton at the base of the food chain may be adversely affected by decreases in pH and carbonate saturation state (IPPC 2007b; Bates 2007). A higher carbonate saturation state favors the precipitation of calcium carbonate, a mineral, while a lower state supports its dissolution into the water. Carbonate-depositing organisms will have to expend more energy to maintain shell

construction and structural integrity in a lower pH environment (Peterson et al. 2007; SCCP 2008; FOCC 2009; USEPA CRE 2008).

With decreases in the pH of seawater, some marine plants may show increases in production until a particular threshold is met, and then will show a decline (FOCC 2009). Some marine organisms will not be able to tolerate decreases in pH (FOCC 2009). It is probable that the die-offs of sponges, seagrasses, and other important components of coastal and marine ecosystems from increased sea surface temperatures will become more frequent (FOCC 2009; USEPA CRE 2008). Ocean acidification may lead to shifts in marine ecosystem structure and dynamics that can alter the biological production and export from the ocean surface of organic carbon and calcium carbonate (Royal Society 2005). Important fisheries habitats, such as coral reefs, will markedly decline or disappear (Kleypas et al. 2006; Ishimatsu et al. 2005).

The thermal tolerance limits of some coral species will be surpassed. The rates of sea-surface temperature change predicted by global climate models suggest that coral bleaching events will be more frequent and severe in the future (Wilkinson and Souther 2008; FOCC 2009; Ramsar 2002; USEPA CRE 2008). Current predictions of future coral bleaching events indicate that certain coral species will not be able to adapt to warmer water (Wilkinson and Souther 2008). Coral reef community structure will shift towards coral species with a higher tolerance of changing conditions, resulting in major shifts in coral reef communities and a decrease of biodiversity (FOCC 2009).

The geographic range of marine species, including corals, will shift northward as sea-surface temperatures continue to rise. The species composition of Florida's native marine and estuarine communities will change, perhaps drastically. With further rises in water and atmospheric temperatures, conditions will probably become more favorable for certain exotic plant and animal species to invade Florida's coastal waters (FOCC 2009). Some native species may be able to survive farther north than in current ranges, but interactions among communities with new species compositions cannot be predicted. Moreover, reproduction in some fishes decreases in warmer temperatures, potentially resulting in population decreases (Straile and Stenseth 2007).

Increased numbers and altered ranges of jellyfish are also expected with some invasion of exotic jellyfish species, and with increased predation on local prey species. Some highly vulnerable prey species may be significantly affected (Perry and Yeager 2006; FOCC 2009; USEPA CRE 2008).

### *Seagrass*

Sea level rise is expected to cause migration of seagrass beds landward with subsequent depletion of existing beds at the deeper waterward edges due to less penetration of sunlight. This coupled with increased turbidity from erosion and breakup of coastlines, increased storm season runoff, and human activities will likely lead to die-off at deeper edges. Where natural shoreline exists, seagrass beds are expected to migrate into appropriate depths. Where opportunities for landward migration of the shallow subtidal zone is blocked by human bulkheads or other barriers, the seagrass beds will be reduced

and then disappear if the water depths at the sea wall barriers exceeds the light extinction coefficient for the seagrasses (USCCSP 2008; USEPA CRE 2008).

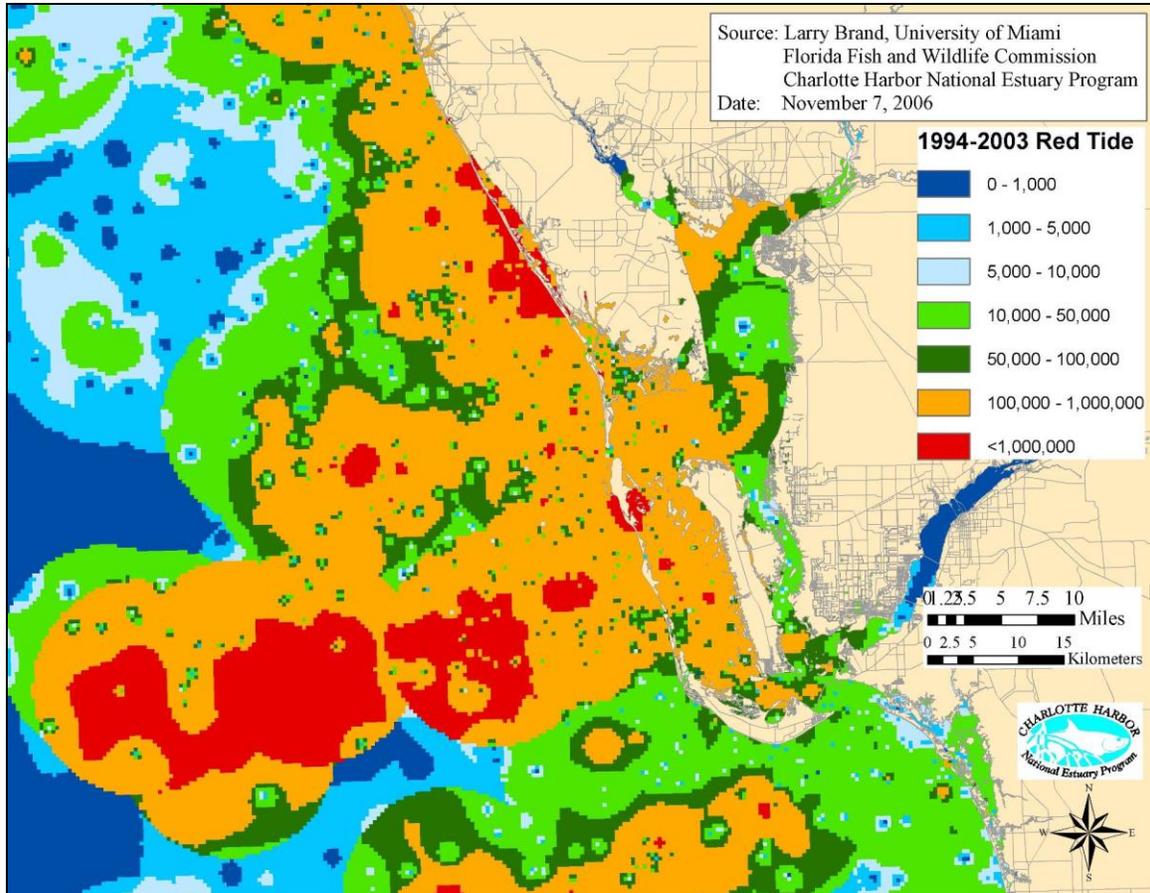
### *Algae*

Harmful blooms are caused by microscopic algae in the water column that can produce biological toxins, such as those generated by red tide in coastal marine waters, blue-green algae in estuarine waters., Larger species of marine and estuarine algae that grow on the bottom can smother corals and other native plants and animals. Environmental factors, including light, temperature, and nutrient availability, set the upper limit to the buildup of biomass in marine algae (Smyda 1997). The algae that cause harmful blooms in coastal marine and estuarine waters are favored over other algal species when water temperature is high and becomes thermally stratified (Paerl and Huisman 2008, Peperzak 2005, Van Dolah 2000; FOCC 2009; Twilley et al.1991; Coastal States Organization Climate Change Work Group 2007; Holman 2008; USEPA Office of Policy, Planning and Evaluation 1997; USEPA CRE 2008). The increased occurrence, intensity, and toxicity of harmful algal blooms may result in the disruption of coastal marine and estuarine food webs, more frequent fish kills, and adverse impacts to people in or near an affected coastal area (Smyda 1997; Paerl and Huisman 2008; Van Dolah 2000). Harmful algal blooms have been reported throughout Florida’s coastal marine and estuarine waters (Carder and Steward 1985).



**Photograph 3: Caloosahatchee River Algae Bloom resulting from Lake Okeechobee flow management.**  
*Source: J. Cassani 2006*

If climate change systematically increases nutrient availability and this alters the amount of available light and the stability of the water column, there may be substantive changes in the productivity, composition, and biomass of marine algae, including harmful species (Smetacek and Cloern 2008).



**Figure 45: Intensity and location of red tides in Charlotte Harbor and nearshore areas 1994-2003. Source indicated on key.**

### *Coastal Wetlands*

Although southwest Florida tide ranges are relatively small, tidal effects extend far inland because much of the state is so low in relative elevation and flat in topography. Because sea level change has been relatively constant and slow for a long time, tidal wetlands such as mangrove forests and salt marshes have been able to grow into expansive habitats for estuarine and marine life. However, these tidal wetlands are sensitive to the rate of sea level rise and can perish if that rate exceeds their capacity to adapt. With rising sea levels, sandbars and shoals, estuarine beaches, salt flats, and coastal forests will be altered, and changes in freshwater inflow from tidal rivers will affect salinity regimes in estuaries as well as patterns of animal use. Major redistributions of mainland and barrier island sediments may have compensatory or larger benefits for wetland, seagrass, or fish and wildlife communities, but these processes cannot be forecast with existing models.

Sea level change is an important long-term influence on all mangroves and salt marshes (Gilman et al. 2008). Based on available evidence, of all the climate change outcomes, relative sea level rise may be the greatest threat to mangroves. Most mangrove sediment surface elevations are not keeping pace with sea level rise, although longer term studies from a larger number of regions are needed. Rising sea level will have the greatest impact on mangroves experiencing net lowering in sediment elevation, where there is limited area for landward migration.

Depending on the rate and extent of local sea level change, mangrove and salt marsh systems will respond differently (Titus 1987, Wanless et al.1994). If rates of sea level rise are slow, some mangrove salt marsh vegetation will migrate upward and inland and grow without much change in composition. If rates are too high, the salt marsh may be overgrown by other species, particularly mangroves, or converted to open bodies of water. If there is no accretion of inorganic sediment or peat, the seaward portions of the salt marsh become flooded so that marsh grass drowns and marsh soils erode; portions of the high marsh become low marsh; and adjacent upland areas are flooded at spring tide, becoming high marsh.

Don Cahoon of the USGS has stated that if wetland plant communities are unable to keep vertical pace with sea level rise they will likely to also be unable to keep pace with lateral migration upslope. This can occur because on some soil types when saltwater inundates formerly unsubmerged uplands, sulfate reduction reactions can cause the land to sink up to six inches in micro-tidal areas that then shift from nontidal wetlands directly to open subtidal waters. (Titus 2009). This would be mediated by fetch and wave action as well as the emergent vegetation that is present, since both red mangroves and cordgrass can colonize low energy intertidal zones.

Extirpation of cooler water temperate fishes that seasonally visit the Charlotte Harbor estuaries and alteration of reproductive rates and maturation in invertebrate species leading to declining populations can be expected from increases in global surface water temperatures (USEPA CRE 2008; Rubinoff et al. 2008; Holman 2008; USNOAA 2008).

There will be changes associated with inundation of coastal wetlands and marshes including altered tidal ranges, tidal asymmetry leading to changes in tidal mixing, changes in sediment transport, migration of estuarine salinity gradients inland, migration inland of marsh species zonation, altered diversity of foundation dominant plant species, structural and functional habitat changes, and less sunlight available to submerged marsh plants (USEPA CRE 2008;USNOAA 2008; Titus 1998; Bollman 2007; Volk 2008a).

Higher maximum temperatures, with more hot days and heat waves over nearly all land areas will negatively affect wetlands and freshwater bodies. Fish and wildlife will experience increased heat stress, with increased mortality. Many invasive tropical species are likely to extend their ranges northward. Native plants and animals, already stressed and greatly reduced in their ranges, could be put at further risk by warmer temperatures and reduced availability of freshwater (Twilley et al.2001; USEPA CRE 2008).

Changes in precipitation will affect different wetlands differently with regional increases or decreases depending on the type and landscape position. Local extirpations of fish, amphibians, or water-dispersed plants are expected due to drought conditions that isolate and dry down tributaries and connected wetlands (USEPA CRE 2008; Holman 2008; FOCC 2009).

As rising sea temperatures causes a 5 to 10% increase in hurricane wind speeds, storm events will result in increased beach erosion and losses of mangroves, marshes, and other wildlife habitats (USCCSP 2008; USNOAA 2008; USEPA CRE 2008). With sea level rise there will be an increased inundation of low marsh dominated by *Spartina* and *Juncus*. Subsequently there will be a migration up-gradient and inland of low marsh habitat into the high marsh areas with a resultant expansion of low marsh and a depletion of high marsh if high marsh does not have adjacent native upland to migrate into (USCCSP 2008; USEPA CRE 2008). More frequent or longer lasting droughts and reduced freshwater inflows could increase the incidence of extreme salt concentrations in coastal ecosystems, resulting in a decline of valuable habitats such as the mangroves and seagrasses (Twilley et al. 2001).

Beach nourishment, or the addition of sand to an eroded beach, may be utilized as a mitigation factor to protect shorelines and human infrastructure. However, it disturbs indigenous biota living on and in the beach, and disrupts species that use the beach for nesting, nursing, and breeding. Wetlands elsewhere are perishing as estuarine and coastal forests and swamps are retreating and being replaced by marsh vegetation (Williams et al. 1999; Raabe et al. 2004; Desantis et al. 2007). Open estuarine waters, some brackish marshes, and mangroves in south Florida estuaries are expanding (Glick and Clough 2006; Hine and Belknap 1986). Even at constant rates of sea level rise, some tidal wetlands will eventually be “pinched out” where their upslope migration is prevented by upland defenses such as seawalls (Estevez 1988; Schlepner 2008).

#### *Up-gradient wetland and upland habitats*

Climate change is predicted to be one of the greatest drivers of ecological change in the coming century. Increases in temperature over the last century have clearly been linked to shifts in species distributions (Parmesan 2006). Given the magnitude of projected future climatic changes, Lawler et al. (2009) expects even larger range shifts over the next 100 years. These changes will, in turn, alter ecological communities and the functioning of ecosystems. Despite the seriousness of predicted climate change, the uncertainty in climate-change projections makes it difficult for conservation managers and planners to proactively respond to climate stresses. To address one aspect of this uncertainty, Lawler et al. (2009) identified predictions of faunal change for which a high level of consensus was exhibited by different climate models. Specifically, they assessed the potential effects of 30 coupled atmosphere-ocean general circulatory model (AOGCM) future-climate simulations on the geographic ranges of 2,954 species of birds, mammals and amphibians in the Western Hemisphere. Eighty percent of the climate projections based on a relatively low greenhouse-gas emissions scenario result in the local loss of at least 10% of the vertebrate fauna over much of North America. The largest changes in fauna are not predicted for Florida.

Southwest Florida has national treasures in the Big Cypress Swamp, the Corkscrew Regional Ecosystem Watershed (CREW), and the barrier island chain (Stanton and Ackerman 2007). These three ecosystems are interlinked and have a common history. The Big Cypress Swamp is part of the broad, shallow sheet flow river moving fresh water south into Florida Bay. The CREW is the northernmost extent of the greater Big Cypress Swamp with major strands of cypress that form headwaters for Estero Bay, coastal Collier County estuaries, and the Picayune and Fakahatchee Strands. The barrier islands mark the last outposts of the tropical hardwood hammocks. Once hummocks of higher vegetation set in a prehistoric swamp, they have struggled against the rising sea. Mangroves on their perimeters collect silt and organic material, building a barricade secure against all but the most severe hurricane winds and tides.

Already stressed by water diversions, invading species of plants and animals, and the natural phenomena of drought, flood, and storms, these ecosystems will be stressed further by climate change. A 20-inch sea level rise would cause large losses of mangroves in southwest Florida. Increased salinity, resulting from saltwater rising into the Everglades from Florida Bay, would also damage freshwater slough ecosystems. Communities of wet prairie would also decline with the rise in sea level. Climatic conditions in central Florida may become suitable for subtropical species such as the gumbo-limbo tree, now confined to subtropical hummocks in the southern part of the peninsula and the Keys. Theoretically, such species could move as far north as Gainesville and Jacksonville, but agricultural and urban development could preclude such migration (USEPA OPPE 1997).

Upland plant communities along tidal rivers and estuaries will be replaced by low-lying, flood-prone lands. Changes in soil moisture could shift forest dynamics and composition. For instance, natural pine forests can tolerate lower soil moisture than oak-pine forests (Twilley et al. 2001). Extensive open grassland and forest areas in South Florida could become more vulnerable to damaging invasion by exotic species such as Chinese tallow, *Melaleuca* and *Casuarina* trees (Twilley et al. 2001). Increased saline flooding will strip adjacent upland soils of their organic content (Williams et al 1999; Raabe et al. 2007).

Increased air temperatures affecting wetland hydrology will alter salinity gradients. Subsequently there will be altered species distributions associated with salinity and the timing, depth, and duration of inundation. Species interactions will be altered and metabolic activity decreased with drought. Many species will experience increased risk of disease and parasitism. Changes in drought and salinity will open niches for invasive species (USEPA CRE 2008; Holman 2008; FOCC 2009, Peterson et al. 2007; Lee County Visitor and Convention Bureau 2008).

Climate changes such as warmer temperatures, fewer freezes, and changes in rainfall or storm frequency will tend to shift the ranges of plant and animals species and alter the makeup of biological communities (Twilley et al. 2001). Populations of amphibians, reptiles, birds and mammals may have major faunal shifts including elimination from current range, reduction in range, shift to alternate ranges, overuse of new ranges, and

isolation or prevention from coastal or temperature retreat due to barriers to new ranges from land use changes and flooding (Lawler et al. 2009)

Listed species that are already endangered such as the Cape Sable seaside sparrow and Florida panther could become more vulnerable as their preferred habitats change or shift with global warming. Current water management practices and human development create additional challenges for species migration and adaptation (Twilley et al. 2001).

Shifts in behavior phenology of perching birds, seabirds, and farmland birds have been observed and are expected to continue. Perching birds will breed earlier in the calendar year. Seabird populations are expected to decline due to reduction in needed prey items at the right locations at the right time of the year. Farmland birds are expected to decline due to reduced food items being available at breeding time. This disjuncture between the breeding season and vital food or other resources availability is termed “mismatching” (Eaton et al. 2008; USEPA CRE 2008).

Climate change will affect the phenology of pest and beneficial insects by altering reproductive cycles, feeding and predation, and mismatching with host plants and pollinators (Backlund et al. 2008). For example, moth phenology will be shifted to earlier dates. This will affect birds and other animals that depend upon the moths for food, the host plant vegetation that moth larvae feed on, and the plants that depend upon the moths for pollination (Eaton et al. 2008; USEPA CRE 2008). There will be both positive and negative outcomes depending upon the phenological sequence and nature of the participants. In any case significant change could be expected.

Air temperature increases will affect soil temperatures in uplands and other areas where reptiles nest. The increased soil temperatures may affect nesting lizards, changing hatchling gender determination, fitness, and hatch date, which may expose hatchlings to different prey availability and predation potentials (Telemeco 2009). Amphibian populations' ranges, health, and phenology will also be affected (Backlund et al. 2008; FOCC 2009; USEPA CRE 2008). Increased air temperatures will also affect animal health, resulting in reduced feeding; reduced reproduction; reduced milk production (in mammals) for offspring; and increased pathogens and parasites (Backlund et al. 2008).

In freshwater streams, warmer water temperatures and a longer growing season could reduce habitat for cooler-water species, particularly fish, insects, snails, and shellfish. In very shallow water systems, higher temperatures could lead to oxygen depletion and cause potentially massive die-offs of fish and invertebrates (Twilley et al. 2001).

The altered timing of seasonal temperature changes is expected to disrupt predator/prey availability, food and reproductive cycles, patterns of upstream faunal migration, disruption of temperature-driven behavior including breeding and hibernation, and disruption of biological ocean-estuary exchanges of fishes and invertebrates (Peterson et al. 2007). Events occurring in spring or summer may occur later or have a longer "window". Events occurring in fall or winter may occur later or have a smaller "window". Events dependent on seasonal rainfall may occur differently with changes in rainfall patterns. Some animal and plant populations may migrate northward or inland to

conditions supporting their required limiting life/reproductive cycles. There may be local extirpation of some plant and animal populations with replacement by exotic species tolerant of/or advantaged by the new climate conditions.

Increases in precipitation of five to 10% over levels of the 20th century, including more heavy and extreme precipitation events will result in increased flash flooding, affecting ground-dwelling species (UWCES 2007; USNOAA 2008; SECCP SDRT LCCP 2005, FOCC 2009, USEPA CRE 2008).

### *Listed Animal Species*

As of April 21, 2009 the southwest Florida study area provides habitat for 56 State Listed Species with 20 of these also Federally Listed.

### State Endangered Species

Florida panther (*Puma concolor coryi*), everglades mink (*Mustela vison evergladensis*), West Indian manatee (*Trichechus manatus latirostris*), Florida mastiff bat (*Eumops glaucinus floridanus*), sei whale (*Balaenoptera borealis*), fin whale (*Balaenoptera physalus*), North Atlantic right whale (*Eubalaena glacialis*), humpback whale (*Megaptera novaeangliae*), sperm whale (*Physeter macrocephalus*), peregrine falcon (*Falco peregrinus*), wood stork (*Mycteria americana*), snail kite (*Rostrahamus sociabilis plumbeus*), Bachman's warbler (*Vermivora bachmanii*), Kirtland's warbler (*Dendroica kirtlandii*), Florida grasshopper sparrow (*Ammodramus savannarum floridanus*), American crocodile (*Crocodylus acutus*), green sea turtle (*Chelonia mydas*), leatherback sea turtle (*Dermochelys coriacea*), Kemp's Ridley sea turtle (*Lepidochelys kempii*), hawksbill sea turtle (*Eretmochelys imbricata*), small-toothed sawfish (*Pristis pectinata*), shortnose sturgeon (*Acipenser brevirostrum*)

### State Threatened Species

Florida black bear (*Ursus americanus floridanus*), Big Cypress fox squirrel (*Sciurus niger avicennia*), southeastern American kestrel (*Falco sparverius paulus*), Florida sandhill crane (*Grus canadensis pratensis*), least tern (*Sterna antillarum*), roseate tern (*Sterna dougallii*), piping plover (*Charadrius melodus*), snowy plover (*Charadrius alexandrinus*), white-crowned pigeon (*Columbia leucocephalus*), Florida scrub jay (*Aphelocoma coerulescens*), crested caracara (*Caracara cheriway*), eastern indigo snake (*Drymarchon corais couperi*), Atlantic loggerhead turtle (*Caretta caretta*)

### State Species of Special Concern

Sherman's fox squirrel (*Sciurus niger shermani*), Florida mouse (*Podomys floridanus*), Sanibel Island rice rat (*Oryzomys palustris sanibelli*), Sherman's short-tailed shrew (*Blarina carolonensis shermani*), roseate spoonbill (*Platalea ajaja*), little blue heron (*Egretta caerulea*), reddish egret (*Egretta rufescens*), snowy egret (*Egretta thula*), tricolored heron (*Egretta tricolor*), white ibis (*Eudocimus albus*), whooping crane (*Grus americana*), limpkin (*Aramus guarauna*), brown pelican (*Pelecanus occidentalis*),

American oystercatcher (*Haematopus palliatus*), black skimmer (*Rhynchops niger*), burrowing owl (*Athene cunicularia floridana*), red-cockaded woodpecker (*Picoides borealis*), gopher tortoise (*Gopherus polyphemus*), Florida pine snake (*Pituophis melanoleucus mugitus*), American alligator (*Alligator mississippiensis*), gopher frog (*Rana capito*), Atlantic (Gulf) sturgeon (*Acipenser oxyrinchus desotoi*), mangrove rivulus (*Rivulus marmoratus*), Florida tree snail (*Liguus fasciatus*)

All of the listed species inhabiting southwest Florida can be expected to be impacted by potential climate change effects including habitat losses and translocations of habitat, water quality effects, and decreases in aquatic vegetation and forage fishes. Eleven (11) listed animal species (above) occur in the waters of the marine and estuarine ecosystems of southwest Florida including the manatee, the whales, crocodile, sea turtles, sturgeons and small-toothed sawfish.



**Photograph 4: Small-toothed sawfish (*Pristis pectinata*) in the Caloosahatchee River**

Source: FWC 2008

Twenty-three (23) listed species utilize coastal strand habitats of barrier islands and mainland coasts. Problems for shore-nesting species of birds and reptiles, such as least tern, roseate tern, piping plover, snowy plover, American oystercatcher, black skimmer, American crocodile, and the sea turtles will include:

- Increased Sea level

- Increased Storm Frequency and Severity
- Higher-High Tides
- Increased erosion and narrowing of shorefront (beach)
- Increased Harmful Algae Blooms including Macroalgal Drifts
- Shifts in location of food resources to deeper waters
- Changes in beach particle size and compaction if renourishment is employed to detain erosion
- Increased shore-armoring to protect human financial investments in place



**Photograph 5: American crocodile at J. N. Ding Darling National Wildlife Refuge, Sanibel Island**  
*Source: H. Greening*

Thirty-three (33) listed animal species utilize the mangrove habitats of southwest Florida including Florida panther, Florida black bear, Big Cypress fox squirrel, West Indian manatee, peregrine falcon, wood stork, American crocodile, green sea turtle, leatherback sea turtle, Kemp's Ridley sea turtle, hawksbill sea turtle, small-toothed sawfish, shortnose sturgeon, southeastern American kestrel, least tern, roseate tern, piping plover, snowy plover, white-crowned pigeon, eastern indigo snake, Atlantic loggerhead turtle, roseate spoonbill, little blue heron, reddish egret, snowy egret, tricolored heron, white ibis, brown pelican, American oystercatcher, black skimmer, American alligator, Atlantic (Gulf) sturgeon, and mangrove rivulus.



**Photograph 6: Florida panther utilizing the wildlife undercrossing bridge at Corkscrew Road, Lee County March 28, 2008 taken with an infra-red triggered camera**

*Source: Lee County Natural Resources 2008*

Pine flatwoods, in combination with other forested upland and seasonal wetland habitats, provide critical foraging, breeding, and wildlife corridor habitat for the Florida panther (*Puma concolor coryi*). The documented foraging and breeding territories of radio-collared Florida panthers and documented sightings of Florida panther include large expanses of undisturbed forests (Maehr 1992). The panther utilizes hydric, mesic, and xeric pine flatwoods, and savanna, hardwood hammocks, and mixed swamp forest. Ecotones are particularly important to the panther because they support an increased variety and density of species. Prey animals, including white-tailed deer and wild hog, utilize the plant diversity of edge communities such as the hydric pine flatwoods (Layne and McCauley 1976). Recently burned pine flatwoods provide more prey for panther, and panthers have been documented moving toward fires and staying in areas of recent burns (Belden 1986). Panthers require large territories and abundant prey. Adult male panther territories average 400 square kilometers and adult female territories average 200 square kilometers (Maehr 1992). Panthers may travel up to 19 miles overnight, or stay in the same wooded habitat for a week or more (USFWS 1987). Additionally, forests associated with natural drainage patterns provide the travel corridors essential to the panther for moving between the fragmented foraging areas remaining in Florida. In a 1986 Florida Game and Freshwater Fish Commission (GFC) study, adult male territories averaged 414 square miles, adult female territories averaged 119 square miles, and a juvenile male territory was 269 miles. The hydric and mesic pine flatwoods of southwest Florida provide both the large territories and abundant prey that panthers require.



are also eaten. Black bears utilize all the natural forested systems of south Florida, with a decided preference for ecotones, including the boundaries between mangroves and other plant communities. Documented movements of radio collared Florida black bears in Lee and Collier counties and documented signs/sightings of Florida black bears in Charlotte, Collier, and Lee counties indicate that the large areas of relatively undisturbed mangrove forest, in combination with mesic forests and the major wetland basins, provide the principal habitat of the black bear in southwest Florida (Maehr 1984, Brady and Maehr 1985, Maehr *et al.* 1988, Maehr and Wooding 1992, Beever and Dryden 1992). Movement by individuals can be extensive and may be related to both mating and food availability. Black bears will swim between mangrove islands in Collier County (Dryden and Beever 1994).



**Photograph 7: Florida Black Bear**

Source: FWC 2006

The Big Cypress (mangrove) fox squirrel (*Sciurus niger avicennia*), listed as threatened by the state, is found in mangroves south of the Caloosahatchee River, along the estuarine coast south to the western edge of the Everglades sawgrass marshes. The Big Cypress fox

squirrel utilizes a wide variety of forested and non-forested upland and wetland systems including mangroves. The Big Cypress fox squirrel possesses a large territory from which it harvests seasonally available bounties of cones, nuts, and seeds. The fox squirrel forages on mangrove propagules, in particular, the black mangrove. Nesting occurs in pines, hardwoods, cypress, cabbage palms, bromeliad clumps, and black mangroves.

The Everglades mink (*Mustela vison evergladensis*) is found in the Big Cypress Swamp, the western edge of the Everglades, southern Lee County, Collier County, and mainland Monroe and Miami-Dade counties (Allen and Neill 1952, Humphrey and Setzer 1989, Humphrey 1992). Mink are nocturnal and crepuscular predators of mammals, reptiles, birds, amphibians, fishes, and eggs. The species does not appear to be numerous and, given its period of activity, the literature on distribution is based primarily on road kills. The Everglades mink is found in a wide variety of shallow wetland systems, including mangrove swamps.

The white-crowned pigeon (*Columba leucocephala*) is a resident of the mangrove arboreal habitat for nesting and nearby tropical hardwood hammock areas for foraging. This herbivorous pigeon found from Collier County on the southwest coast, Biscayne Bay on the southeast coast and south through the Marquesas Keys is listed as a threatened species by FWC and FCREPA (Bancroft 1996). The white-crowned pigeon requires undisturbed mangrove communities for nesting and foraging. Over half of the state's pigeon population nest on islands in the upper Florida Keys (Bancroft 1996). Nesting on the mainland is rare, but does occur (Strong *et al.* 1991). Most of the population migrates to the Caribbean for the winter breeding season, but some birds are present in south Florida year-round. Breeding occurs from March to June. The white-crowned pigeon's mangrove and hardwood hammock habitat continues to decline as residential and commercial development increases. The continued existence of this species in Florida and the Caribbean is dependent upon the integrity of its nesting and foraging habitat here in south Florida.

The eastern brown pelican, a state species of special concern, nests predominantly on overwash mangrove islands and forages over open water, mudflats, and seagrass beds in the shallow waters of estuaries, creeks, and nearshore areas. Brown pelican rookeries are located on isolated red mangrove islands with a substantial water depth barrier that protects the nests from mainland predators. Diet consists of fish of all sizes. Foraging consists of plummeting dives, short plunges, and swimming scoops of fish. Historically, brown pelican populations were reduced as a result of pesticides. Today, the greatest threats to brown pelicans are still human-caused. Brown pelicans and their nesting/roosting/loafing sites are vulnerable to disturbance from construction activities and monofilament line entanglement. Brown pelicans are especially susceptible to death and injury caused by sport fishing equipment. It has been estimated that over 500 individuals die each year as a result of entanglement with fishing tackle (Schreiber 1978). The brown pelican provides an example of the interaction of stressors to negatively impact successful nesting at mangrove overwash island rookeries. The brown pelican nesting on overwash mangrove island rookeries will be threatened by increased sea levels, increased storm frequency, and increased storm severity. The forage fish that the young nestlings depend upon will be negatively affected by increased nutrient run-off

from the watershed from increased precipitation that will stimulate and maintain increased harmful algae blooms. Increases in water temperature will move forage fish schools into the Gulf of Mexico away from rookeries and tidal passes. In addition, global warming will assist the magnificent frigate bird to increased summer range in the Charlotte Harbor area. The frigate bird is a food stealer and predator on young chicks. With increased presence there can be an expected increase in food stealing from parents attempting to feed young, resulting in malnutrition or starvation for chicks, and increased direct predation on chicks.



**Photograph 8: Brown pelican chick (*Pelecanus occidentalis*) and magnificent frigate bird (*Fregata magnificens*)**

Source: USFWS 2008

Tricolored heron, little blue heron, white ibis, and snowy egret forage and nest in mangroves. Little blue herons and white ibis are the most common of the listed wading bird species observed in mangroves in southwest Florida (Beever1992). Diet consists of small fish, crustaceans, insects, frogs, and lizards (Ogden 1978a). Nesting in mangroves typically occurs on overwash islands. They appear to prefer to forage in freshwater habitats even when nesting in saltwater wetlands. The little blue heron forages throughout the wet and dry season in mangroves. Adjacent tidal wetlands are used throughout the year with greater emphasis during low tides on seagrass beds. The snowy egret forages throughout the wet and dry season in mangrove wetlands of the proper depth to allow for their foraging methods. Snowy egrets are the third most abundant listed wading bird observed. Preferred foraging areas are the seagrass beds and mudflats adjacent to the mangroves. Their diet consists of crustaceans, insects, and small fish (Ogden 1978c).

Reddish egrets and roseate spoonbills are obligate mangrove breeders. Reddish egrets forage on the sandbars and mudflats adjacent to mangroves, in an active fashion with

spread wings and rapid steps over unvegetated bottoms. Reddish egrets are the least abundant of the listed wading birds associated with mangroves. Reddish egrets utilize a limited set of saltwater habitats that allow for use of their unique foraging method. Diet consists of crustaceans and small fish. Kale and Maehr (1991) indicate that red mangrove rookeries are used during the December through June breeding period. Roseate spoonbills use dry-down pools in the high marsh, and during low tides, adjacent to mangroves. Preferred foraging areas included sheltered coves. They often forage in groups and with other wading birds including wood storks, great egret (*Casmerodius albus*), white ibis, and snowy egret. Roseate spoonbills nest exclusively in mangrove forests, typically on overwash islands, and forage wherever concentrations of small fish and crustaceans allow the birds to utilize their unique bills for feeding (Ogden 1978b).

A wide variety of shorebird species forage on the mudflats of mangrove estuaries. Among the State listed species are the threatened least tern; the black skimmer, a species of special concern; and the American oystercatcher, a species of special concern. Least terns and roseate terns require open beach or bare substrates for nesting near areas where schools of forage fish concentrate. American oystercatchers utilize oyster bars and mudflat areas in mangroves and nest on bare unvegetated shores. Foraging occurs throughout the year with seasonal movements tracking warmer conditions.

Mangrove rivulus is a small fish living only in and around mangrove areas as far north as Indian River County south through the Keys and north to Tampa Bay on the west coast of Florida (Taylor and Snelson 1992). It is the only species of *Rivulus* in North America and has adapted to conditions of varying water levels and low oxygen levels of the mangrove community. It is an important link in the food chain, as it has been found to constitute part of the diet of many organisms including the wood stork (Ogden *et al.* 1976). It is listed as a species of special concern by the state because of its limited distribution and vulnerability to loss of its habitat.

Tropical hardwood hammocks are located in coastal areas immediately adjacent to the coast. In southwest Florida, these tropical hardwood hammocks support nine listed animal species, two of which, the white-crowned pigeon and the Florida tree snail, occur nowhere else. These endemics do not have a natural location to retreat to from sea level rise. On the other hand it is possible that the range of tropical hardwoods may expand northward and inland on undeveloped preserve lands. For a species with restricted mobility like the Florida tree snail, physical relocation may be necessary in order for it to find the new hardwood hammock locations.

Salt marshes support 23 listed animal species in southwest Florida. Southwest Florida freshwater marsh support 19 listed animal species. Two marsh endemics, the Cape Sable sea-side sparrow and the Sanibel Island Rice Rat, have a limited distribution in coastal marshes of the Everglades and the interior of a barrier island. Both are in the direct path of increased sea levels, increased storm frequency, and increased storm severity. In addition these delimited marshes may be disrupted by climate instability resulting in fire increases and declines in food base and overtopping flooding from increased precipitation during more severe wet seasons. These species may also need relocation to maintain viable populations. Other marsh species that have preferred hydrologic needs for prey

item selection include the wood stork, the Everglades mink, the snail kite, and a variety of wading bird with water depth niche partitioning including roseate spoonbill, little blue heron, reddish egret, snowy egret, and tricolored heron.

There will be problems for listed species and other wildlife as humans retreat inland from the coast. Most southwest Florida xeric oak scrub is coastal or along rivers and streams. Inland retreat will eliminate the rarest of the upland habitats with endemic animals such as the Florida scrub jay and endemic listed plants. The “Eastward Ho!” paradigm so popular on the east coast of Florida has the reverse effect in southwest Florida since it will push development into the wetlands of the Big Cypress Swamp and Corkscrew Swamp systems. The interior pinelands and other uplands are the last refuge in southwest Florida of the Florida panther, Florida black bear, Big Cypress fox squirrel and red-cockaded woodpecker.

### *SLAM Modeling of Effects on Marshes*

With higher tides including higher high tides, higher normal tides, and higher low tides resulting from sea level rise, mangroves and *Spartina* will be unable to establish in water deeper than the ordinary high tide line so an apparent retreat of the waterward edge of the mangrove fringe will occur, along with coastal forest loss is to be expected, including an expected die off of *Sabal palmetto* and other shoreline species (Titus 1998, USEPA CRE 2008). To determine the possible extent of such loss, SLAMM modeling has been employed.

The Sea Level Affecting Marshes Model (SLAMM) was developed with USEPA funding in the mid 1980s (Park et al. 1986), and SLAMM2 was used to simulate 20% of the coast of the contiguous United States for the USEPA Report to Congress on the potential effects of global climate change (Park et al. 1989a, Park et al. 1989b, Park 1991, Titus et al. 1991). Subsequently, more detailed studies were undertaken with SLAMM3, including simulations of St. Mary’s Estuary, FL-GA (Lee et al. 1991, Lee et al. 1992, Park et al. 1991), Puget Sound (Park et al. 1993), and South Florida (Park and Lee 1993). More recently SLAMM4 was applied to all of San Francisco Bay, Humboldt Bay, and large areas of Delaware Bay and Galveston Bay (Galbraith et al. 2002, Galbraith et al. 2003).

SLAMM Version 4.1 is the latest version of the model, developed in 2005 and based on SLAMM 4.0. SLAMM 4.1 provides additional sea level rise scenarios based on the IPCC findings as of the Third Assessment Report (IPCC 2001) and additional data examination tools to ensure that data quality is acceptable. Model flexibility has been improved with respect to accretion rates, and the model now accepts data from the USGS seamless data distribution tool ([seamless.usgs.gov](http://seamless.usgs.gov)). To accurately model erosion in larger sites, maximum fetch is now calculated on a cell-by-cell basis rather than being input as a site characteristic.

SLAMM simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise. A complex decision tree incorporating geometric and qualitative relationships is used to represent transfers among

coastal classes. Each site is divided into cells of equal area, and each class within a cell is simulated separately. Earlier versions of SLAMM used cells that were usually 500 by 500 meters or 250 by 250 meters. Version 4.1 uses cells that are 30 m by 30 m, based on NOAA tidal data, Fish & Wildlife Service National Wetland Inventory data, and USGS Digital Elevation Model data that are readily available for downloading from the Web. Map distributions of wetlands are predicted under conditions of accelerated sea level rise, and results are summarized in tabular and graphical form.

Relative sea level change is computed for each site for each time step; it is the sum of the historic eustatic trend, the site-specific rate of change of elevation due to subsidence and isostatic adjustment, and the accelerated rise depending on the scenario chosen (Titus et al. 1991). Sea level rise is offset by sedimentation and accretion using average or site-specific values. For each time step, the fractional conversion from one class to another is computed on the basis of the relative change in elevation divided by the elevational range of the class in that cell. For that reason, marshes that extend across wide tidal ranges are only slowly converted to unvegetated tidal flats. If a cell is protected by a dike or levee it is not permitted to change. The existence of these dikes can severely affect the ability of wetlands to migrate onto adjacent shorelines. Diked wetlands are assumed to be subject to inundation when relative sea level change is greater than 2 m, although that assumption can be changed. In one study, alternate management scenarios involving maintenance of dikes were simulated (Park et al. 1993).

In addition to the effects of inundation represented by the simple geometric model described above, second-order effects occur due to changes in the spatial relationships among the coastal elements. In particular, the model computes exposure to wave action; if the fetch (the distance across which wind-driven waves can be formed) is greater than 9 km, the model assumes moderate erosion. If a cell is exposed to open ocean, severe erosion of wetlands is assumed. Beach erosion is modeled using a relationship reported by Bruun (1962) whereby recession is 100 times the change in sea level. Wetlands on the lee side of coastal barriers are subject to conversion due to overwash as erosion of backshore and dune areas occurs and as other lowlands are drowned. Erosion of dry lands is ignored; in the absence of site-specific information, this could underestimate the availability of sediment to replenish wetlands where accelerated bluff erosion could be expected to occur. Coastal swamps and fresh marshes migrate onto adjacent uplands as a response of the water table to rising sea level close to the coast; this could be modified to take advantage of more site-specific predictions of water table elevations.

Congressional testimony by Park (1991) included predictions of increases and then declines in the brown shrimp catch for the Gulf Coast based on the predicted breakup and loss of marsh habitat (Park 1991). More recently, the model was used to predict loss of habitat for shorebirds (Galbraith et al. 2002, Galbraith et al. 2003).

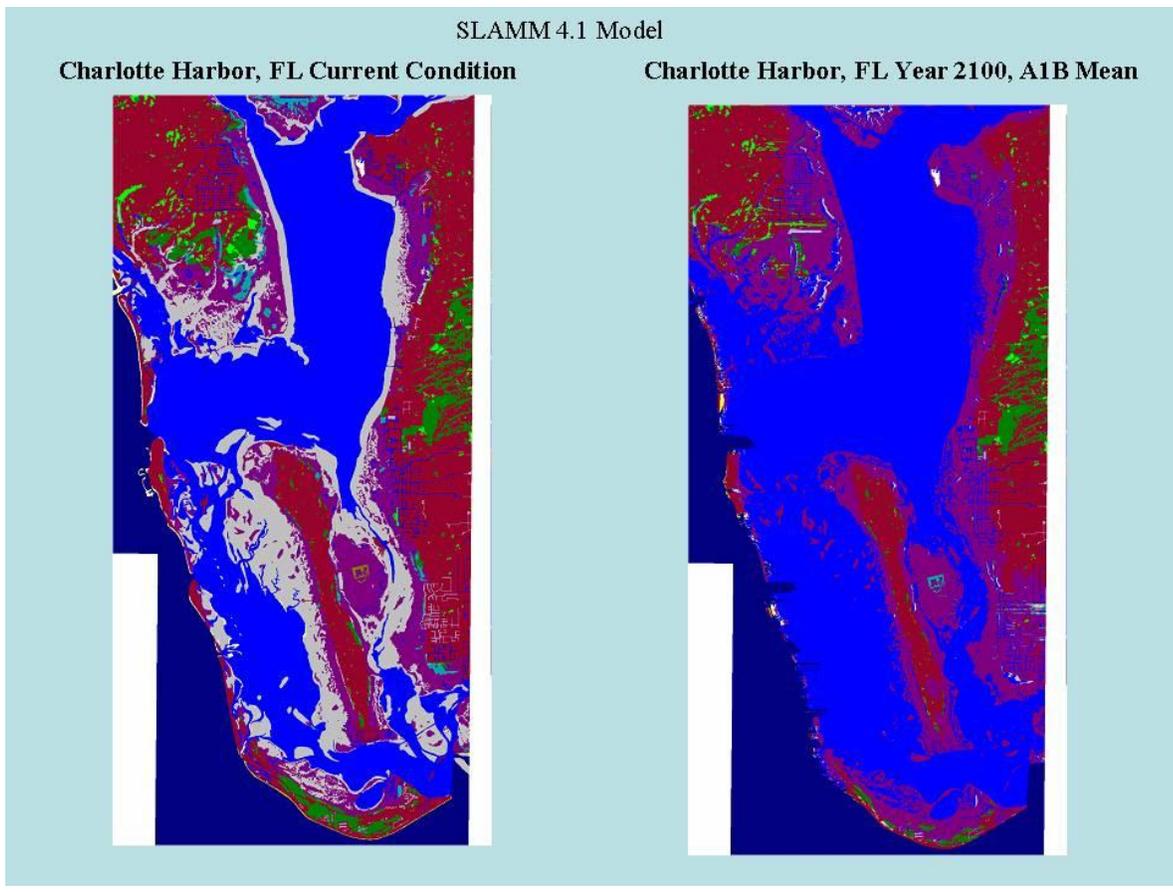
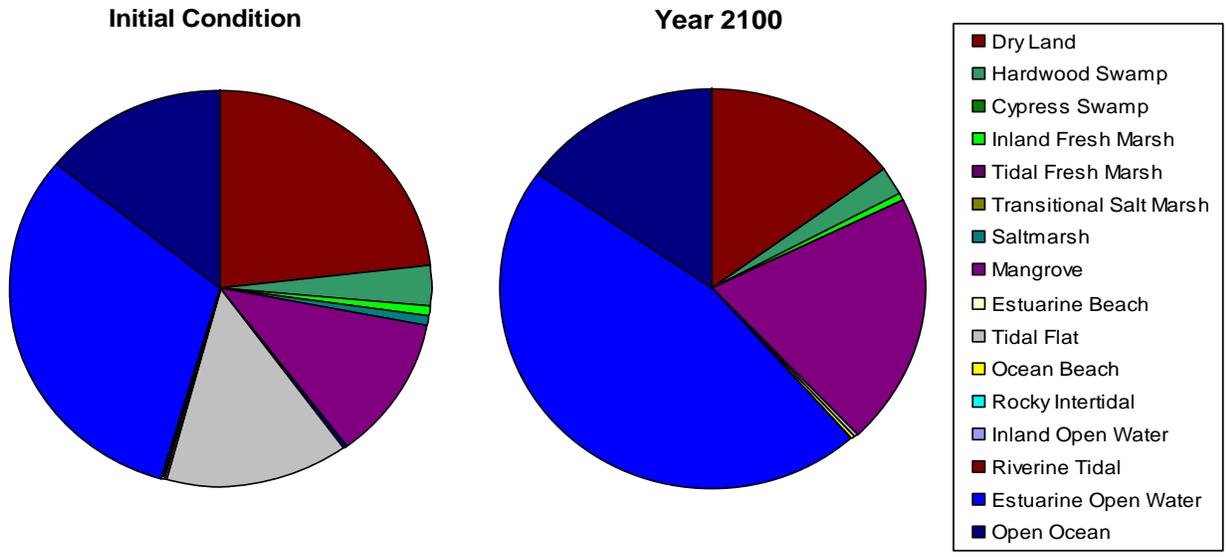
The model was run given the minimum, mean, and maximum estimates of each of the SRES (Special Report on Emissions Scenarios). A brief description of each of these scenarios can be found in the SLAMM 4.1 technical documentation (Glick 2006); more extensive descriptions are in the IPCC Third Assessment Report (IPCC 2001). For simplicity, this report will focus on the A1 scenario in which the future world includes

very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. In particular, the A1B scenario assumes that energy sources will be balanced across all sources.

Significant overwash is predicted for the barrier islands around Charlotte Harbor resulting in major upland loss. Saturation and inundation will also negatively affect uplands that are predicted to decrease by 35-55% depending on whether the mean or maximum scenario is run. Existing tidal flats are also predicted to be all but eliminated by sea level rise. Mangroves are predicted to thrive under these scenarios increasing by 75% to 119% provided the sea level rise is gradual.

<b>Habitat</b>	<b>Initial Condition</b> Hectares	<b>Percent of Initial</b>	<b>Year 2100</b> Hectares	<b>Area Changed</b> Hectares	<b>Percent Loss</b> mean	<b>Percent Loss</b> maximum
Upland	37,805	23%	24,468	-13,337	-35%	-55%
Hardwood Swamp	5,000	3%	3,196	-1,804	-36%	-51%
Cypress Swamp	31	0%	32	1	3%	5%
Inland Freshwater Marsh	1,261	1%	1,036	-225	-18%	-55%
Transitional Salt Marsh	73	0%	15	-58	-79%	-167%
Saltmarsh	1,384	1%	151	-1,233	-89%	-98%
Mangrove	18,577	11%	32,535	13,958	75%	119%
Estuarine Beach	492	0%	143	-349	-71%	-76%
Tidal Flat	22,835	14%	612	-22,223	-97%	-99%
Marine Beach	97	0%	70	-27	-28%	-100%
Hard bottom Intertidal	3	0%	3	0	0%	0%
Inland Open Water	517	0%	212	-305	-59%	73%
Estuarine Open Water	50,921	31%	74,501	23,580	46%	48%
Marine Open Water	22,691	14%	24,711	2,020	9%	11%
<b>TOTAL</b>	<b>161,687</b>		<b>161,685</b>			

**Table 21 SLAMM 4.1 Predictions of Habitat Fates under Scenario A1B, Mean (Max) for Charlotte Harbor,**



**Figure 47: SLAMM Predictions of Habitat Fate under Scenario A1B, Mean for Charlotte, FL**

## *Habitat Migration*

Conceptual diagrams are a technique developed by the University of Maryland Center for Environmental Science Integration and Application Network (IAN) to communicate science. The technique uses Adobe Illustrator and symbol libraries designed to communicate to an international audience. This conceptual diagramming technique was used to illustrate application of several principals of climate change as they related to southwest Florida native ecosystems.

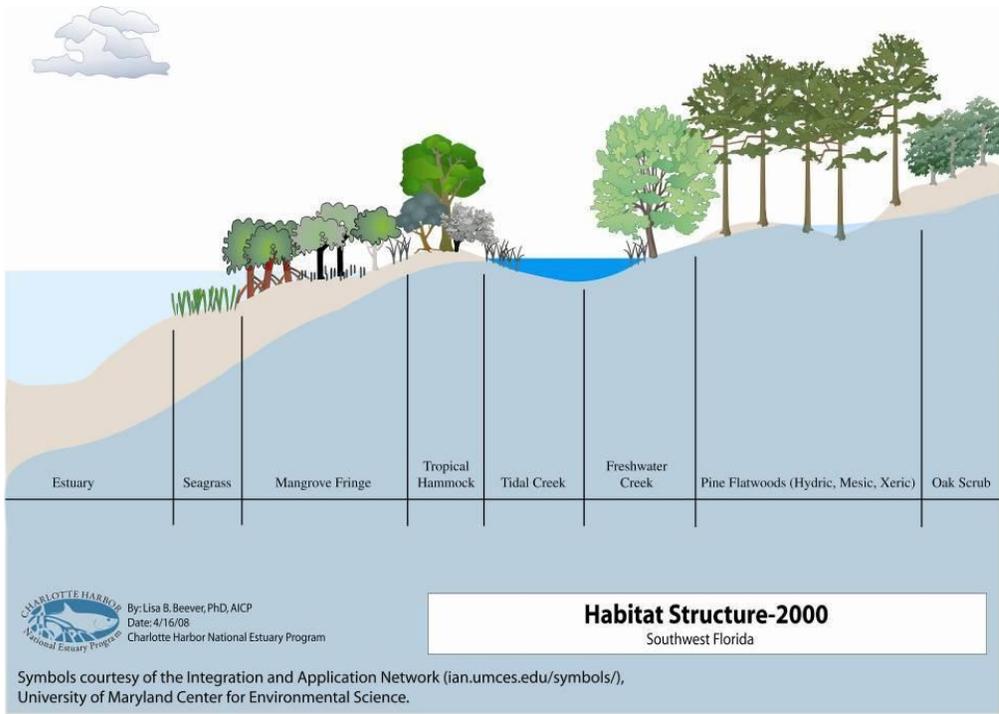
“Figure 48: Habitat Structure 2000 Southwest Florida” is a conceptual diagram that identifies a typical cross-section of southwest Florida native ecosystems from the estuary to the high oak scrub. Such habitats include the estuary, seagrass, mangrove, tropical hardwood hammock, tidal and freshwater creeks, pine flatwoods, and oak scrub.

Several climate change processes were applied to the typical cross-section to observe potential impacts to create “Figure 49: Habitat Structure 2200 Southwest Florida”. The processes include:

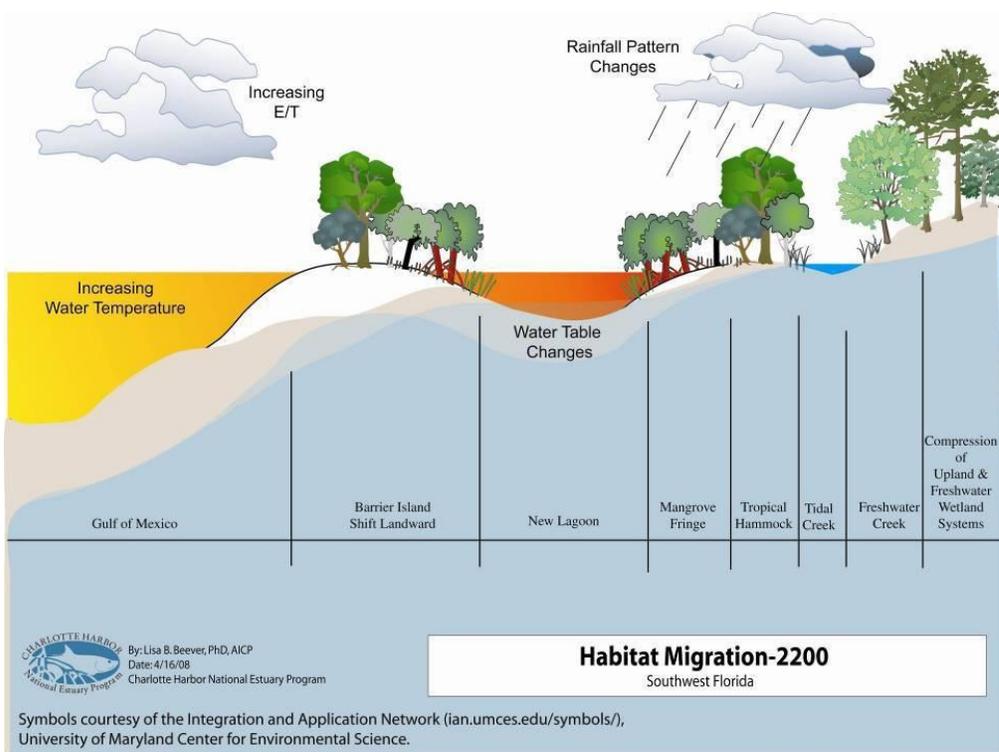
- Sea level rise
- Increasing water temperature
- Geomorphic changes related to
  - movement of the shoreline to maintain the coastal energy gradient, and
  - sediment accretion by mangroves

Effects of these processes include:

- Landward migration of the Gulf of Mexico,
- increasing evapotranspiration,
- changes in rainfall patterns,
- movement of tidal creeks up into the freshwater creek systems,
- water table changes as a result of sea level rise, shoreline movements, rainfall changes, and mangrove sediment accretion,
- compression of freshwater wetland and upland systems,
- compression of estuarine areas, and
- loss of suitable seagrass areas.



**Figure 48 Habitat Structure 2000 Southwest Florida**



**Figure 49: Habitat Structure 2200 Southwest Florida**

## Land Use Changes

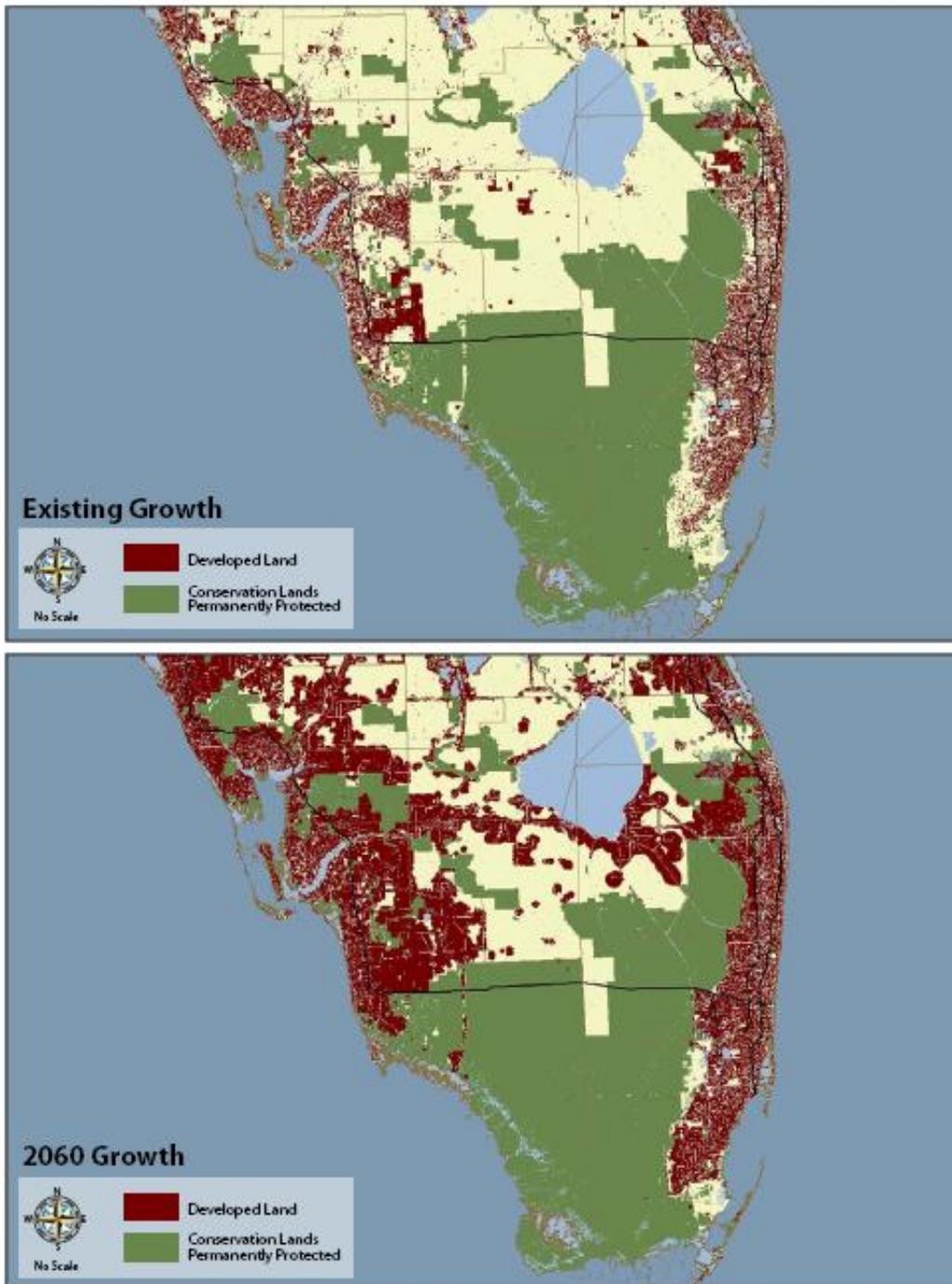
### Known Land Use Changes and Events that Have Occurred

#### *Land use projections for Florida*

The most important economic and political issue facing Florida over the next decade is land use. Assuming that Florida chooses to participate in mitigation efforts, policy makers will need to make hard choices between urban expansion and alternative land uses associated with greenhouse gas (GHG) mitigation and adaptation. Even assuming a net reduction in immigration to the state, Florida's population will likely increase by at least 50 percent over the next twenty-five years, and may double in fifty years. Urban development, suburban sprawl, transportation pressures, coastal human population densities, habitat fragmentation, and reduced agricultural and forest lands will be the inevitable result of this population increase unless growth is managed wisely with attention to enhancing sustainability (Mulkey 2006).

Seventy-seven percent of Florida's population lives in coastal counties, 31% on the Gulf coast. Population density in shoreline counties is approximately 444 people per square mile, while the density inland was an estimated 170 people per square mile, the differences partially due to large cities along the coast. Inland counties, with smaller population levels, have grown faster than shoreline counties with population and housing growth at approximately 42% during the period 1990-2004. Florida ranks third among the coastal states for shoreline county population and 13<sup>th</sup> for shoreline county population density (Kildow 2006).

The constraints on land use and natural resources are made ever more critical by the unfolding consequences of climate change, which will impact densely populated coastal regions as sea level rises. The central challenge and opportunity for Florida policy makers is to include the potential for GHG mitigation and adaptation to climate change in this mix of constraints. Since the early 1800s, the history of Florida has been characterized by periodic land speculation, and over the last two decades the urban expansion of the state has been dramatic. Although recent declines in public school enrollment suggest that this growth may be slowing, given the large number of people of reproductive age in Florida, growth will continue to be high for the next few decades. Figure 50 shows the projected residential growth by 2020 in which 2 to 3 million acres of aquifer recharge lands will be developed (estimated by the Florida Chapter of The Nature Conservancy). A recent study published by 1000 Friends of Florida shows that, by 2060, an additional 7 million acres will be needed to support growth if it continues at the rate measured through December 2005 (Zwick and Carr 2006).



**Figure 50: Projected 2060 Land Use Growth**

Source: *FLORIDA 2060: A POPULATION DISTRIBUTION SCENARIO* (1000 Friends of Florida 2006)

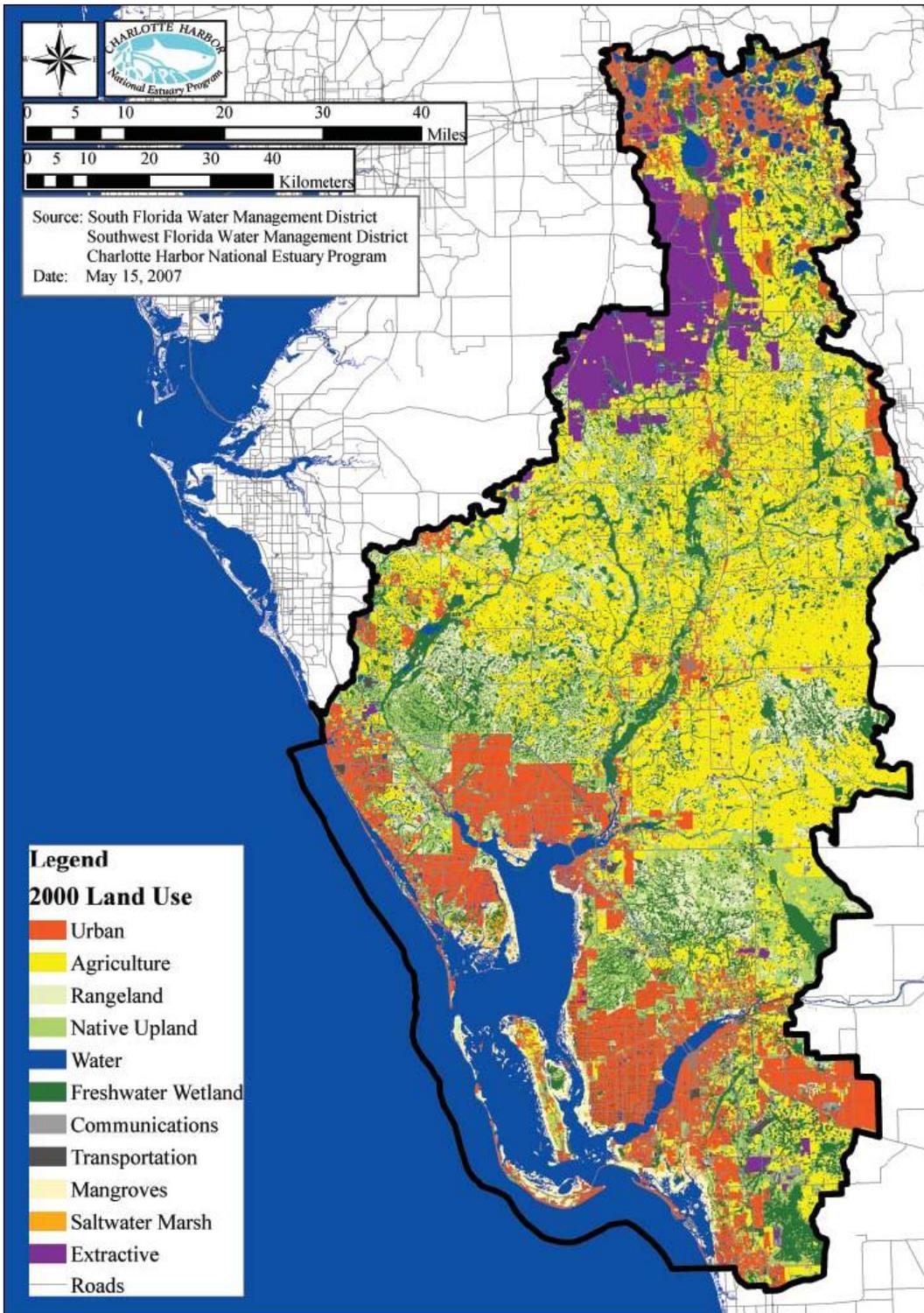
<b>Year</b>	<b>Population</b>	<b>Urban Acres</b>	<b>% of Region Acres</b>
2005	1,238,844	662,294	15
2060	3,539,766	1,800,131	40
<b>Difference</b>	<b>2,300,922</b>	<b>1,137,837</b>	<b>25</b>

**Table 22: Southwest Florida Projected Growth in Charlotte, Collier, DeSoto, Glades, Hendry, Lee, Sarasota Counties**

*Source: FLORIDA 2060: A POPULATION DISTRIBUTION SCENARIO (1000 Friends of Florida 2006)*

Charlotte, Lee and Collier counties are expected to build out before 2060 causing an almost continuous band of urban development along the southwest Florida coast and population spillover into adjacent inland counties. Large amounts of this spillover are projected for DeSoto, Hendry and Glades counties. These three counties are projected to experience the greatest transformation over the next 50 years as they go from largely rural to largely urban in character. Glades is expected to have more than 15 times the urban area it does today, DeSoto almost nine times, and Hendry almost five times as much urban land as today. Another result will be an almost continuous urban strip linking Ft. Myers to West Palm Beach. Consequently only a few large areas of contiguous open space are likely to remain in the inland counties. The natural systems and wildlife habitat corridors in this region will be fragmented, if not replaced, by urban development. This region is projected to have the third largest percentage of urban land use (40%) of any region in the state by 2060.

Forests currently cover about 15 million acres, and crop and pasturelands cover more than eight million acres of Florida's total 34.3 million land acres (2002 data). By 2060, the projected urban expansion would consume 2.7 million acres from both agricultural and native habitat lands, respectively. This vision of the future is not consistent with either the goals of sustainable development or maximizing the opportunity for climate mitigation and adaptation through land management.



**Figure 51: Year 2000 Land Use in the Charlotte Harbor National Estuary Program Study Area**

Both the Southwest and South Florida Water Management Districts map land uses using the Florida Land Use Code and Classification System (FLUCCS). The land use map for

2000 (Figure 51) illustrates the distribution of urban, extractive, agriculture, wetlands and uplands within the CHNEP study area.

Exclusive of urbanization, Florida land cover has been altered extensively in the last century, contributing to changes in temperature trends. While there has been a general trend toward higher mid-summer maximum and minimum temperatures throughout south Florida, the draining of southern wetlands has resulted in an increased severity and frequency of economically damaging frosts for the region between Lake Okeechobee and the Everglades. The thermal inertia of intact wetlands retains heat in the lower atmosphere, while their loss allows dissipation of this heat overnight (Marshall et al. 2003).

Similarly, changes in meteorological parameters (clear sky downward long wave radiation) have been associated with land use change in the subtropical climate of the St. Johns River Water Management District in northeastern Florida (Rizou and Nnadi 2007). This mesoscale, or regional, climate change has been shown to result from human alteration on the landscape. Unlike California, the whole of Florida has not been surveyed for possible effects of land use change on the mesoscale climate. It is likely that the effects of changes in vegetation cover on Florida climate have been extensive during the 20<sup>th</sup> century.

The urban heat island effect has increased dramatically for many of Florida's growing urban areas over the last century. Buildings, parking lots, roads and other paved surfaces of urban areas exhibit greater solar radiation absorption, greater thermal conductivity, and thus a greater capacity for releasing overnight heat that is stored during the day. Thus, urban areas tend to be warmer than surrounding areas in direct relation to the amount of impervious surface present in the landscape.

In a study comparing the urban heat island effect in two metropolitan areas, the urban area of the Tampa Bay watershed was found to have a daytime heating effect, whereas the urban surface in Las Vegas showed a daytime cooling effect. These thermal effects are strongly correlated with urban development densities and percent imperviousness. Las Vegas may be cooler in part due to the tendency of the arid suburbs to become more vegetated as the city has expanded, but overall there is a greater density of impervious surface in the metropolitan core of Tampa Bay relative to that in Las Vegas (Xian and Crane 2006). A strongly increasing heat island effect has been observed for the Miami metropolitan area as the city has grown, with the number of heat stress nights increasing by more than 24 per year during the period 1950-1999. A similar trend has been documented for Tampa (Physicians for Social Responsibility 2001). The heat island effect has important implications for Florida energy use because, for every 1° F increase in daytime temperature, as much as 225 MW (megawatts) additional power generation is required during periods of peak electricity demand in a large urban area.

Climatologists (Pielke 2005) have argued convincingly that land use change, including urbanization, should be considered a "first order" or primary forcing agent for mesoscale climate. For some regions, over relatively short timescales, this effect can be greater than the climate forcing of the GHGs. Thus, the concept of heterogeneous forcing is the most

appropriate paradigm for understanding climate change. The top-down approach inherent in the Global Circulation Models (IPCC 2007) assumes that with sufficient model resolution one can accurately project climate many decades into the future. While this is a reasonable assumption for projections of globally averaged climate under the dominant influence of GHG, it may not be true for regions on a shorter time scale as land use patterns change.

Moreover, because the extremes of weather have important implications for human well being, the average values derived from the Global Circulation Models can be misleading. Land use change often affects meteorological maxima and minima (e.g., Marshall et al. 2004). Based on current knowledge of the importance of land use for climate, it is appropriate that both a bottom-up and top-down approaches are utilized when assessing climate change for a region. Climate models incorporating the GHGs, land use, and regionally relevant meteorological variables would be useful for predicting climate variability and change for regions the size of the state of Florida and smaller (Pielke et al. 2007). Ideally, mesoscale climate models would operate over timescales consistent with the rate of land use change and allow projections of how specific changes would affect climate. Although such models are being developed, significant resources are needed to advance this science, and there is an urgent need to assess land use impacts on climate given the rapid pace of urbanization of the state (Zwick and Carr 2006).

When expanding urbanization breaks up natural lands then habitat fragmentation results. The remaining isolated landscapes are often too small to support breeding pairs of animals and preclude intermixing of breeding populations. Also, the margins of these fragmented natural lands create “edge habitat” that alters species composition and can increase human impacts (CHNEP CCMP 2008). The CHNEP study area has lost more than 38 percent of its original wetland habitat, mostly to agricultural drainage, mining and urban development. Land drained by connector ditches for farming accounts for the largest loss of freshwater wetlands. More recently, wetland conversions to farmland or open water have accelerated, especially in smaller unregulated wetlands. It is not known what the balance in temperature would be between wetland removal and urban heat islands. If a removed wetland is subsequently paved, an even warmer heat island effect outcome could result.

Mining activities have also impacted wetlands. Prior to 1975, phosphate companies strip-mined but didn't restore many wetlands. This happened especially along tributaries of the Peace River in Polk County when mining was the leading economic force in the region. Now, due to regulation, the phosphate industry is required to reconstruct and replace wetlands that it destroys. Urban and rural development also destroys wetlands, filling them to provide a more stable substrate for building. Most elimination of wetlands goes through a permitting process with mitigation requirements. However, some wetland losses are currently permitted with no mitigation requirements (CHNEP CCMP 2008; SWFRPC 2007).

### *Potential Future Climate Changes*

There is compelling evidence that not all climate change on a regional scale can be attributed to the atmospheric forcing effect of GHGs. For example, conversion of tropical savanna to grassland has resulted in regional decreases in precipitation in South America, Africa, and Australia (McPherson 2007). A recent survey of California climate variability shows that about half of warming of the state since 1950 can be attributed to global warming through statistical association with increased Pacific Ocean sea surface temperatures. The remaining half of the warming can be attributed to land use change, with large urban areas exhibiting two to five times more warming than the state average (LaDochy et al. 2007). A similar pattern has been shown for the Eastern U.S. (Kalnay and Cai 2003). The urban heat island effect does not account for all of the warming associated with land use change because changes in vegetation cover can significantly affect long wave and short wave emissivity, albedo (reflectivity), boundary layer thickness, potential evapotranspiration, and other factors contributing to local variation in temperature and precipitation (Pielke 2005; McPherson 2007; Waters et al. 2007).

Sea level rise is expected to push most human habitation inland. As larger populations move toward the interior, there are likely to be other changes that complicate effects of climate change. Changes in groundwater use patterns ranging from agricultural cycling to human consumption patterns will exacerbate drought conditions. A decrease in inland water quality may be expected due to increased human habitation combined with fertilizer use, and wastewater and stormwater runoff increases. There will be encroachment of humans into some relatively less-disturbed habitats. This will further reduce the natural areas occupied by wide-ranging listed species such as the Florida panther and Florida black bear. There will be reduced land available for agriculture operations providing food for local and export economies. There will be less interior options for carbon sequestration. There will be competition between people and wildlife for habitat. Under current permitting standards, an extensive loss of short-hydroperiod freshwater wetlands will occur and more of the landscape will become open water from borrow pit operations and creation of stormwater treatment retention areas (USCCSP 2008; Cerulean 2008; Titus 1998; Volk 2008; Bollman 2007).

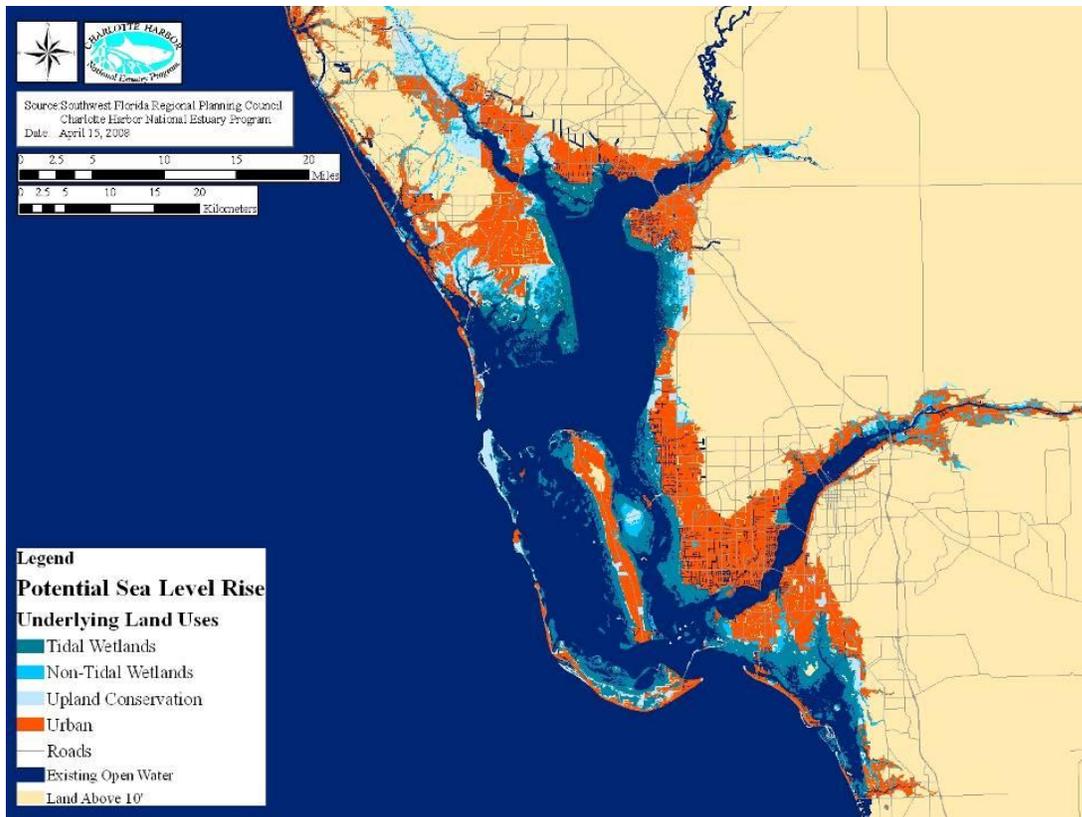
Sea level rise reduces the amount of land available above the tide for conservation both by direct physical replacement with submerged habitats and by shifting needs for human habitable and cultivation lands. In balance this could decrease the amount of land available for conservation (USNOAA 2008; Titus 1998; Volk 2008; USEPA CRE 2008).

<b>County</b>	<b>Total Area</b>	<b>Vulnerable Zone</b>	<b>% of County Area</b>
Sarasota	578	27	4.7
Charlotte	726	85	11.7
Lee	837	150	17.9
Collier	2,039	378	18.5
<b>Total</b>	<b>4,180</b>	<b>640</b>	<b>15.3</b>

**Table 23: Total Florida Landcover by County in Vulnerable Zone (27 inches of Sea Level Rise by 2060) In Square Miles**

<b>Year</b>	<b>Population</b>	<b>Urban Acres</b>	<b>% of Region Acres</b>
2005	1,238,844	662,294	15
2060	3,539,766	1,800,131	40
<b>Difference</b>	<b>2,300,922</b>	<b>1,137,837</b>	<b>25</b>

**Table 24: Population and Urban Area 2005-2060 projection for Southwest Florida (Charlotte, Collier, DeSoto, Glades, Hendry, Lee, and Sarasota Counties)**



**Figure 52: Year 2200 5-10 Foot Sea Level Rise with Location of General Land Use Types Affected in Southwest Florida**

The most significant negative short-term effect on mesoscale, or regional, climate will be from changes to urbanization and vegetation cover associated with sprawl and land use change. Efforts at climate mitigation that are most likely to have near-term positive effects should be directed toward managing the state's growth and land use so as to stabilize mesoscale changes in climate.

Because of Florida's rapid human population growth, there is likely less than a decade remaining to avoid significant additional mesoscale climate change from land use. It is still possible, though, to develop and implement best-practices that can mitigate for some of these changes (Mulkey 2007). For example, the forest, agricultural, and natural lands in Florida have yet to be managed for GHG offsets and mitigation, and thus they represent obvious targets for inclusion in a climate action plan for the state

It is important that Florida develop regional climate models capable of modeling heterogeneous atmospheric forcing (climate change derived from more than one source, including land use change, within the three climate zones of Florida. Targeted major funding for climate research groups at the state universities, and collaboration of state agencies with national and international climate modeling groups would help move this effort forward. The results of these models can be integrated into the state's economic projections.

## Human Economy

### Potential Future Climate Changes

Climate change will affect Florida's economy. The economic and financial costs associated with such change can be direct or indirect. Some costs are called "hidden" because they are difficult to identify and quantify. Many environmental and human costs cannot be measured in dollars. These include the effects on human quality of life and the destruction of ecosystems that currently provide essential ecological functions at no cost. Some sectors of the economy may actually benefit from climate change, and some of the costs of climate change may be offset by mitigation efforts. However, the net costs of climate change are likely to exceed the benefits. A recent national study, sponsored by the Center for Health and the Global Environment at Harvard Medical School, indicates that the economic impacts of climate change will be felt throughout the United States (Center for Integrative Environmental Research (CIER) 2007). These impacts will be unevenly distributed across regions and society, and negative impacts will outweigh benefits for most sectors that provide goods and services. The impacts will place immense strains on public sector budgets. The secondary impacts of climate change may include higher prices, reduced incomes, and job losses.

The CIER study (2007) predicts that major impacts on the southeast United States (including Florida) will be felt most acutely in coastal infrastructure. Forests, agriculture and fisheries, water supplies, water quality, and energy sources may be subject to considerable change and damage. Many of these sectors are closely linked. For example, energy supply depends on cooling water availability to power plants; emergency preparedness depends on transportation, energy supply, water availability, and more. Only a few of these interrelationships typically enter economic impact and cost assessments. These indirect links need to be considered as well as the economic cost assessments.

Another recent study also estimated the costs of inaction for Florida, should greenhouse gas emissions continue unchecked (Stanton and Ackerman. 2007). This study addresses both optimistic scenarios (rapid stabilization though greatly reduced emissions) and pessimistic scenarios (no change in the growth of emissions). The cost of inaction is the difference between these two scenarios. For just four categories of economic activity—tourism, hurricanes, electric power, and real estate—the cost of inaction ranged from \$27 billion by 2025 (or 1.6 percent of the projected gross state product) to \$354 billion in 2100 (about 5 percent of the projected gross state product). If estimates include other sectors, such as agriculture, fisheries, insurance, transportation, water systems, and ecosystem damages, the cost of inaction is even greater.

If climate change results in reduced runoff and lower groundwater levels for parts of the year, the consequence could be a shortage of water to satisfy both ecosystem needs and the growing and competing human demands (Twilley et al. 2001), resulting in wetland loss. Wetland loss will continue to convert land to open water, threatening the region's enormously valuable fisheries, aquaculture and coastal agriculture, as well as navigation and other industries located near the coast. Future wetland loss rates could increase as sea

level rise accelerates in the latter part of the 21st century (Twilley et al. 2001; Twilley et al. 2001).

Changes in estuarine water quality will affect ecosystem services which are provided by the environment at no investment cost, but which greatly enhance the Florida economy. These include sediment stabilization, water quality treatment, nursery functions for fisheries, and watchable wildlife (Peterson et al. 2007; USEPA CRE 2008).

Increases in drought-related fires would have severe impacts on managed forests and the timber-based economy of the region and would also pose substantial risks to nearby human development (Twilley et al. 2001). Most southern pine plantations are not managed regularly with prescribed burns because of management costs and legal liabilities, despite awareness of the need to reduce fuel loads. High fuel loads will increase the risks of wildfire, especially if the climate becomes more favorable to intensified fire cycles (Twilley et al. 2001).

In contrast, wildfires are critical for maintaining grassland communities such as coastal prairies, where woody plants typically invade prairies that are not mowed or burned. Increased fire frequency should help prairie conservation and the maintenance of grazing lands (Twilley et al. 2001).

Warmer average temperatures and milder winters are likely to result in a higher incidence of damage by agricultural and forestry pests such as the Southern Pine bark beetle (Twilley et al. 2001).

Plant growth and productivity could increase with higher atmospheric concentrations of carbon dioxide (CO<sub>2</sub>) and modestly warmer temperatures, as long as rainfall is not reduced. However, increased plant growth in response to higher CO<sub>2</sub> varies among species and higher CO<sub>2</sub> could drive changes in the mix of species and interactions within communities. Further, gains in plant productivity due to increased CO<sub>2</sub> could be countered by other climate-driven changes such as reduced moisture availability, higher ultraviolet-B radiation, limited nutrient availability, increased water stress, increases in pests and fires, and air pollution. For example, certain agricultural crops such as corn, sorghum, and rice could become more productive with higher CO<sub>2</sub> concentrations, assuming other stresses do not counter the fertilizer effects of CO<sub>2</sub> (Twilley et al. 2001). However, if the climate of the Gulf Coast turns drier overall, cotton, soybean, rice, and sorghum productivity could drop without irrigation and citrus production may shrink moderately in Florida (Twilley et al. 2001).

As rising sea temperatures cause a 5 to 10% increase in hurricane wind speeds, storm events will result in increased coastal erosion and there will be increases in insurance rates due to more severe wind-related hurricane damage to dwellings and other buildings, agriculture and public infrastructure. This will discourage creation and maintenance of dwelling units, public investment and utilities in coastal high hazard areas (USNOAA 2008; FOCC 2009; USEPA CRE 2008). Increasing population growth and increasing wealth structure has already vastly raised the potential financial damage a storm can inflict (USNOAA 2008).

Climate change will have other economic consequences including regional water shortages, increased ocean acidity affecting sport/commercial fishing, and increased salinity of drinking water supplies will make potable water more expensive. There will be road and infrastructure damage. Coastal cities' expenses will increase. Beachfront property will be lost. Coastal business expenditures will increase. The state may become less desirable to tourists. (USCCSP 2008; USNOAA 2008; USEPA CRE 2008).

It should be noted that adaptations to climate change effects will have consequences of their own. Short-term climate change adaptations implemented in the coastal zones by humans including canals, floodgates, levees, etc. may actually reduce the ability of coastal wetlands to deliver valuable ecosystem services. These structures cause changes in water availability for wetlands reducing their ability to store, distribute and purify water. Construction of bulkheads eliminates upslope vegetative transition zone migrations, causes loss of seaward habitat, and causes the loss of the ability of all habitat types to migrate inland with rising sea level (Ebi et al. 2007; Peterson et al. 2007; USEPA CRE 2008).

### *Tourism*

Each year visitors make 85 million trips to Florida's scenic beaches, rich marine ecosystems and abundant amusement parks, staying for an average of five nights per trip. Of these trips to Florida, 78 million are taken by domestic U.S. travelers—one trip per year for every fourth U.S. resident—and seven million trips by international visitors, one third of which are Canadian. A further 13 million Florida residents take recreational trips within Florida, and many more travel on business within the state, or participate in recreational activities near their homes (VISITFLORIDA 2007a; b).

In 2006, almost a tenth of the state economy—9.6 percent, or \$65 billion, of Florida's gross state product (GSP)—came from tourism and recreation industries including restaurants and bars; arts, entertainment and recreation facilities; lodging; air transportation; and travel agencies.

Tourism is the second biggest contributor to Florida's economy, after real estate (in 2007). As Gross State Product (GSP) grows six-fold over the next century, Stanton and Ackerman (2007) project that, in the rapid stabilization case, tourism and its associated taxes will remain a steady 9.6 percent of total GSP. Under these assumptions, Florida's tourism industry will bring in \$317 billion in revenues in 2050. Today, approximately 980,000 people make their living in Florida's tourism and recreation sector, 6 percent of the state's population. If the same share of state residents is still employed in tourism in 2050, 1.9 million Floridians will draw paychecks from restaurants, amusement parts, hotels, airports, and travel agencies (VISITFLORIDA 2007a; b).

The gradual climate change under the rapid stabilization case should have little impact on tourism, however, sea level rise and higher temperatures will alter the state's tourist economy to some degree. Negative impacts to state and local economies, individuals' livelihoods, and commercial/sport fishing could be expected. Erosion and/or destruction

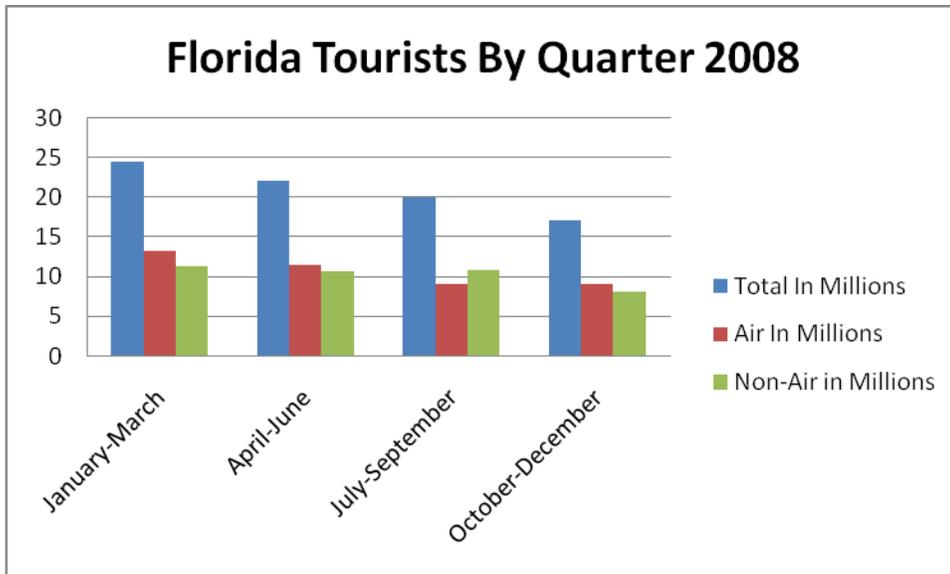
of beaches may greatly decrease tourist activity in those areas. Declines in fisheries may decrease sport fishing. Impacts to reefs may decrease interest in scuba diving and related activities (Fiedler et al. 2001; Lee County Visitor and Convention Bureau 2008).

In the Stanton and Ackerman (2007) worst case scenario, the future of Florida's tourism industry is clouded. By this estimation, Florida's average temperature increases 2.5°F by 2025, 5°F by 2050, and 10°F by 2100. In January, warmer temperatures are unlikely to deter many tourists, but in July and August, when the average high temperature on Miami Beach will rise from 87°F to 97°F over the next century, and the July heat index (temperature and humidity combined) will increase by 15 to 20°F, Florida's already hot and sticky weather is likely to lose some of its appeal for visitors.

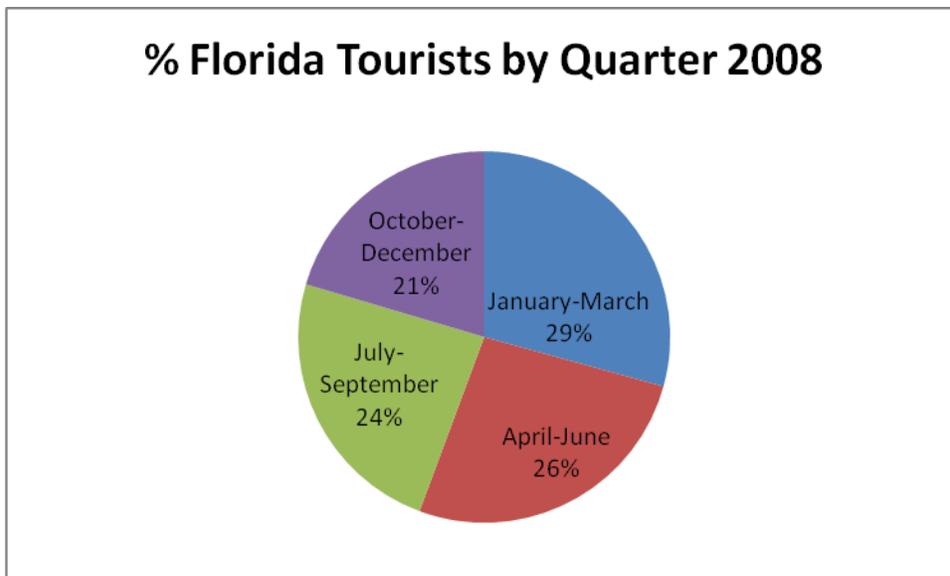
In the Stanton and Ackerman (2007) worst case scenario, sea levels in 2050 will have risen by 23 inches, covering many of Florida's sandy beaches. In theory, these beaches could be "renourished" by adding massive amounts of sand to bring them up to their former elevation, or the new coastline could be converted to beach recreation use, but only if residential and commercial properties in the zone most vulnerable to sea level rise are not "shored up" by sea-walls or levees.

With 45 inches of sea level rise over the next century, a Florida nearly devoid of beaches in 2100 is a possibility. Many of the marine habitats that bring divers, snorklers, sport fishers, birdwatchers and campers to Florida will also be destroyed or severely degraded over the course of the next century. Tourists are also attracted by Florida's natural environments and wildlife, but sea level rise will drown the Everglades and with it the American crocodile, the Florida panther, and many other endangered species. As Florida's shallow mangrove swamps and seagrass beds become open water (unless wetland ecosystems are permitted to migrate inland by allowing Florida's dry lands to flood) manatees and other aquatic species that rely on wetlands for food, shelter and breeding grounds will die out. Similarly, Florida's coral reefs will bleach and die off as ocean temperature and acidity increases.

Tourists are unlikely to come to Florida to see the dead or dying remnants of what are today unique treasures of the natural world.



**Figure 53 : Florida tourists by quarter 2008**



**Figure 54: Percent of Florida tourists by quarter 2008**

Estimates of the direct impact of hurricane damage on Florida’s economy are dealt with in a separate section of this report, but there are also important indirect effects on Florida’s reputation as a vacation destination. As the intensity of storms increases in the worst case, fewer visitors are likely to plan trips to Florida, especially during the June-to-November hurricane season. The possibility of being caught in a storm or forced to evacuate to a storm shelter will become a greater concern for tourists as the effects of climate change are featured more frequently on the evening news. Under these conditions, Florida’s tourism industry is almost certain to suffer; the exact decline in

future revenues and employment is, however, nearly impossible to estimate with any certainty. The calculations that follow are, therefore, a rough estimate based on a broad interpretation of existing data. Because Florida received 19 percent of its tourists in October through December in 2007, the fewest visitors of all four quarters, Stanton and Ackerman (2007) infer that the lowest number of trips to Florida in any month is about five million (VISIT FLORIDA 2007a; b). Stanton and Ackerman (2007) consider this to be the base rate for Florida's tourism at present; and assume it is the rate that is insensitive to weather: regardless of hurricanes and sweltering summers, at least five million people come to Florida each month. Some come for business, some to visit amusement parks (many of which are air conditioned, though outdoor areas, including waiting lines, obviously are not), and some, despite rain, humidity, and scorching heat, to the beach. This projection implies that three-quarters of all tourists would still come to Florida despite the worst effects of climate change, while one-quarter would go elsewhere or stay home.

Stanton and Ackerman (2007) make the same assumption for Florida residents' share of tourism and recreation spending: for one out of four recreational activities that Florida families would have taken part in, they will instead choose to stay in their air conditioned homes. They assume that under the worst case scenario, tourism and recreational activities decline gradually to 75 percent of the rapid stabilization case level by 2100. Midway through that decline, in 2050, Florida's tourism industry will be bringing in \$40 billion less in annual revenue and employing one million fewer people than it would in the rapid stabilization case, a loss of 1.2 percent of GSP. The annual cost of inaction reaches \$167 billion in 2100 — 2.4 percent of GSP.

### *Agriculture*

The mix of crop and livestock production in a state is influenced by climatic conditions and water availability. As the climate warms, some production patterns will shift northward. Increases in climate variability could make adaptation by farmers more difficult. Warmer climates and less soil moisture due to increased evaporation may increase the need for irrigation. However, these same conditions could decrease water supplies, which also may be needed by natural ecosystems, urban populations, and other economic sectors. Most studies have not fully accounted for changes in climate variability, water availability, and imperfect responses by farmers to changing climate. Including these factors could substantially change modeling results. Analyses based on changes in average climate and which assume farmers effectively adapt suggest that aggregate U.S. food production will not be harmed, although there may be significant regional changes.

Florida is one of the leading states in terms of cash revenue from farming, with irrigated cropland accounting for the high value of farm production. Yields of citrus fruits could decrease with warmer temperatures in the southernmost part of the state because of a lack of a sufficient dormant period. Changes in cotton and sorghum production are unclear — increasing CO<sub>2</sub> levels and rainfall would be likely to increase yields, but the shortened growing season brought on by increasing temperatures could result in plants producing fewer or smaller seeds and fruit, which would decrease yields. Increases in temperature

(about 6°F) and rainfall (10%) are projected to reduce corn yields by 14% (USEPA 1997).

Due to increases in precipitation of five to 10% over levels of the 20th century, including heavy and extreme precipitation events, in some areas of the state, certain crops, such as corn, soybeans, sorghum and peanuts could be reduced in their yields by as much as 20%. (Mulkey 2007)

Despite its profitability and importance to the state and the nation, Florida's agriculture faces serious constraints even in the best case scenario. Currently, there is little land remaining for expansion of agriculture. There is likely to be continued pressure on existing agricultural land from population growth, residential development, and sprawl. Florida's citrus industry will continue to suffer from citrus canker, a bacterial disease that causes fruit and leaves to be shed prematurely, and from citrus greening.

The citrus canker bacteria can be spread quite rapidly by wind-blown rain; hurricanes have transported the disease beyond the quarantine zones set up by farmers. The 2004 hurricanes led to the infection of 80,000 acres of commercial citrus; Hurricane Wilma in 2005 caused the disease to spread to an additional 168,000 to 220,000 acres (Schubert et al. 2001; Anderson et al. 2004; FDACS 2006a; d; 2007a). The increases predicted in wind speeds and storm intensities under various climate change scenarios could result in the further spread of this disease.

Even greater pressure on agriculture will result from the scarcity of water in the state. Florida's agricultural sector is already heavily dependent on irrigation: 80 percent of all farmed acres (excluding pasturelands) are irrigated (Marella 2004). In 2000, just under half of all freshwater withdrawals were used for agriculture. Citrus and sugarcane commanded 47 and 22 percent of agricultural water withdrawals, respectively; all vegetables, including tomatoes, used just over 10 percent; greenhouses and nurseries about 5 percent; and livestock less than 1 percent (FDACS 2003;Marella 2004).

In the worst case scenario, Florida's climate changes much more quickly: the state will become hotter and drier, and hurricanes and other extreme weather events will become more frequent. Temperatures climb four times as quickly in the worst case; as a result, impacts that don't arise until 2100 in the rapid stabilization case become important by 2025 in the business-as-usual case. The warmer weather and increased carbon dioxide levels that come with climate change could, at first, have some short-term benefits for Florida agriculture. Even in Florida, farmers can face heavy damages when temperatures dip below freezing, and these losses result in higher fruit and vegetable prices across the country. Rising temperatures would, on average, mean fewer winter freezes, a welcome change for many farmers.

In addition, some types of plants can photosynthesize more productively when levels of carbon dioxide are somewhat higher than at present. All the major crops grown in Florida, except sugarcane, fall into this category. The magnitude of this effect, however, is uncertain and by the end of the century, under the worst case scenario, carbon dioxide levels well beyond those which have been tested on plants will have been reached.

But reduced damages from freezing and benefits from carbon dioxide fertilization are not the only effects on agriculture in the worst case, and most of the other impacts are detrimental. As temperatures increase, citrus production in South Florida will begin to decline as periods of dormant growth, necessary to the fruit's development, are reduced (EPA 1997). Optimal temperatures for citrus growth are 68-86°F; at higher temperatures, citrus trees cease to grow (Ackerman 1938; Morton 1987). Production of tomatoes, too, will begin to decrease before the end of the century, as Florida's climate moves above their mean daily optimal temperature range of 68-77°F (Sato et al. 2000; U.S. Global Change Research Program 2001; Lerner 2006). Sugarcane may also suffer a reduction in yield; it belongs to a class of plants that benefit little from higher levels of carbon dioxide in the air, and it will have to compete with carbon-loving weeds (IPCC 2007a). If farmers increase herbicide use as a result, their production costs will increase accordingly, as will the environmental impacts of herbicide use. Sugarcane will also grow more slowly in the hotter, worst case climate; the optimal average growing temperature for sugarcane is 77–79°F (Vaclavicek 2004).

Due to the increased presence of pests, spraying is already much more common in warmer areas than in cooler areas (Karl et al. 2009). For example, Florida sweet corn growers spray their fields 15 to 32 times a year to fight pests such as corn borer and corn earworm, while New York farmers average zero to five times (Hatfield et al. 2008).

Even those agricultural commodities that thrive in higher temperatures and higher concentrations of carbon dioxide are at risk from other consequences of climate change, including the northward shift of some pest insects and weed species (IPCC 2001a). Flooding from sea level rise is another concern. With 27 inches of sea level rise in 2060, 4,500 acres of current pasture, 7,000 acres of citrus groves and 26,000 acres of other farmlands will be inundated.

Florida also has a long history of severe crop damage from hurricanes, and more intense storms may cause still greater losses. The 2004 hurricane season, for example, caused extensive damage to citrus groves, decreasing yields by 17 percent in the following year. In Indian River County, where Hurricanes Francis and Jeanne both struck, citrus production dropped by 76 percent and several other counties lost 40 to 50 percent of their crop (FDACS 2006b). Sugarcane is another vulnerable crop: flooding from hurricanes can easily damage sugarcane roots when moisture levels become too high (NRDC and Florida Climate Alliance 2001).

Climate change's biggest threat to Florida agriculture, however, may be increased water requirements for irrigation of crops and for livestock, accompanied by a decreased supply of freshwater. In addition to the water problems discussed above, higher temperatures will result in greater irrigation needs, as more water is lost to increased evaporation from the soil and transpiration from plants, while five to 10 percent less rainfall reaches plants in the Stanton and Ackerman (2007) worst case. In a statistical analysis of USDA data, Florida citrus and sugarcane was found to require approximately five and seven percent more water, respectively, for each degree (Fahrenheit) of mean temperature increase (USDA 2003).

## **Human Health**

### **Current Relationship of Human Health to Climate Changes**

Existing changes in climate patterns and extreme climatic events have already had a wide range of negative effects on human health and well-being in the United States and around the world. For example, severe heat waves, hurricanes, and floods have resulted in many deaths and injuries (Epstein 2005; Patz et al. 2006). In addition, stormwater discharges carry nutrients, toxins, and fecal contaminants from the landscape into receiving waterbodies. Pulses of fecal contaminants in stormwater runoff have caused the closure of beaches and shellfish beds and affect humans through recreational exposure (Dowell et al. 1995). Storm-induced increases in fertilizer runoff from agricultural and residential areas could affect the frequency, intensity, and duration of toxin producing red tides or harmful algal blooms, and promote the emergence of previously unknown toxic algae (Harvell et al. 1999). In other parts of the world, increases in waterborne diseases, such as cholera, have been directly linked to warming and extreme weather outbreaks. In the future, the potential exists for the reintroduction of mosquito-borne diseases, such as malaria and dengue fever, into areas where they do not currently exist, such as warmer regions of the United States, including Florida (Colwell 1996). Threats to ecosystems rich in biodiversity, such as coral reefs, mangroves, and seagrasses, will result in the loss of marine algae and invertebrates, some of which are sources of chemicals with disease-fighting properties (Epstein and Mills 2005).

The ability of the health care system to reduce these health risks in the face of climate change is an important consideration in any projections of vulnerability during the 21st century (Twilley et al. 2001).

Clear effects of climate change have now been established for several human infectious diseases, including malaria (Pascual et al. 2006; Hay et al. 2002), cutaneous leishmaniasis (Chaves and Pascual 2006), cholera (Koelle et al. 2005), plague (Stenseth et al. 2006, Snall et al. 2008), and dengue (Gazelles et al. 2005), as well as for diseases afflicting livestock (Gubbins et al. 2008), wildlife (Harvell et al. 2002), and coral (Harvell et al. 2002, Bruno et al. 2007). The complexities of these systems pose enormous challenges for the detection of climate effects, and for the isolation and integration of climatic and non-climatic effects. Most of the studies cited were able to detect a climate signal because they obtained high-quality data over long time (Ostfeld 2009).

Increased temperatures will affect the occurrence, extent and virulence of disease and parasitism in human, animal and plant populations. Increased parasite survival, increases in development rate, increases in geographic range, increased transmission, increased host susceptibility, compromised physiological function of hosts, decreased host immunity, and decreased survival of obligate symbiotes, such as the coral/algae symbiosis, are all to be expected (Peterson et al. 2007; FOCC 2009; USEPA CRE 2008). Gastrointestinal diseases, respiratory diseases, and skin, ear, and eye infections can result from eating contaminated fish and shellfish and can be acquired during the

recreational use of coastal waters. Since temperature, rainfall, and salinity all influence the risk of waterborne infectious diseases, this risk may increase with climate change (Twilley et al. 2001). Most of the germs that cause water-borne disease, such as viruses, bacteria, and protozoa, survive longer in warmer water. Bacteria also reproduce more rapidly in warmer water. Increasingly intense rainfall projected for Florida could also increase the prevalence of water-borne disease. Outbreaks of two of the most common forms of water-borne diseases, *Cryptosporidium parvum* and *Giardia lamblia*, have been found to occur after heavy rainfall events and cause contamination of drinking water (Rose et al. 2001). For most healthy people, an infection from a water-borne disease will cause diarrhea for a limited time and go away with no treatment needed. However, in the elderly, infants, pregnant women, and anyone with a weakened immune system, waterborne diseases can be very serious and even fatal. There are some water-borne diseases, such as hepatitis, that can cause serious and long-lasting illness even in previously healthy people (NRDC 2001).

Hotter temperatures, extreme rainfall and increased runoff can increase populations of disease carrying insects and boost the potential for transmission of diseases such as malaria and dengue fever. But actual incidences of these diseases will depend primarily on the responsiveness of the public health system and on the adequate maintenance of water-related infrastructure (Twilley et al. 2001). Vector-borne diseases are spread by mosquitoes, rodents, ticks, and other insects and animals. Malaria, encephalitis, and dengue fever are three examples of vector-borne diseases, as is the mosquito-transmitted West Nile Virus, which has recently caused several deaths in Florida. Rising temperatures could expand the range of many vectors, and can play a role in transmission of the disease itself. Each vector and disease will respond differently to temperature and other factors, including efforts at control. Because of high standards of living and better health infrastructure in Florida, vector-borne disease is less of a problem than elsewhere in the world (Balbus and Wilson 2001). Close monitoring and vigilance will be needed to ensure that diseases such as malaria, encephalitis, dengue fever, and West Nile Virus do not become more widespread problems in Florida (NRDC 2001).

Lafferty (2009) has asserted that early reviews about climate change exaggerated claims that diseases will increase in the future (Randolph 2009). Commentaries from ecologists with considerable expertise in infectious diseases illustrate several examples and case studies which correlate increases in infectious disease with existing climate variation, though alternative explanations exist for many of these patterns (Dobson 2009; Harvell et al. 2009; Ostfeld 2009; Pascual and Bouma 2009; Randolph 2009).

Although we need to focus control efforts on areas where diseases may expand with climate change (Dobson 2009; Pascual and Bouma 2009), it would not be appropriate to then build a general theory of climate change and infectious disease around the one-tailed prediction that climate change will increase the problem of infectious diseases (Randolph 2009). A neutral starting hypothesis is that the ranges of infectious diseases will likely shift with climate change, but not necessarily expand or contract (Lafferty 2009). While public health officials might view this as callous, conservation biologists might find it overly generous.

The shift in the habitat suitability for malaria illustrates the rich set of interacting factors that make it difficult to predict net outcomes in the geographic range of disease and the number of infected humans. Exposure to malaria induces temporary immunity (Dobson 2009) and, over evolutionary time scales, has led to adaptations to reduce infection or increase tolerance (e.g., sickle-cell trait; Allison 1954). If the range of climate suitability for malaria transmission shifts, then newly exposed human populations will be more susceptible to infection and likely suffer greater morbidity (Dobson 2009, Pascual and Bouma 2009). This is particularly relevant for moderate-scale shifts in transmission that could occur within the present poverty prone areas where malaria is endemic (Ostfeld 2009). Whether malaria will disappear from areas where it becomes too hot or arid may depend on how human societies respond to climate change, particularly with respect to damming and irrigation practices to compensate for drought (Pascual and Bouma 2009). In contrast, larger-scale shifts in habitat suitability into wealthier nations at higher latitudes are likely to be countered by control efforts, urbanization, and lack of suitable habitat for vectors (Randolph 2009). Table 25 includes information on climate related disease occurrence in the study area.

County	Dengue and dengue hemorrhagic fever	Malaria	West Nile Virus	Yellow Fever	Encephalitis including St. Louis, California	Equine Encephalitis (Eastern & Western)	Lyme Disease ( <i>Borrelia burgdorferi</i> )	Rocky Mountain Spotted Fever	Ehrlichiosis	Typhus Fevers
Charlotte	1	4	0	0	7	0	14	0	1	0
Collier	3	44	3	0	11	0	3	0	1	0
DeSoto	0	0	1	0	0	0	0	0	0	0
Glades	0	0	0	0	0	0	2	0	0	0
Hardee	0	1	0	0	3	0	0	1	0	0
Hendry	0	1	0	0	0	1	0	0	1	0
Lee	5	31	5	0	17	0	37	6	2	2
Manatee	2	8	1	0	3	0	19	0	2	0
Polk	4	21	1	0	4	2	9	2	1	0
Sarasota	0	13	6	0	28	0	55	5	3	0
<b>Totals</b>	<b>15</b>	<b>123</b>	<b>17</b>	<b>0</b>	<b>73</b>	<b>3</b>	<b>139</b>	<b>14</b>	<b>11</b>	<b>2</b>

County	Plague ( <i>Yersinia pestis</i> )	Chagas ( <i>Trypanosoma cruzi</i> )	Rabies (possible exposures)	Hantavirus	Tularemia ( <i>Francisella tularensis</i> )	
Charlotte	0	X	0 (298)	0	0	
Collier	5	X	1 (382)	0	0	
DeSoto	1	X	0 (4)	0	0	mosquito-borne
Glades	0	X	0 (1)	0	0	tick-borne
Hardee	0	X	0 (35)	0	0	flea-borne
Hendry	1	X	0 (44)	0	0	other insect-borne
Lee	2	X	0 (624)	0	0	mammal-borne
Manatee	0	X	0 (225)	0	0	
Polk	2	X	0 (21)	0	0	
Sarasota	0	X	0 (189)	0	0	
<b>Totals</b>	<b>11</b>		<b>1 (1823)</b>	<b>0</b>	<b>0</b>	

Table 25: Tropical diseases occurrence in southwest Florida

Higher temperatures poses potential health threats of several kinds: direct health stresses, increased prevalence of disease, and potentially increased smog formation. Although these effects cause concern, there is considerable uncertainty in the level of harm that will occur and some specialists believe that increased threats could be handled adequately by the healthcare system (Natural Resources Defense Council (NRDC) 2001).

Given the make-up of Florida's population, the state is particularly vulnerable to health impacts of climatic warming. In general, the elderly, the young and other segments of the population with impaired health will be most affected. Low-income populations may also be at risk because they typically have less access to high quality healthcare (NRDC 2001).

Increased heat stress could result in increased human mortality, particularly for the elderly, ill and less wealthy in the population and those that exercise strenuously in midday heat such as athletes, exterior construction workers, and children. Southwest Florida is vulnerable to increased frequencies of heat waves, which could increase the number of local heat-related deaths and the incidence of heat-related illnesses, particularly among the large numbers of older residents and visitors (Twilley et al. 2001). Projected changes in the heat index for Florida are the most dramatic in the nation: an increase of eight to 15 degrees Fahrenheit is likely during the next century (United States Global Change Research Program 2001).

The elderly are particularly vulnerable to severe heat-related illness and death. Seniors over 65 years old today constitute about 18 percent of Florida's population, and that figure is forecast to climb to over 26 percent by 2025 ( U.S. Census Bureau 2004b). At the same time that Florida's climate is increasingly affected by global warming, the population of the most severely affected age group is growing rapidly. Many factors combine to put Florida's 2.8 million senior citizens at greater risk of suffering a heat-related illness or death (NRDC 2001):

- Impaired ability to disperse heat through the body's physiological mechanisms
- Greater risk of having underlying diseases
- Greater risk of taking medications that may contribute to heatstroke
- Limited mobility
- Compromised temperature perception

Others vulnerable to heat stress are persons working or exercising in the heat, such as construction workers, farmers, theme park workers, and even tourists themselves (Kilbourne1998). Low-income households are less likely to have air conditioning and may be at higher risk than the general population. One study projected that the number of people dying each year from heat stress in Tampa would more than double by the year 2020 (Kalkstein 1997). However, Florida is well adapted to high temperatures compared to more northern regions, and may be able to adjust without substantial harm. Additional research is required to draw more certain conclusions about heat-related deaths (NRDC 2001).

Sea level rise will also affect the availability and distribution of high-quality freshwater available for drinking because many Gulf Coast aquifers are susceptible to saltwater intrusion. Drinking water supplies taken from surface waters for coastal communities such as Punta Gorda and Fort Myers will be more frequently threatened by saltwater intrusion caused by a combination of sea level rise, land subsidence, and periodic low river flows (Twilley et al. 2001).

The concentration of air pollutants such as ozone is likely to increase in Gulf Coast cities. Ground-level ozone has been shown to reduce lung function, induce respiratory inflammation, and aggravate chronic respiratory diseases like asthma, obstructive pulmonary disease (Twilley et al. 2001). Higher temperatures that increase the rate of smog formation will result in cardiovascular diseases, chronic respiratory diseases like asthma or obstructive pulmonary disease and reduced lung function (Fiedler et al. 2001; SCCP 2005). Increased use of fossil fuels could increase a range of air pollutants. Ground-level ozone, which is a major component of smog, is formed from nitrogen oxides and volatile organic compounds. With warmer temperatures and sunlight, this reaction proceeds faster and forms more smog. Higher temperatures also cause more evaporation of volatile organic compounds when refueling and operating vehicles, further contributing to smog formation. Smog formation is also influenced by rain and wind patterns, not just temperature. Increased rainfall and stronger winds could actually decrease smog formation. Predictions of changes in air quality as a result of global warming are very difficult to make, because global warming will affect rainfall and wind patterns in uncertain ways (NRDC 2001).

Fossil-fuel use is projected to increase under the scenarios considered. In fact, there may even be an increase in energy consumption to power air conditioners as people adapt to warmer temperatures. Without improvements in technology, this would lead to increased amounts of air pollutants, such as sulfur oxides, nitrogen oxides, volatile organic compounds, and particulate matter. However, increased air pollution could be avoided by technological developments and more stringent regulations that would increase energy efficiency and further control air pollutants. In the absence of controls, carbon monoxide, sulfur oxide, and nitrogen oxides aggravate existing cardiovascular diseases, and may produce lung irritation and reduced lung function. As with heat effects, seniors, the young, and those with existing health problems are particularly at risk. Seniors over the age of 65 are more apt to have underlying conditions exacerbated by air pollution and therefore are at higher risk of suffering the consequences of air pollution (NRDC 2001).

### **Potential Future Climate Changes**

Heat waves are considered to be events in which there are temperatures greater than 90°F for several days in a row with warm, stagnant air masses and consecutive nights with higher-than-usual low temperatures. Heat waves are expected to increase in severity and frequency as a result of climate change. Heat waves are already the cause of the most weather-related deaths in the U.S. Studies suggest that, if current emissions hold steady, excess heat-related deaths in the U.S. could climb from an average of about 700 each year currently, to between 3,000 and 5,000 per year by 2050. The elderly are especially

vulnerable (CDC, Heat waves, 2009). Higher temperatures and increased frequency of heat waves may increase the number of heat-related deaths and the incidence of heat-related illnesses. Recent scientific work suggests that 28 people die every year in Tampa from heat-related causes during the summer. Even if people adjust to climate change, a 3°F warming could more than double this figure; as many as 68 additional heat-related deaths could occur every year in Tampa during the summer. The elderly, particularly those living alone, are at greatest risk (USEPA OPPE 1997).

There is concern that climate change could increase concentrations of ground-level ozone. For example, specific weather conditions, strong sunlight, and stable air masses, tend to increase urban ozone levels. While Florida is in compliance with current air quality standards, increased temperatures could make remaining in compliance more difficult. Ground-level ozone has been shown to aggravate existing respiratory illnesses such as asthma, reduce lung function, and induce respiratory inflammation. In addition, ambient ozone reduces agricultural crop yields and impairs ecosystem health (USEPA OPPE 1997). Ozone and airborne particulate matter have well-documented human health effects that may be exacerbated with the increases in their concentrations that will likely occur with climate change. Fine particulate matters are associated with respiratory and cardiovascular diseases, including asthma, COPD, and cardiac dysrhythmias, and are responsible for increased school and work absences, emergency department visits, and hospital admissions (CDC, Air quality and respiratory disease, 2009).

Changing climate conditions also may affect human health through impacts on terrestrial and marine ecosystems. In particular, warming and other climate changes may expand the habitat and infectivity of disease-carrying insects; increasing the potential for transmission of diseases such as malaria and dengue fever. Although dengue fever is currently uncommon in the United States, conditions already exist in Florida that makes it vulnerable to the disease. Warmer temperatures resulting from climate change could increase this risk (USEPA OPPE 1997).

Sea surface warming and sea level rise could increase health threats from marine-borne illnesses and shellfish poisoning in Florida. Warmer seas could contribute to the increased intensity, duration, and extent of harmful algal blooms. These blooms damage habitat and shellfish nurseries, can be toxic to humans, and can carry bacteria like those causing cholera. In turn, algal blooms potentially can lead to higher incidence of water-borne cholera and shellfish poisoning. Acute poisoning related to the consumption of contaminated fish and shellfish has been reported in Florida (USEPA OPPE 1997).

Increased ambient temperatures and humidity along with increased ground-level carbon dioxide will result in increased plant metabolism and pollen production, fungal growth and spore release. Pollen and mold spores can aggravate allergic rhinitis and several other respiratory diseases including asthma. Allergic diseases are already the sixth leading cause of chronic disease in the U.S. Aero-allergens can also combine with pollutants to worsen respiratory diseases (CDC, Aero-allergens, 2009).

Climate change is likely to affect insects and animals that spread diseases, much as it will wildlife. Increased temperature is likely to speed up the metabolisms and life cycles of

disease-spreading organisms such as mosquitos and ticks and allow increases in ranges for species that have been confined to tropical environments. Mosquitoes' metabolism and consumption of blood meals speeds up with increased temperatures, up to a certain point which varies with species. Lyme disease and hantavirus have shown evidence of seasonality, thus the ranges of those diseases could change with climate change. Flooding from more intense rain events may introduce standing water in which mosquitoes can breed, while increased drought may improve conditions favorable to ticks. (CDC, Vector-borne and zoonotic disease, 2009)

Experts estimate water- and food-borne diseases already cause more than 210 million cases, 900,000 associated hospitalizations, and 6,000 deaths annually, caused by bacteria, viruses and parasites. Several water- and food-borne diseases show seasonal patterns, suggesting that they are subject to environmental influences, in terms of pathogen replication, survival, and persistent rates; transmission rates; and disease ranges overall. Temperature and precipitation, both of which will increase with climate change, will affect the spread of water- and food-borne diseases, resulting in higher pathogen replication, persistence, survival, and transmission for bacterial pathogens, and having mixed effects on viral pathogens. Higher temperatures seem to produce a greater number of water- and food-borne parasitic infections. Overall, increased precipitation is associated with increased burdens of disease for bacteria, viruses, and parasites, though the causes of these increases differ by pathogen and ecologic setting. (CDC, Water- and food-borne diseases, 2009)

Indirect health effects include injuries or death from wildfires resulting from more frequent and prolonged drought; conflict over water and other scarce resources; mass population movement; and increased ocean acidity resulting in severe stress on ocean ecosystems, particularly in the tropics. Adaptation to climate change may also increase the risk of certain health conditions, including adoption of new fuels, shifting to other energy sources such as nuclear power, and new methods of reclaiming and purifying waste-water for human consumption. (CDC, Other indirect health effects, 2009)

Other circumstances may interact with climate change in varying ways. Geologic and political limitations on the supplies of fossil fuels; increasing worldwide population; decreased freshwater availability worldwide; worldwide migration to urban areas; and increasing worldwide cost of food and resulting food shortages, among other factors may have effects on human health worldwide. (CDC, Interacting trends, 2009)

## **Infrastructure**

### **Potential Future Climate Changes**

Much of Florida's infrastructure, water, power, telecommunications, transportation, and buildings, were constructed to last at least 75 years. Infrastructure longevity was thus based on past environmental design criteria and specifications, many of which may have been exceeded already by aspects of climate change (Alvarez 2008). Much of this infrastructure will need to be replaced or improved during the time course of ongoing

climate changes. An opportunity exists to relocate, harden, and adapt the infrastructure to conditions in ways that avoid or mitigate the potential effects of climate change. (Victorian Climate Change Program (VCCP) 2008)

Climate change is likely to have a significant impact on human infrastructure, particularly at the coasts (FOCC 2009). Sea level rise will stress this infrastructure (buildings, roads, bridges, etc) physically, as salinity changes may affect the structural integrity and/or functionality of physical materials that comprise the features of roads, ports, airports, rail systems, increasing fatigue, reducing effective functional life and requiring accelerated maintenance (USNOAA 2008; SCCP 2005; USEPA CRE 2008). More frequent flooding and erosion will occur. Bridges may be too low for new water levels (USCCSP 2008; University of Washington 2007; US NOAA 2008; Volk 2008; SCCP 2005; USEPA CRE 2008). Increased flooding will affect human-inhabited areas and result in more roadway washouts (USNOAA 2008; USEPA CRE 2008).

Whether or not global warming increases the number or intensity of hurricanes, future storm damages are likely to rise substantially because of the increasing amount of development in harm's way and the aggravating impacts of higher sea levels and degraded coastal ecosystems. Predictions of future wave and storm surges accompanying severe hurricanes (categories 3-5) indicate that significant wave heights (between three and six feet) could reach further inland if barrier islands and wetlands are lost as buffers (Twilley et al. 2001).

With 88 % of all structures in Southwest Florida vulnerable to tropical storms hurricanes and surge events; debris management capacity (as has been observed in Charley and other devastating storm events) is a key critical vulnerability and the capability to manage this level of debris and damage, some of which will be hazardous will need to be considered. While solid (and hazardous) waste facilities and landfills are considered as critical facilities in local government's local mitigation strategies many of the facilities in southwest Florida are located in low-lying wetland areas and within the storm surge and 100 year floodplains. There was significant difficulty with managing the debris from the 2004-2005 hurricane seasons in southwest Florida with the need to designate temporary staging areas and no long term plan than to expand existing facilities in place in vulnerable locations. To date significant waste and debris is found in the estuary and associated wetlands and native uplands where little official effort, other than volunteer efforts, was undertaken to remove anthropogenic materials of all types, including hazardous material, from non-navigable waters and wetlands.



Photograph 9: Raccoons take shelter under building debris post Hurricane Charley, Matlacha Pass, mangroves, Lee County.

Source: L. Beever CHNEP 2004

### *Energy Infrastructure*

The state's electricity market is growing rapidly. These increasing demands on the energy sector are expected to be strained by global climate change, at significant cost to Florida's consumers. Among the impacts of climate change projected in the IPCC 2007 report, several will affect electricity demand, generation, and distribution capacity in Florida, including warmer and more frequent hot days and nights; an increase in the frequency of heat waves; more intense hurricanes; possible coastal flooding from storms surges and sea level rise; and changes in the availability of water for cooling processes.

Additional regulation of energy providers (power plants) is likely to increase consumer costs. There will possibly be greater variability in energy availability depending upon the local conditions that make solar, wind, hydrologic and geothermal sources available. Development of new technologies could offset the costs and decreases in reliability when completed but there will be a period of transition with concomitant inefficiencies that will translate as costs (USEPA CRE 2008).

While much of Florida experiences over a half year of comfortable temperatures between 70 and 85°F, the state has the warmest daily average temperatures in the nation, and

summers are hot and humid (O'Brien and Zierden 2001). In 2005, 74 days had highs of 90°F or more, while winter highs dropped below 70°F on only 19 days. Higher atmospheric temperatures will mean that air conditioners run through more of the year, power plants will use significant energy to cool equipment, and power lines will operate less efficiently than they would in a cooler climate. Rising temperatures will dramatically increase demand and further degrade system-wide efficiencies.

The state's older population, highly dependent on air conditioning, will ensure that energy demand remains tightly coupled to temperature. With more frequent heat waves, there may be a need for costly emergency energy infrastructure to reduce heat-related injuries or illness. Without mitigation, the increasing number of Florida customers will stretch current infrastructure, particularly when power demands peak.

### *Electricity demand projections*

In the rapid stabilization case outlined previously, electricity demand will rise mostly due to rapid demographic growth and increasing demands for electricity from residential and commercial consumers; climate change will play only a minor role. The Florida Public Service Commission recorded an increase in residential use per capita of 7 percent between 1995 and 2005, and has projected future increases of 0.84 percent per year (Murelio 2003). The Energy Information Administration (EIA) (2007) projects a 0.76 percent annual increase in commercial use per capita until 2030. Residential housing, amongst the fastest growing sectors in the state, will consume increasing amounts of electricity for lighting, air conditioning, and entertainment. The EIA estimates that, after lighting, the largest use of residential electricity is for air conditioning, a factor which is expected to grow through 2030 at nearly 1 percent per year (EIA 2007). Coupled with Florida's rapid demographic growth, the Florida Reliability Coordinating Council (FRCC) expects an annual compounded growth rate of 2.4 percent in summer peak demand and 2.8 percent in total state energy consumption between now and 2015.

Based on this picture of a rapidly growing state population and economy, Stanton and Ackerman (2007) project average annual growth in electricity demand, from 2005 through 2100, of 1.54 percent before considering any effects of temperature changes. A review of Florida's electricity generation by hour indicates that it is closely correlated with temperature (EPA 2007c; NOAA 2007b). Power generation increases at both low and high temperatures to meet heating and cooling demand, respectively, and is lowest at approximately 67°F. In 2005, 85 percent of the hours of the year were above 67°F, a percentage that will rise to 93 percent by 2050 and to 96 percent by 2100. All other things being equal, therefore, we would expect a steep increase in electricity demand in line with warming. In the worst case scenario, average annual temperatures rise by more than 9.7°F by 2100, causing a much more noticeable impact on the electricity system.

On the one hand, this will ease the pressure of winter demand for heating, surprisingly a major factor in Florida's electricity use at present. In 2003, winter demand prompted the state to issue an advisory while local utilities asked consumers to conserve power (Murelio 2003). On the other hand, air conditioning demand on scorching days in the summer will quickly push up against the limits of system capacity. In 2005, 74 days had

highs exceeding 90°F. This may climb to more than 90 days a year by 2020, 150 days by 2050, and nearly two-thirds of the year by 2100. In the rapid stabilization case, where a temperature increase of only 2.2°F is expected by 2100, warming will add only 0.07 percent to electricity demand growth each year, for a combined annual growth rate of just over 1.6 percent. By 2100, Stanton and Ackerman (2007) project Florida's total electricity demand will be about 4.5 times as large as in 2005.

For the worst case scenario, Stanton and Ackerman (2007) project that warming will add an average of 0.34 percent to the growth of electricity demand each year, for a combined annual growth rate of 1.88 percent. By 2100, they project Florida's total electricity demand will be about 5.9 times as large as in 2005. There is a large gap between the sizes of the electricity system in the two scenarios: by 2100 the difference between the two scenarios amounts to 1.4 times the total amount of electricity the state produced in 2005.

### *Electricity supply projections*

Unfortunately, the same high temperatures that cause electricity demand to spike also impair the efficiency of power system components, including central generating stations as well as transmission and distribution equipment.

Due to their inability to cool components as quickly, thermal generators have lower efficiency at higher ambient temperatures. When air temperatures rise above design expectations, they are unable to produce as much power. For example, in gas turbines, performance decreases with increasing temperatures, and power output drops off significantly at temperatures over 100°F. In Florida's current system, gas and oil systems lose approximately one percent efficiency for every 4°F temperature increase (EIA 2007). Florida relies heavily on seawater to cool power plants; increases in ocean temperature will reduce the cooling efficiency, and thus impair generation efficiency. At a New York nuclear plant, generation efficiency drops rapidly if river water used for cooling rises above 50 to 60°F; output drops by as much as 2 to 4 percent when water temperatures reach 85°F (Powers 2003). While these declines in efficiency may appear relatively small, the losses can have dramatic consequences across the system, particularly during heat waves when these resources are needed most urgently.

There is a high likelihood that water shortages will limit power plant electricity production in many regions (Karl et al. 2009), and future water constraints on electricity production in thermal power plants are projected for Florida by 2025 (Bull et al. 2007).

When the amount of electricity carried over transmission lines increases (for example on a hot day when many people are using air-conditioning), power lines heat up, stretch, and sag. An overloaded power line can sag so much that it comes in contact with a tree, or comes close to the ground, creating a short-circuit as electricity is discharged, and potentially leading to power outages. Higher ambient temperatures also decrease the maximum current carrying capacity of transmission and distribution lines.

The effect of high temperatures on power system components was highlighted during the widespread power system outages in the summer of 1999. On July 6<sup>th</sup>, a heat wave with

sustained temperatures of 100°F caused overloads and cable failures, knocking out power to 68,000 customers (U.S. Department of Energy 2000). Outages in New York City were due to heat-related failures in connections, cables and transformers. In the South Central region, power plants were not able to produce as much power as predicted, leading to system failures. Small inefficiencies at multiple power plants added up to losses equivalent to 500 megawatts.

To calculate costs for the two scenarios (rapid stabilization and business-as-usual), Stanton and Ackerman (2007) constructed a simple simulation of electricity demand and supply in Florida to 2100. The model accounts for changes in population, per capita demand, and temperature, but holds fuel prices and the cost of new power plants constant (EIA 2007). For the rapid stabilization scenario, the simulation assumes a slowly changing fuel mix, migrating towards increasing efficiency measures and use of renewable energy sources such as wind power, while phasing out oil and coal. With increasing petroleum scarcity, adoption of policies to reduce greenhouse-gas emissions, and resulting demand for better efficiency and widespread renewable energy sources, Stanton and Ackerman (2007) envision a cleaner portfolio with coal use falling steadily by 2100 and use of oil for electricity generation discontinued by 2050. In place of fossil fuels, the cleaner portfolio relies on rigorous new conservation measures that will reduce demand by 40 percent, along with expanded renewable electricity production, supplying 30 percent of electricity demand by 2100.

Such changes are entirely in line with Governor Crist's Executive Orders on climate change of July 2007; indeed, in order to meet the governor's targets for reduced greenhouse gas emissions, as set out in those orders, a massive shift to energy efficiency and renewable energy sources will be necessary. A June 2007 report from the American Council for an Energy-Efficient Economy (ACEEE) argues that Florida can afford to do even more than the cleaner portfolio used in the simulation (Elliott 2007).

For the worst case, on the other hand, Stanton and Ackerman (2007) assumed that the state will satisfy the growing demand for electricity by maintaining the current fuel mix. In this scenario, Florida will need to build approximately five gas plants, four oil plants, and one coal plant in Florida *every year* for the foreseeable future. Even assuming that it was possible to obtain regulatory approval for all these facilities, and to site and construct them and the associated transmission lines, it is uncertain where adequate cooling water would be obtained. And the costs of securing those approvals, and siting and constructing those plants and transmission lines, would inevitably lead to price increases.

Stanton and Ackerman (2007) estimate that in the worst case, the *annual* cost of power in Florida will rise to \$43 billion in 2050 and to \$78 billion by 2100 (see Table 28). A substantial portion of this growth can be attributed to booming population and energy demand, and is required even in the rapid stabilization case, but the difference between the two scenarios accounts for an added \$18 billion a year by 2100. By the end of the century, every additional degree Fahrenheit of warming will cost electricity consumers an extra \$3 billion per year.

According to the simulation, the increasing population and demand for power in the business as-usual scenario will require an untenable 1,500 new sources of generation, nearly 400 more than would be required in the rapid stabilization case (EIA 2007). Significant new construction may be required in any case to supply electricity for Florida’s growing economy, but the costs will be much higher under the worst case scenario than under the rapid stabilization scenario.

	2025	2050	2075	2100
<b>Best Case</b>	22.4	37.6	48.1	60.2
<b>Worst Case</b>	23.5	42.5	58.4	78.2

**Table 26: Electricity Sector: Costs of Climate Change in billions of 2006 dollars**

In the worst case scenario, the electric system has to adapt not only to gradual average temperature increases, but to increasing temperature variability as well, presenting additional challenges and expenses to the energy sector. Highly variable temperatures require a greater number of expensive “peaking” power plants to be online, that sit idle most of the time, but provide enough electrical generation capacity to meet peak demand for cooling on hot summer afternoons. As a result, both the costs of generation and the overall size of the power grid in Florida will be larger than would be needed in the absence of climate change.

	2004 Hurricanes				2005 Hurricanes			
	Charley	Frances	Ivan	Jeanne	Dennis	Katrina	Rita	Wilma
Hurricane Category	4	2	3	3	3	2	2	3
Florida sustained winds (mph)	145	105	130	120	120	80	62	125
Number of Utility Restoration Personnel	19,860	21,172	6,430	27,320	5,353	14,820	546	19,121
Customer Power Outages (thousands)	1,800	4,500	400	3,500	500	1,200	25	3,551

**Table 27 Hurricane Impacts on Florida’s Electric Utilities**

*Sources: Florida Division of Emergency Management, Hurricane Impact Report (Florida Division of Emergency Management 2004); Florida Division of Emergency Management, Draft Hurricane Impact Report (Florida Division of Emergency Management 2007).*

Infrastructure vulnerability to storm damage has already been keenly felt in Florida during the 2004 and 2005 hurricane seasons. The four hurricanes that struck the state during each of those two years resulted in damage restoration costs for Florida's privately owned electric utilities of over \$1.2 billion in 2004 and \$0.9 billion in 2005.

Currently there are 15 plants, representing 22 percent of Florida's total generation capacity (13 GW) located in storm surge zones for Category 1 hurricanes, and up to 36 plants (over 37.8 percent of capacity) are vulnerable to Category 5 hurricanes. Some of Florida's largest coastal resources are also the most vulnerable, as estimated from the state's "surge zones" (Florida State Emergency Response Team 2006).

### *Other infrastructure*

Increases in precipitation of five to 10% over levels of the 20th century, including heavy and extreme precipitation events, will result in increased flash flooding, thereby affecting road washouts (UWCES 2007; USNOAA 2008; SECCP SDRT LCCP 2005, FOCC 2009, USEPA CRE 2008).

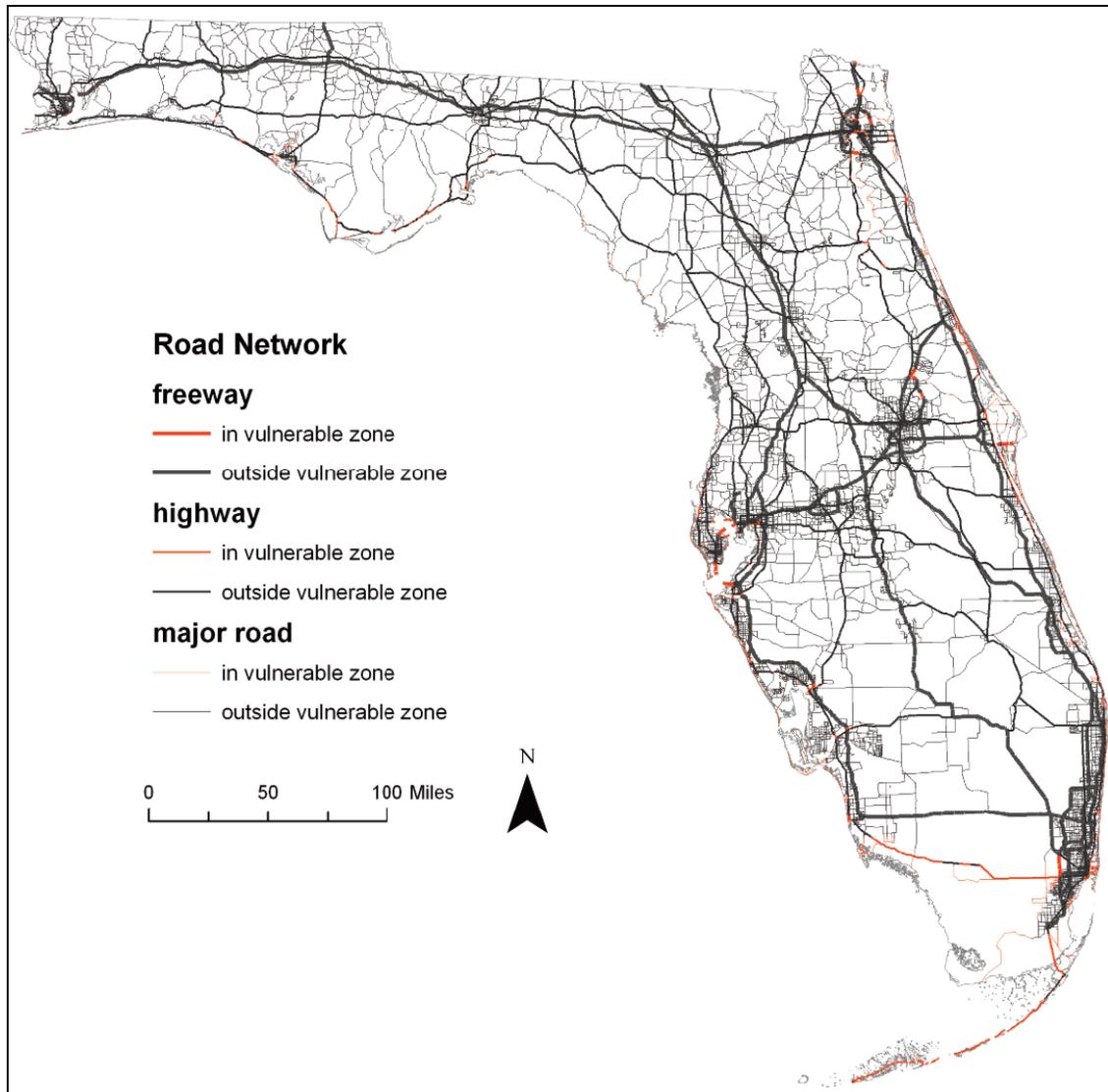
Sea level rise, combined with high rates of subsidence in some areas, will make much of the existing transportation infrastructure more prone to frequent or permanent inundation; 27 percent of the major roads, nine percent of the rail lines, and 72 percent of the ports in the southeastern United States are built on land at or below four feet in elevation, a level within the range of worst case projections for relative sea level rise in this region in this century. Increased storm intensity may lead to increased service disruption and infrastructure damage (Karl et al. 2009). More than half of the southeastern United States' major highways (64 percent of interstates, 57 percent of arterials), almost half of the rail miles, 29 airports, and virtually all of the ports, are below 23 feet in elevation and subject to flooding and damage due to hurricane storm surge. These factors will merit consideration in today's transportation decisions and planning processes (Kafalenos et al 2008).

Transportation infrastructure in Florida will be damaged by the effects of sea level rise, particularly in combination with storm surge (Stanton and Ackerman 2007). Many types of transportation infrastructure, including port facilities, airport runways, railways, and especially roads, are at risk. Docks and jetties, for example, must be built at optimal heights relative to existing water levels, and more rapid sea level rise may force more frequent rebuilding. Roads, railroads, and airport runways in low-lying coastal areas all become more vulnerable to flooding as water levels rise, storm surges reach farther inland, and coastal erosion accelerates. Even roads further inland may be threatened, since road drainage systems become less effective as sea levels rise. Many roads are built lower than surrounding land to begin with, so reduced drainage capacity will increase their susceptibility to flooding during rainstorms (Titus 2002).

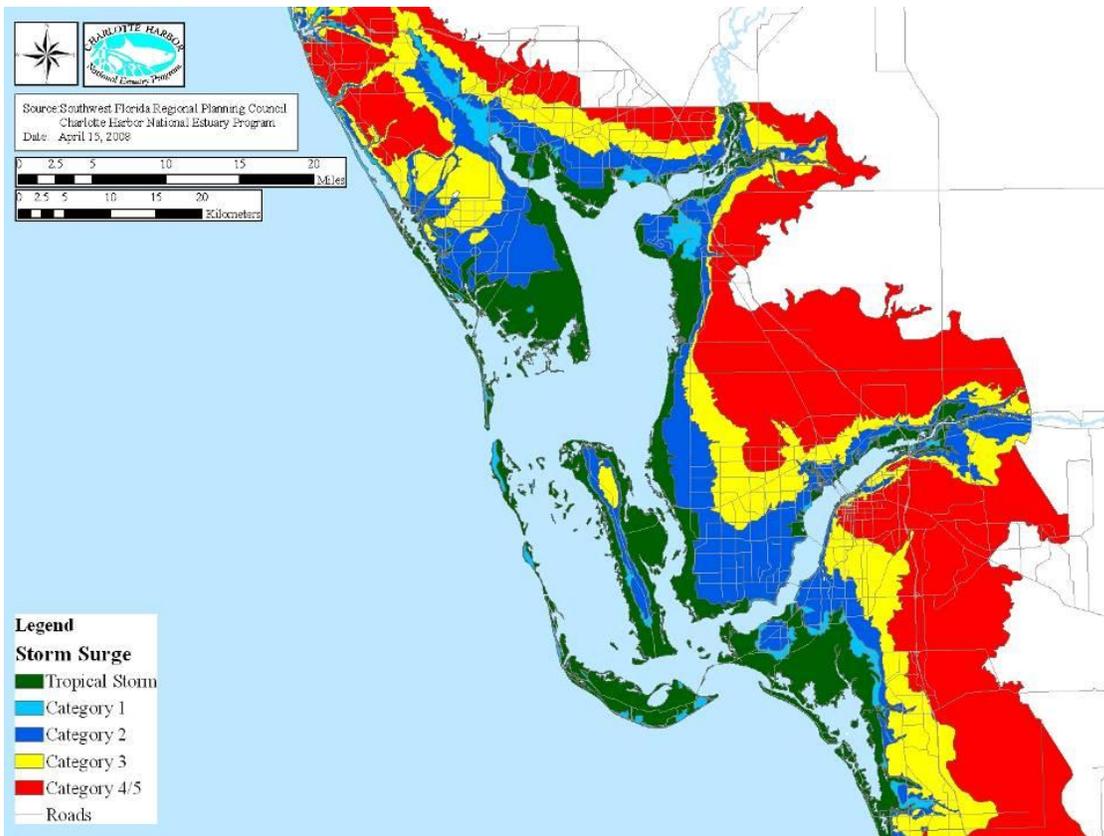
	Limited Access Highways (miles)	Other Highways (miles)	Major Roads (miles)	Railroads (miles)
<b>Florida Total</b>	<b>75.5</b>	<b>390.8</b>	<b>1972.4</b>	<b>181.3</b>
<b>Charlotte</b>	1.9	6.1	51.4	3.5
<b>Collier</b>	46.4	101.4	2.3	
<b>Lee</b>	1.4	3.5	97.5	1.5
<b>Manatee</b>	8.8	3.3	40.6	2.8
<b>Sarasota</b>	0.1	12	44.2	
<b>Region</b>	12.2	71.3	186.3	10.1

**Table 28: Roads and Railroads in Areas Vulnerable to 27 Inches of Sea level Rise**

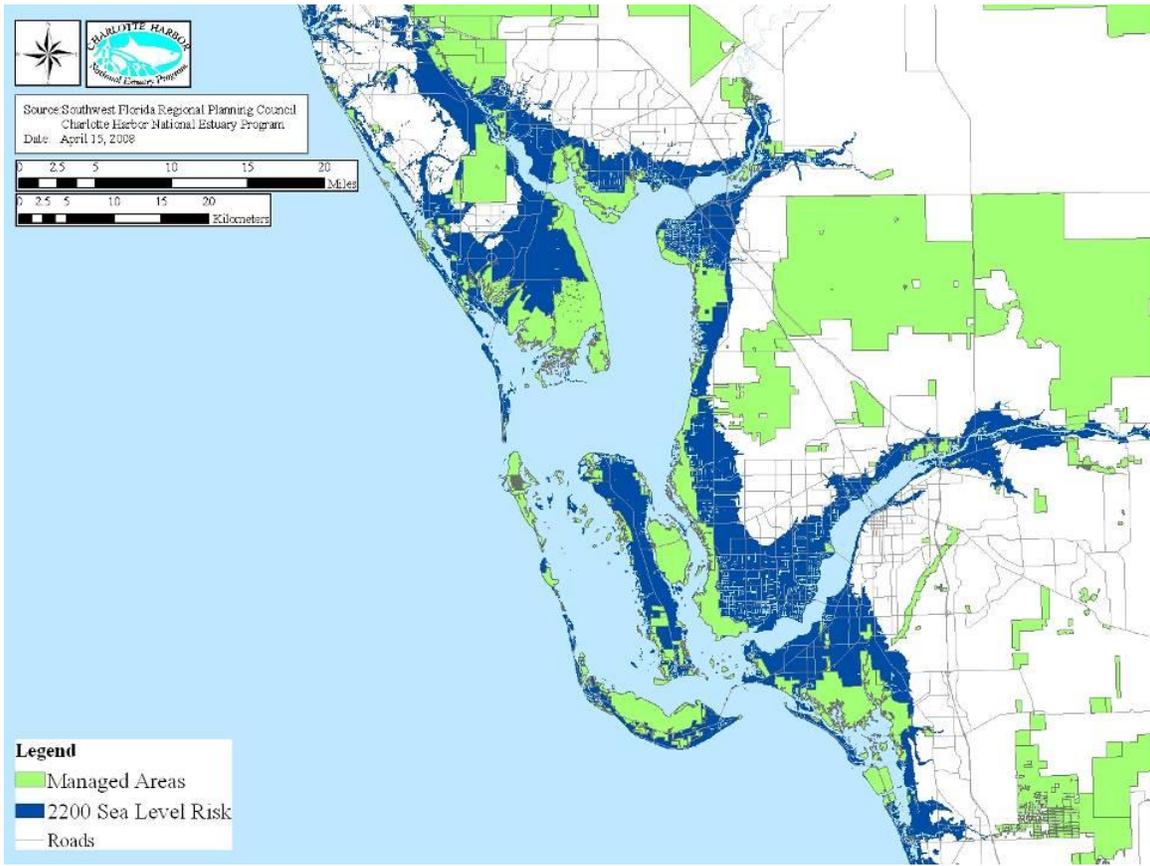
*Sources: road network data from U.S. Streets Dataset (Environmental Systems Research Institute 2005) and Rail Network dataset (Federal Railroad Administration and Research and Innovative Technology Administration's Bureau of Transportation Statistics 2006); vulnerable zones data from NOAA Medium Resolution Digital Vector Shoreline (U.S. Geological Survey 2007), USGS 1:250,000 Digital Elevation Model (University of Florida: GeoPlan 2007), and Historic and Projected Populations of Florida Counties (University of Florida: GeoPlan 2007). Note: Limited access highways are accessed via a ramp and/or numbered exits, like all Interstates and some intrastate highway*



**Figure 55: Major Florida roads vulnerable to projected worst case sea level rise**



**Figure 56: Current Storm Surge Boundaries Southwest Florida**



**Figure 57: Year 2200 5-Foot Sea Level Rise with Location of Lands Managed for Conservation Southwest Florida**

## **Variable Risk and Property Insurance**

### **Known Variable Risk Changes and Events that Have Occurred**

Insurance companies are designed to operate assuming predictable risks. Variable risk is a significant danger to their profitable operation. Insurance companies make their profit based upon their ability to accurately predict the risks associated with the objects or persons they are insuring and by obtaining a fee or premium that is greater than the amount that is expended in claims for damages accrued.

The Florida insurance industry has made mistakes at times by setting premiums too low to cover claims, and at other times charging more than their customers can afford. Under the best case scenarios, hurricane damages will continue to vary widely from year to year, and the industry will need to take a long-term perspective to avoid bouncing between very low and very high rates.

Under the median case scenarios, about the same number of hurricanes will occur but more of them will be Category 4 or 5 status, and damages will be higher on average and more variable from year to year. Worst case scenarios include more severe storms with a higher frequency of storm events. With greater uncertainty (higher variable risk) the insurance companies will be more likely err in either direction, either under- or over-collecting premiums. It will become harder for homeowners, businesses, and governments to pay the increased average cost of insurance. Greater and greater public subsidies will be required as private insurers raise their rates, or leave the market. Currently, many of the largest national insurance firms in the country have left or are planning to leave the riskiest parts of the Florida market after the strong hurricanes of recent years. Smaller, state-based insurance firms, an increasingly important part of the industry, do not have the resources to provide adequate coverage for hurricane damages on their own. As a result, the state and federal governments have been drawn into subsidizing Florida property insurance. Florida's property insurance industry is second only to California's in value of premiums sold (Florida Office of Insurance Regulation 2006).

In Florida, property insurance is provided by leading private companies such as State Farm and Allstate, as well as smaller companies active only in Florida; by a state-created not-for-profit insurer called Citizens' Property Insurance Corporation; and by the federal government's National Flood Insurance Program (NFIP). Homeowners living on the coast often have one policy from a private insurer covering general threats such as theft or fire, another from Citizens' to cover wind risk from hurricanes, and a third from NFIP for flood damage. There is a \$250,000 limit to NFIP, so either additional private coverage is obtained or the property owner suffers exposure to uninsured damages.

Before Hurricane Andrew hit in 1992, many property insurers, eager to increase their market shares, were charging rates that proved too low to pay for the claims filed after the storm. These low rates made high risk areas look misleadingly attractive and affordable, encouraging investment in real estate. As a result of Andrew, Florida insurers

faced \$15.5 billion in claims, and 12 insurance companies went bankrupt (Florida Office of Insurance Regulation 2006; Scott 2007). Premiums went up an average of 82 percent across the state (Wilson 1997). For the companies that remained in the state's insurance industry, rates increased enough to restore financial health. From 1996 to 2006, the loss ratio for Florida insurers was less than 70 percent of all premiums collected, meaning that insurers paid less than seventy cents in claims out of every dollar of premiums paid by consumers. Florida's loss ratio was only two percentage points higher than the average for all insurers nationwide (Florida Office of Insurance Regulation 2007a; Hundley 2007). Insurance companies were somewhat better prepared for the massive storms of 2004 and 2005. One large Florida-based insurer, Poe Financial Group, was bankrupted, and many other companies dropped their policies in vulnerable parts of Florida to limit their exposure to future storms. Rate increases after these storms roughly doubled the average premium charged across the state, according to a spokesperson for the Florida Office of Insurance Regulation (Kees 2007). These increases brought the loss ratio down to 45 percent in 2006, allowing insurers to rapidly recoup their losses from 2004 and 2005 (Florida Office of Insurance Regulation 2007b). But despite the higher rates, several of the larger insurance companies continued to move out of the Florida market: the two largest insurers, State Farm Group and Allstate Insurance Group, reduced their share of the market from 50.9 percent in 1992 to 29.9 percent in 2005 (Grace and Klein 2006). Although a few large national firms remain in Florida, 12 of the state's top 15 insurers sell only Florida residential property insurance (Florida Office of Insurance Regulation 2006).

The state government plays an active role in Florida's insurance markets, and has expanded its involvement in response to recent hurricane activity. One key role of the state is to regulate insurers' activities to prevent sudden abandonment of policyholders or unfair premium hikes. All rate increases are subject to public hearings and require regulatory approval; companies wishing to cancel policies must provide 90 days' notice and some assurance that their withdrawal is "not hazardous to policyholders or the public" (Florida State Legislature 2006; Kees 2007). Companies have pursued a strategy of dropping the policyholders with the riskiest properties, which allows them to reduce their risk and improve their expected level of profitability without requiring state approval for rate increases (Grace and Klein 2006; Florida Office of Insurance Regulation 2007b). The state has also played an ever-growing role as an insurer of last resort for homeowners who cannot find private insurance. Prior to Hurricane Andrew, the state acted as an insurer of last resort through the Florida Windstorm Underwriting Association (FWUA), but only to a limited set of customers. When thousands of customers were dropped after Andrew, a new insurer of last resort was set up called the Residential Property and Casualty Joint Underwriting Association (JUA), which grew to 936,000 policies by September of 1996, before shrinking again as new private insurers moved into the state (Wilson 1997). The FWUA and JUA merged in 2002 to become Citizens' Property Insurance Corporation, partly in response to private insurers' demands that the government assume some of their wind risk. After the 2004 and 2005 storms, many more customers were dropped by private insurers and picked up by Citizens', raising the number of its policyholders to over 1.3 million. In June 2007, a new bill was passed which froze Citizens' rates until January 1, 2009 and allowed policyholders of private companies to switch to Citizens if their private insurer charged 15 percent more

than the state's rates. With these changes, the number of properties insured by Citizens was projected to reach 2 million by the end of 2007 (Liberto 2007).

The state has also increasingly taken on the role of providing reinsurance for private insurance companies. After the wave of bankruptcies following Hurricane Andrew, the state government set up the Florida Hurricane Catastrophe Fund or CAT Fund for short, to provide a limited level of reinsurance to private insurers, which would cover a portion of their claims in the event of a hurricane. The rates charged were below private market rates for reinsurance, especially after the storms of 2005 nearly doubled private reinsurance rates (Florida Office of Insurance Regulation 2007a). In January 2007, the state injected more money into the CAT fund, expanding it from \$16 billion to \$28 billion, and required private insurers to purchase more reinsurance through them, and to pass on the savings to customers through lower rates (Florida Office of Insurance Regulation 2007a). The projected savings, however, did not materialize.

One impact of this expanded government role in insurance markets is that the state's potential liability in the event of a large hurricane has increased. In 2005, the state had to bail out Citizens', which had a \$1.4 billion deficit. This was done through a combination of a charge to all insurance companies, which is passed on to policyholders and a payment from the state budget of \$750 million (Kees 2007). With the expansion of Citizens' and the increase in subsidized reinsurance, the state could be left with an even larger bill in the event of another big storm.

All these changes have increased the amount that the state government effectively subsidizes property insurance rates. Citizens' rates may not appear artificially low to policyholders, but according to a spokesman for the organization, the rates necessary for the premiums of homeowners in high risk coastal areas to cover their own claims would be entirely prohibitive (Scott 2007). In addition, the federal government provides flood insurance through NFIP that is often pegged at rates too low to break even with claims. The nationwide effects of Hurricane Katrina left NFIP bankrupted 10 times over by the \$16 billion it paid in flood claims.

The estimates for sea level rise under the business-as-usual case diverge in scale somewhat from the U.S. Geological Survey (USGS) maps. Geographic Information System (GIS) technology makes it possible to show an approximation of Florida's coastline at 27 inches of sea level rise, which is projected to be reached by around 2060 in the business-as-usual case. This is equivalent to the 80% probable sea level rise predicted in the IPCC's Fourth Assessment Report (2007). For simplicity, Stanton and Ackerman (2007) refer to the land area that would be inundated in Florida with 27 inches of sea level rise as the year 2060 "vulnerable zone." The 2060 vulnerable zone includes nine percent of Florida's current land area, or some 4,700 square miles. Absent successful steps to build up or otherwise protect them, which will be expensive and in some areas is likely impossible, these lands will be submerged at normal high tide. Almost one tenth of Florida's current population, or 1.5 million people, already live in this vulnerable zone.

Statewide, the vulnerable zone also includes residential real estate now valued at over \$130 billion, half of Florida's existing beaches, and 99 percent of its mangroves, as well as the following significant structures statewide (among many others):

<b>Statewide Critical Facilities Vulnerable to a 27-inch Sea Level Rise</b>
2 nuclear reactors
3 prisons
37 nursing homes
68 hospitals
74 airports
82 low-income housing complexes
115 solid waste disposal sites
140 water treatment facilities
171 assisted livings facilities
247 gas stations
277 shopping centers
334 public schools
341 hazardous-material cleanup sites, including 5 Superfund sites
1,025 churches, synagogues, and mosques
1,362 hotels, motels, and inns
19,684 historic structures

**Table 29: List of Statewide Critical Facilities Vulnerable to a 27-inch Sea Level Rise**

### *Potential Future Climate Changes*

Changing climate conditions and trends from increased atmospheric and aquatic temperatures together with sea level rise will cause current risk models to become obsolete. It is not possible to develop forecasting for an uncertain climate-changed future from an actuarial table based upon prior performance under a more stable climate with less severe storms and less harsh climatic conditions. Changes in risk modeling may not keep up with changes in climate with financial ramifications to the insurance industry and the consumer (USEPA CRE 2008).

In Florida's insurance industry, an already bad situation will be made much worse if climate impacts intensify. Under the rapid stabilization scenario, continuing the current frequency and intensity of storms, the industry might be able to muddle along with the current arrangements, premiums, and state and federal subsidies. Under the worst case scenario, with more intense storms as well as higher sea levels that will increase the height of storm surges, the insurance crisis will become more severe. Either premiums or subsidies, or likely both, will have to increase to cover the rising average costs of storm damages. As storms intensify, private firms are likely to continue withdrawing from the

market for Florida property insurance, leaving the government, and the taxpayers, with an increasingly expensive drain on public resources. The cost of hurricane damages will be borne by property owners through increased premiums and/or reduced coverage and by state and federal governments through subsidies to insurance companies. Increased insurance costs and increased storm damages will contribute to a decline in property values, worsening climate damages to the real estate industry. (Stanton and Ackerman 2007)

Despite a growing awareness of the threats posed by climate change, there are relatively few organizations already preparing to adapt to these changes. For example, many states acknowledge sea level rise as a concern in their coastal zone management assessments, but have not yet developed a comprehensive strategy to deal with it. Part of this failure to act can be traced to institutional barriers to changes in management and individuals' behavior (Martinich 2008). Some of the primary institutional barriers to adaptation in estuarine systems include policy biases and decision paralysis due to uncertainty.

Established policies often favor one type of response over another, causing institutional biases. Policies at the federal level tend to favor shore protection over retreat in developed areas, and retreat over shore protection in undeveloped areas. Hard structures tend to be favored over living shorelines in some longstanding federal policies, but more recent state policies (e.g., Maryland) favor living shorelines that rely on less-constructed solutions such as rebuilding an eroded marsh or bay beach (Martinich 2008). Uncertainty surrounding impacts, the relative benefits of different adaptation options, and how others respond to climate change stressors all may lead to failure to decide whether and how to protect or abandon resources that cannot be saved. The specific effects of climate change stressors on specific systems are still highly uncertain, as are the expected responses that will result from implementing adaptation strategies. Decision makers are hesitant to act in the face of an uncertain future. Furthermore, interdependent agencies manage various estuarine systems; not knowing how other decision makers will respond to stressors makes it difficult to decide what actions to take (Martinich 2008).

## **Prioritizing Climate Change Effects**

This report assesses significant potential climate changes in air and water and the effects of those changes on climate stability, sea level, hydrology, geomorphology, natural habitats and species, land use changes, economy, human health, human infrastructure, and variable risk projects, in southwest Florida.

Depending upon the method of prioritization utilized, some climate change effects will be experienced more proximally in time and location; others with longer time lines will be more costly in terms of total cumulative habitat impact or in human economic terms. There are a number of planning actions that, if undertaken now, could significantly reduce negative climate change effects and their costs in the future while providing positive environmental and financial benefits in the near term.

Many of the anticipated consequences of climate change occur via mechanisms involving interactions among the stressors and variables, and therefore may not be widely appreciated by policy makers, managers, stakeholders, and the public. The magnitude of such interactive effects typically declines as each stressor or variable is better controlled, so enhanced adaptive management of traditional estuarine stressors has value as a management adaptation to climate change as well.

Among the consequences of climate change that threaten estuarine ecosystem services, the most serious involve interactions between climate-dependent processes and human responses to those climate changes. In particular, conflicts will arise between sustaining natural coastal habitats and coastal private property, since current activities of protecting private shoreline property from erosion with hardening and placement of fill will become increasingly injurious to sub-tidal, inter-tidal littoral, and wetland habitats if continued as climate changes and sea level rises.

There are crucial areas where adaptation planning and implementation will be needed to avoid, minimize, mitigate, and adapt to the anticipated effects to the natural and man-altered areas of southwest Florida. Some effects such as air temperature and water temperature will be experienced throughout the region. Others such as sea level rise and habitat shifts will occur in specific geographic and clinal locations. In the course of this project, we identified 246 climate change management adaptations (Beever et al. 2009) that could be utilized to address the various vulnerabilities identified for the region. Future adaptation plans will identify the management measures best suited for each geographic location.

When examined in consideration of what climate change effects would most imperil the implementation of the goals of the CHNEP CCMP, the following prioritization is derived (where 1 is top priority and others follow in order):

- 1) Altered Hydrology
- 2) Storm Severity/Climate Instability
- 3) Water Temperature and Chemistry
- 4) Habitat and Species Changes
- 5) Sea Level Rise
- 6) Geomorphic (Landform) Changes
- 7) Air Temperature and Chemistry
- 8) Infrastructure
- 9) Human Economy
- 10) Human Health

11) Land Use Changes

12) Variable Risk

When examined in terms of the climate change effects currently experienced in the southwest Florida region (i.e. what effects with perceived negative effects are occurring now and in the nearer future vs. what changes will occur later), the prioritization of effects is (where 1 is top priority and other follow in order):

- 1) Altered Hydrology
- 2) Storm Severity/Climate Instability
- 3) Variable Risk
- 4) Habitat and Species Changes
- 5) Geomorphic (Landform) Changes
- 6) Human Health
- 7) Air Temperature and Chemistry Changes
- 8) Infrastructure Impacts
- 9) Human Economy
- 10) Land Use Changes
- 11) Sea Level Rise
- 12) Water Temperature and Chemistry Changes

When examined in terms of what climate change effects will have the most severe impacts on the coastal portion of the study region in terms of habitat loss in the estuary, the prioritization of effects is (where 1 is top priority and other follow in order):

- 1) Altered Hydrology
- 2) Sea Level Rise
- 3) Storm Severity/Climate Instability
- 4) Land Use Changes
- 5) Habitat and Species Changes
- 6) Water Temperature and Chemistry Changes
- 7) Geomorphic (Landform) Changes

- 8) Air Temperature and Chemistry Changes
- 9) Infrastructure Impacts
- 10) Human Economy
- 11) Human Health
- 12) Variable Risk

When examined in terms of what climate change effects will have the most severe impacts on the interior portion of the study region in terms of habitat loss in the watersheds, the prioritization of effects is (where 1 is top priority and other follow in order):

- 1) Altered Hydrology
- 2) Storm Severity/Climate Instability
- 3) Water Temperature and Chemistry Changes
- 4) Habitat and Species Changes
- 5) Geomorphic (Landform) Changes
- 6) Land Use Changes
- 7) Human Health
- 8) Air Temperature and Chemistry Changes
- 9) Infrastructure Impacts
- 10) Human Economy
- 11) Variable Risk
- 12) Sea Level Rise Sea Level Rise

Combining the rankings provides the following priority matrix for climate change vulnerabilities:

Prioritization	CHNEP CCMP Goal Implementation	Proximity in Time	Habitat Loss in the Estuary	Habitat Loss in the Watersheds	Sum of Scores	Average Rank
Air Temperature and Chemistry	7	7	8	8	30	7.5
Altered Hydrology	1	1	1	1	4	1.0
Climate Instability	2	2	3	2	9	2.3
Geomorphic Changes	6	5	7	5	23	5.8
Habitat and Species Changes	4	4	5	4	17	4.3
Sea Level Rise	5	11	2	12	30	7.5
Water Temperature and Chemistry	3	12	6	3	24	6.0
Human Economy	9	9	10	10	38	9.5
Human Health	10	6	11	7	34	8.5
Infrastructure	8	8	9	9	34	8.5
Land Use Changes	11	10	4	6	31	7.8
Variable Risk	12	3	12	11	38	9.5

**Table 30: Prioritization of climate change effects in southwest Florida**

The resultant prioritization ranking is:

- 1) Altered Hydrology
- 2) Climate Instability/ Storm Severity
- 3) Habitat and Species Changes

- 4) Geomorphic (Landform) Changes
- 5) Water Temperature and Chemistry Changes
- 6) Air Temperature and Chemistry Changes and Sea Level Rise
- 7) Land Use Changes
- 8) Human Health and Infrastructure Impacts
- 9) Human Economy and Variable Risk

## Conclusions

The primary focus of this project is the vulnerability of coastal regions to climate change in the CHNEP and the SWFRPC. This project includes an assessment of significant potential effects of climate change on the human and native ecosystems of the southwest Florida portion of the Charlotte Harbor National Estuary Program study area, including consequences for human and natural resources resulting from and related to sea level rise, aquatic and atmospheric temperature rise, changes in rainfall patterns, increased storm intensity, waterbody acidification, and general weather instability. This overview identifies potentially critical vulnerabilities that will need to be addressed by adaptation or accommodation in the Charlotte Harbor area, and outlines some of the potential options for minimizing the social, economic, and environmental costs of anticipated effects.

This project lays the groundwork for the development of conceptual models of climate change effects, habitat succession predictive tools, and local government guidance resolutions.

The following summation is informed to a large extent by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research 2008 report entitled “Adaptation Options for Climate-Sensitive Ecosystems and Resources Final Report”.

Maintaining the status quo in management of estuarine ecosystems would result in substantial losses of ecosystem services as climate change progresses. In the absence of effective avoidance, mitigation, minimization and adaptation, climate-related failures will appear in all of the important management goals identified in the CHNEP CCMP: hydrologic alteration, water quality, fish and wildlife habitat, and stewardship.

Changes in the climate will occur in the future even if mitigations, such as reductions in greenhouse gas emission, were to be implemented today. The stressors of air temperature and water temperature increases with subsequent changes in air quality and water quality can be expected to continue and the impacts of climate change variability and sea level rise, in particular, are inevitable. Climate change impacts from sea level are already evident in the growing demand for and costs of beach nourishment, increased coastal flooding, and more pronounced storm surges during tropical storm events.

Many of the anticipated consequences of climate change occur via mechanisms involving interactions among the stressors and variables, and therefore may not be widely appreciated by policy makers, managers, stakeholders, and the public. The magnitude of such interactive effects typically declines as each stressor or variable is better controlled, so enhanced adaptive management of traditional estuarine stressors has value as a management adaptation to climate change as well.

Among the consequences of climate change that threaten estuarine ecosystem services, the most serious involve interactions between climate-dependent processes and human responses to those climate changes. In particular, conflicts will arise between sustaining natural coastal habitats and coastal private property, since current activities of protecting private shoreline property from erosion with hardening and placement of fill will become increasingly injurious to sub-tidal, littoral, and wetland habitats if continued as climate changes and sea level rises.

Mangrove ecosystems of the CHNEP are particularly threatened by climate change. Based on available evidence, of all the climate change outcomes, relative sea level rise may be the greatest threat to mangroves (Gilman et al.2008). Most mangrove sediment surface elevations are not keeping pace with sea level rise, although longer term studies from a larger number of regions are needed. Rising sea level will have the greatest impact on mangroves experiencing net lowering in sediment elevation, where there is limited area for landward migration. There is less certainty over other climate change outcomes and mangrove responses. More research is needed on assessment methods and standard indicators of change in response to effects from climate change, while regional monitoring networks are needed to observe these responses to enable educated adaptation. Proper adaptation measures can offset anticipated mangrove losses and improve resistance and resilience to climate change. Appropriate coastal planning can facilitate mangrove migration with sea level rise. Management of activities within the catchment that affect long-term trends in the mangrove sediment elevation, better management of other stressors on mangroves, rehabilitation of degraded mangrove areas, and increases in systems of strategically designed protected area networks that include mangroves and functionally linked ecosystems through representation, replication and refugia, are additional adaptation options.

Many management adaptations to climate change to preserve estuarine services can be achieved at all levels of government at a known, measured expense. One major form of adaptation involves recognizing the projected consequences of sea level rise and then applying policies that create buffers to anticipate associated consequences. An important example would be redefining riverine flood hazard zones to match the future projected expansion of flooding frequency and extent. Other management adaptations can be designed to build resilience of ecological and social systems. These adaptations include choosing only those sites for habitat restoration that allows natural recession landward, providing resilience to sea level rise. Hardening of infrastructure will address both the consequences of climate variability while improving degraded infrastructure with more long-lasting durable structures.

Management adaptations to climate change can occur on three different time scales:

- a. reactive measures taken in response to observed or encountered negative impacts;
- b. immediate development of plans for adaptive management to be implemented later, either when an indicator signals that delay can occur no longer, or in the wake of a disastrous consequences that provides a window of financially and socially feasible opportunities; or
- c. immediate implementation of proactive mitigations, minimizations and adaptations.

The factors determining which of these time frames is appropriate for any given management adaptation include balancing costs of implementation with the magnitude of risks of injurious consequences under the status quo of management; the degree of reversibility of negative consequences of climate change; recognition and understanding of the problem by managers and the public; the uncertainty associated with the projected consequences of climate change; the timetable on which change is anticipated; and the extent of political, institutional, physical and financial impediments.

Monitoring of the effects and results of climate changes will be necessary to assess when and where adaptive management needs to be and should be applied. A critical goal of this monitoring is to establish and follow indicators that signal approach toward an ecosystem threshold that, once passed, puts the system into an alternative state from which conversion back is difficult to impossible. Avoiding conversion into such less-desired alternative states is one major motivation for implementing proactive management adaptation. This is especially critical if the transition is irreversible or very difficult and costly to reverse, and if the altered state delivers dramatically fewer valued ecosystem services. Work to establish environmental indicators are already being done in the CHNEP and can be used to monitor climate change impacts.

One critically important management challenge for southwest Florida is to implement actions to achieve an orderly relocation of human infrastructure and development from shorelines that are at high risk of erosion and flooding, or to preclude development of undeveloped shorelines at high-risk from sea level rise and climate variability effects. Such proactive management actions have been inhibited in the past by:

- a. uncertainty over or denial of climate change and its implications;
- b. failures to include the true economic, social, and environmental costs of present policies that encourage, allow and subsidize such risky development; and
- c. legal tenets of private property rights.

One possible proactive management option would be to establish and enforce “rolling easements” along estuarine shorelines as sea level continues to rise, thereby sustaining

the current public ownership of tidal lands. Management adaptations may include ending public subsidies that now encourage and support risky development on coastal barrier and estuarine shores at high risk of flooding and storm damage as sea level rises further and intense storms become more common. Although the flood insurance system as a whole may be actuarially sound, current statutes provide people along the water's edge in eroding areas of highest risk with artificially low rates, subsidized by the flood insurance policies of people in relatively safe areas. Ending such subsidization of high-risk developments would represent a market-based, free enterprise form of management adaptation to sea level rise. The federal Coastal Barriers Resources Act provides some guidance for eliminating such subsidies for public infrastructure and private development, although this act currently applies only to a specific list of undeveloped coastal barriers and would require extension to all barrier islands and to estuarine mainland shorelines to enhance its effectiveness to protect human and natural resources.

It will be important to include climate change sensitivity, resilience, and adaptation responses as priorities on all relevant government funding programs at local, state and federal levels. In the absence of such actions, for example, climate impacts on estuarine wetlands will likely violate the national "no-net-loss of wetlands" policy (which stems from the current application of the Clean Water Act) in two ways: (a) wetland loss due to climate change will increasingly compound the continuing loss of wetlands due to development and inadequate mitigation; and (b) structural measures used to protect coastal human infrastructure from climate impacts will prevent wetland adaptation to climate change as ecotones are compressed to non-existence.

All federal, state, and local programs need to be reviewed to assess whether projected consequences of climate change have been considered adequately, and whether adaptive management needs to be applied to achieve programmatic goals. For example, Jimerfield et al. (2007) conclude that "There clearly needs to be [a] comprehensive approach by federal agencies and cooperating scientists to address climate change in the endangered species recovery context. The current weak and piece-meal approach will waste precious resources and not solve the problem we are facing."

A new synthetic governance structure that unites now disparate management authorities, stakeholders, and the public may be needed to address major impediments to ecosystem based adaptive management (EBAM) of estuarine services. Because of its reliance on stakeholder involvement, the CHNEP could represent such a vehicle for developing and implementing adoptions to climate change vulnerabilities.

The CHNEP approach considers the entire watershed of its included estuaries. Management plans to control estuarine water quality parameters sensitive to eutrophication, for example, must take a watershed approach to develop understanding of how nutrient loading at many sources along the watersheds transfer downstream to the estuary. Watershed management, by its very nature, prospers from uniting jurisdictions and governments across the entire watershed to develop partnerships that coordinate rule development and implementation strategies. To this end of facilitating management adaptation to climate change, new ecologically based partnerships of local governments could be promoted and supported.

Southwest Florida's growing population and development are replacing natural habitat. Without the proper habitat, plant communities and wildlife disappear. Florida is one of North America's most important reserves of biological diversity. Occupying an important transitional zone between tropical and temperate climates, more than 1,300 fish and wildlife species and about 3,500 plant species can be found in Florida. Preserving this biodiversity in the CHNEP study area requires protection and restoration of regional fish and wildlife habitat. High rates of land conversion and habitat modification create a critical need for regional wildlife habitat planning in the CHNEP watershed (CHNEP CCMP 2008).

A diversity of restored habitats will be needed to restore and maintain listed-species biodiversity in the face of the identified anticipated climate changes. Concentration on protecting coastal wetlands alone will not serve upland species, upland-dependent wetland species, marine species, or indeed, the coastal species as ecotones and habitats shift up-gradient. It will be vital to protect refugia, latitudinal and elevational gradients, habitat heterogeneity, and gene flow/population connectivity. Species will be benefited by reducing other non-climate stresses (e.g. invasive species, pollution, etc), protection of freshwater surface sources, and hydrologic restoration, with riverine and landscape scale migratory corridors, such as the one that is being established from Charlotte Harbor through five major landscape scale acquisitions.

The likely effects of climate change and particularly sea level rise on southwest Florida ecosystems and infrastructure development are too great for policymakers, property owners, and the public-at-large to stand by and wait for greater evidence before considering strategies for adaptation. It is essential to plan and act now to mitigate, minimize, and adapt to the negative effects of climate change, and to examine the possibilities of providing benefits to human and natural systems by adapting to the changing planet.

## Citations

- Ackerman, E. A. 1938. Influences of Climate on the Cultivation of Citrus Fruits. *Geographical Review* 28 (2): 289–302.
- AID Environment, National Institute for Coastal and Marine Management/ Rijkswaard voor Kusten Zee (RIKZ), Coastal Zone Management Centre, the Netherlands. 2004. Integrated Marine and Coastal Area Management (IMCAM) approaches for implementing the Convention on Biological Diversity. Montreal, Canada: Secretariat of the Convention on Biological Diversity. (CBD Technical Series no. 14).
- Alber, M. 2002. A conceptual model of estuarine freshwater inflow management. *Estuaries* 25(6), 1246-1261.
- Alexander, T.R. 1967. A tropical hardwood hammock on the Miami (Florida) limestone—a twenty-five-year study. *Ecology* 48(5):863-867.
- Allen, E.R., and W.T. Neill. 1952. Notes on the abundance of Everglades mink. *Journal of Mammalogy* 33:113-114.
- Alley, R.B., P.U. Clark, P. Huybrechts, and I. Joughin, 2005: Ice sheet and sea level changes ice-sheet and sea level changes. *Science*, 310(5747), 456-460.
- Alvarez, Ricardo A. Alvarez, Florida Atlantic University. 2008 <http://www.mitigat.com>.
- American Membrane Technology Association 2006. Membrane Desalination Costs, American Membrane Technology Association.
- Anderson, P. K., A. A. Cunningham, N. G. Patel et al. 2004. Emerging infectious diseases of plants: pathogen pollution, climate change and agrotechnology drivers. *TRENDS in Ecology and Evolution* 19(10):535–544.
- Archer, D. 2005. The fate of fossil fuel CO<sub>2</sub> in geologic time. *Journal of Geophysical Research* 110(c9), c09s95.
- Arrigo, K.R. 2005. Marine microorganisms and global nutrient cycles. *Nature* 437: 349-355.
- Atlas of Florida, 1992. Edward A. Fernald and E. D. Purdum Editors, University Press of Florida, 1992, page 37.
- Backlund, P., A. Janetos, and D. Schimel 2008. The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. Washington, DC: U.S. Climate Change Science Program. 202 pp.
- Badola, R., and S.A. Hussain. 2005. Valuing ecosystem functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India. *Environmental Conservation*, v. 32, no. 1, pp. 85-92.

- Bamberg, M. 1980. Climate. Pages 32-46 in Water use and development plan, Volume III C, lower west coast. South Florida Water Management District. West Palm Beach, Florida.**
- Bancroft, G.T. 1996. White-crowned pigeon, *Columba leucocephala*. Pages 258-266 in J.A. Rodgers, Jr., H.W. Kale II, and H.T. Smith (eds.), Rare and endangered biota of Florida: Volume V. Birds. University Press of Florida, Gainesville, Florida.**
- Barnett, C. 2007. Salty Solution? *Florida Trend*, May 2007.**
- Bates, N.R. 2007. Interannual variability of the oceanic CO<sub>2</sub> sink in the subtropical gyre of the North Atlantic Ocean over the last 2 decades. *Journal of Geophysical Research* 112: 1-26.**
- Beever III, J.W. 1988. Mangrove trimming. Internal report. Florida Department of Natural Resources, Tallahassee, Florida.**
- Beever III, J.W. 1989. The effects of fringe mangrove trimming for view in the Southwest Florida Aquatic Preserves. Reports of the South West Florida Aquatic Preserves Nos. 1-5. Florida Department of Natural Resources, Tallahassee, Florida.**
- Beever III, J.W. 1996. The effects of fringe red mangrove and white mangrove trimming for view in the Southwest Florida Aquatic Preserves. Florida Game and Fresh Water Fish Commission, Office of Environmental Services, Punta Gorda, Florida.**
- Beever III, J.W. and K. Dryden 1992. Hydric slash pine flatwoods: a community profile. Florida Game and Fresh Water Fish Commission. 118 pp.**
- Beever III, J.W. and M. Bryant 2003. Southwest Florida Coastal Conservation Corridor Plan for the Tampa Bay Region in BASIS IV, St, Petersburg, Florida, October 30, 2003**
- Beever, III, J.W., C. Metzger, L. Beever, and M. Bryant 2007. Southwest Florida Coastal Conservation Corridor Project, USFWS, Vero Beach Florida, 15 pp.**
- Beever, III, J.W., D. Simberloff, and L.L. King. 1979. Herbivory and predation by the mangrove tree crab, *Aratus pisonii*. *Oecologia* 43:317-328.**
- Beever, III, J.W., W. Gray, D. Trescott, D. Cobb, J. Utley, and L. B. Beever 2009 City of Punta Gorda Climate Change Adaptation Plan. SWFRPC/CHNEP, 267 pp.**
- Belden, R.C. 1986. Florida panther recovery plan implementation--a 1983 progress report. Pages 159-172 in S.D. Miller and D.D. Everett eds. Cats of the World: biology, conservation and management. Proceedings of the second international cat symposium. Caesar Kleberg Wildlife Research Institute. Kingsville, Texas.**

- Bell, F.W., P.E. Sorensen, and V.R. Leeworthy. 1982. The economic impact and valuation of saltwater recreational fisheries in Florida. Florida Sea Grant College Report No.47. Gainesville, Florida.
- Bell, T.L., D. Rosenfeld, K.-M. Kim, J.-M Yoo, M.-I. Lee and M. Hahnenberger. 2008. Midweek increase in U.S. summer rain and storm heights suggests air pollution invigorates rainstorms. *Journal of Geophysical Research (Atmospheres)* 113:D02209, doi: 10.1029/2007JD008623.
- Bernard, S.M., Samet, J.M., Grambsch, A., Ebi, K.L., Romieu, I. 2001. The Potential Impacts of Climate Variability and Change on Air Pollution-Related Health Effects in the United States, in *Environmental Health Perspectives*, Vol. 109, Supp. 2, pp. 199–209, 2001.
- Bibby, R., P. Cleall-Harding, S. Rundle, S. Widdicombe, and J. Spicer. 2007. Ocean acidification disrupts induced defenses in the intertidal gastropod *Littorina littorea*. *Biology Letters* 3(6):699-701.
- Bird, E. C. F. 1985. Coastline Changes—A Global Review. Chichester, England: John Wiley-Interscience, 219 pp.
- Bollman, Nick. 2007. Florida’s resilient coasts: a state policy framework for adaptation to climate change. Ft. Lauderdale, FL: Florida Atlantic University Center for Urban and Environmental Solutions. 38pp.
- Box, E. O., D.W. Crumpacker and E. D. Hardin (1999). “Predicted Effects of Climatic Change on Distribution of Ecologically Important Native Tree and Shrub Species in Florida.” *Climatic Change* 41(2): 213–248.
- Boyd, P.W., and S.C. Doney. 2002. Modeling regional responses by marine pelagic ecosystems to global climate change. *Geophysical Research Letters* 29: 532-534
- Bradley, J.T. 1972. Climate of Florida. Pages 45-70 in Climate of the States. Environmental Data Service, No. 60-8. Silver Springs, Md.
- Brady, J.R., and D.S. Maehr. 1985. Black bear distribution in Florida. *Florida Field Naturalist* 13:1-7.
- Brander, K.M. December 11, 2007. Global fish production and climate change. Proceedings of the National Academy of Sciences, v. 104, no. 50, 19709-19714; published online as 10.1073/pnas. 0702059104.
- Brooks, N., R. Nicholls and J. Hall 2006. Sea Level Rise: Coastal Impacts and Responses. Berlin, WBGU: 49.
- Bruno, I. F., E. R. Selig, K. S. Casey, C. A. Page, B. L. Willis, C. D. Harvell, H. Sweatman, and A. M. Melendy 2007. Thermal stress and coral cover as drivers of coral disease outbreaks. *PLoS Biology* 5:1220-1227.

- Bruun, Per. 1962. Sea Level Rise, as a Cause of Shore Erosion. *Journal of the Waterways and Harbors Division*, Proceedings of the American Society of Civil Engineers, 88(WW1):117-130.
- Bruun, Per. 1986. Worldwide Impacts of Sea Level Rise on Shorelines. In *Effects of Changes in Stratospheric Ozone and Global Climate*, Vol. 4: Sea Level Rise, edited by James G. Titus, 99-128. Washington, DC, U.S. Environmental Protection Agency.
- Bull, S.R., D.E. Bilello, J. Ekmann, M.J. Sale, and D.K. Schmalzer 2007. Effects of climate change on energy production and distribution in the United States. In: *Effects of Climate Change on Energy Production and Use in the United States* [Wilbanks, T.J., V. Bhatt, D.E. Bilello, S.R. Bull, J. Ekmann, W.C. Horak, Y.J. Huang, M.D. Levine, M.J. Sale, D.K. Schmalzer, and M.J. Scott (eds.)]. Synthesis and Assessment Product 4.5. U.S. Climate Change Science Program, Washington, DC, pp. 45-80.
- Bureau of Economic Analysis 2006. Gross Domestic Product by State.
- Bureau of Labor Statistics 2007. Quarterly Census of Employment and Wages.
- Cahoon, D. R., J. W. Day, Jr., and D. J. Reed, 1999. The influence of surface and shallow subsurface soil processes on wetland elevation: A synthesis. *Current Topics in Wetland Biogeochemistry*, 3, 72-88.
- Carder, K.L., and R.G. Steward. 1985. A remote-sensing reflectance model of a red-tide dinoflagellate off west Florida. *Limnology and Oceanography* 30: 286-298.
- Carlton, J.T. 2001. In *Invasive species in a changing world* (H.A. Mooney and R.J. Hobbs, Eds.). Washington, DC: Island Press, pp. 31-53.
- Castaneda, H., and F.E. Putz. 2007. Predicting sea level rise effects on a nature preserve on the Gulf Coast of Florida: A landscape perspective. *Florida Scientist* 70(2): 166-175.
- CBO Testimony, 2005: *Macroeconomic and Budgetary Effects of Hurricanes Katrina and Rita*. Statement of Douglas Holtz-Easkin, Director, before the Committee on the Budget, U.S. House of Representatives. Congressional Budget Office, Washington, DC, 21pp. <http://www.cbo.gov/doc.cfm?index=6684>
- Center for Integrative Environmental Research. 2007. *The U.S. economic impacts of climate change and the costs of inaction*. ArcView and assessment by the Center for Integrative Environmental Research at the University of Maryland. College Park, MD. [http://dl.klima2008.net/ccsl/us\\_economic.pdf](http://dl.klima2008.net/ccsl/us_economic.pdf).
- Centers for Disease Control and Prevention. 2009. Aero-allergens. <http://www.cdc.gov/climatechange/effects/allergens.htm> (accessed 3/30/09)
- Centers for Disease Control and Prevention. 2009. Air quality and respiratory disease. <http://www.cdc.gov/climatechange/effects/airquality.htm> (accessed 3/30/09)

- Centers for Disease Control and Prevention. 2009. Heat waves.**  
<http://www.cdc.gov/climatechange/effects/heat.htm> (accessed 3/30/09)
- Centers for Disease Control and Prevention. 2009. Vector- borne and zoonotic disease.** <http://www.cdc.gov/climatechange/effects/vectorborne.htm> (accessed 3/30/2009)
- Centers for Disease Control and Prevention. 2009. Water- and food-borne diseases.**  
<http://www.cdc.gov/climatechange/effects/waterborne.htm> (accessed 3/30/09)
- Centers for Disease Control and Prevention. 2009. Other indirect health effects.**  
<http://www.cdc.gov/climatechange/effects/indirecteffects.htm> (accessed 3/30/09)
- Centers for Disease Control and Prevention. 2009. Interacting trends.**  
<http://www.cdc.gov/climatechange/effects/trends.htm> (accessed 3/30/09)
- Cerulean, Susan. 2008. Wildlife 2060: What's at stake for Florida? Tallahassee: Florida Fish and Wildlife Conservation Commission. 28 pp.**
- Charlotte Harbor National Estuary Program (CHNEP) Comprehensive Conservation and Management Plan 2008. 1926 Victoria Avenue, Fort Myers, Florida 33901**
- Chaves, L. F., and M. Pascual. 2006. Climate cycles and forecasts of cutaneous leishmaniasis, a non-stationary vector-borne disease. *PLoS Medicine* 3:1320-1328.**
- Church, J.A., and N.J. White. 2006. A 20th century acceleration in global sea level rise. *Geophysical Research Letters* 33: L01602.**
- Coastal Coordinating Council. 1974. Florida coastal zone management atlas. State of Florida, Tallahassee, Florida.**
- Coastal States Organization Climate Change Work Group. 2007. The role of coastal zone management programs in adaptation to climate change. B. Davis, chair. 30 pp.**
- Colwell, R.R. 1996. Global climate and infectious disease: The cholera paradigm. *Science* 274 (5295): 2025-2031.**
- Committee on Environment and Natural Resources. 2008. Scientific assessment of the effects of global change on the United States. Washington, D.C.: National Science and Technology Council. 271 pp.**
- Cox, J., Kautz, R., MacLaughlin M., and Gilbert, T. 1994. Closing the Gaps in Florida's Wildlife Habitat Conservation System. Office of Environmental Services, Florida Game and Fresh Water Fish Commission, 620 South Meridian Street, Tallahassee, Florida 32399-1600.**

- Crumpacker, D.W., E. O. Box and E. D. Hardin 2001. "Implications of Climatic Warming for Conservation of Native Trees and Shrubs in Florida." *Conservation Biology* 15(4): 1008–1020.
- Dahdouh-Guebas, F., S. Hettiarachchi, D. Lo Seen, O. Batelaan, S. Sooriyarachchi, L.P. Jayatissa, and N. Koedam. 2005. Transitions in ancient inland freshwater resource management in Sri Lanka affect biota and human populations in and around coastal lagoons. *Current Biology* 15: 579-586.
- Dausman, A., and C.D. Langevin. 2005. *Movement of the saltwater interface in the surficial aquifer system in response to hydrologic stresses and water-management practices, Broward County, Florida*. U.S. Geological Survey Scientific Investigations Report 2004-5156. <http://pubs.usgs.gov/sir/2004/5256/>.
- Day Jr., J.W., C.A.S. Hall, W.M. Kemp, and A. Yanez-Arancibia. 1989. Estuarine Ecology. John Wiley & Sons, New York. 1989. 558 pp.
- Desantis, L.R.G., S. Bhotika, K. Williams, and F.E. Putz. 2007. Sea level rise and drought interactions accelerate forest decline on the Gulf Coast of Florida, USA. *Global Change Biology* 13 (11): 2349-2360.
- Dowell, S.F., C. Groves, K.B. Kirkland, H.G. Cicirello, T. Ando, Q. Jin, and J.R. Gentsch et al. 1995. Multistate outbreak of oyster associated gastroenteritis: Implications for interstate tracing of contaminated shellfish. *Journal of Infectious Diseases* 171: 1497-1503.
- Doyle, T.W., G.F. Girod, and M.A. Brooks. 2003. Chapter 12: Modeling mangrove forest migration along the southwest coast of Florida under climate change. In *Integrated assessment of the climate change impacts on the Gulf Coast region*. Gulf Coast Climate Change Assessment Council and Louisiana State University.
- Drew, R.D. and N.S. Schomer 1984. An Ecological Characterization of the Caloosahatchee River/Big Cypress Watershed. U.S. Fish and Wildlife Service. FWS/OBS-82/58.2. 225 pp.
- Dryden, K.A. and J. W. Beaver III 1994 Regional protection of listed wildlife species and other wildlife resources in the greater Charlotte Harbor ecosystem. Office of Environmental Services, Florida Game and Fresh Water Fish Commission, 29200 Tuckers Grade, Punta Gorda, FL 33955).
- Duever, M. J., J. E. Carlson, L. H. Gunderson, and L. C. Duever 1976. Corkscrew Swamp, a virgin strand, ecosystems analysis at Corkscrew Swamp. Pages 707-737 in H. T. Odum, (ed.) Cypress wetlands. 3rd Annual Report on Research Projects. Nov. 1975-Dec. 1976. Center for Wetlands, University of Florida, Gainesville.
- Duever, M.J., J.E. Carlson, J.F. Meeder, L.C. Duever, L.H. Gunderson, L.A. Riopelle, T.R. Alexander, R.F. Myers, and D.P. Spangler. 1979. Resource inventory and analysis of the Big Cypress National Preserve. Final report to the U.S. Department of the Interior, National Park Service. Center for

Wetlands, University of Florida, Gainesville and National Audubon Society, Naples, Florida.

- Eakin, M.C., J.A. Morgan, S.F. Heron, T.B. Smith, G. Liu, L. Alvarez-Filip, and B. Baca et al. In review. Caribbean corals in hot water: Record thermal stress, bleaching, and mortality in 2005. Submitted to *Nature*.
- Easterling, D.R., G.A. Meehl, C. Parmesan, S.A. Changnon, T.R. Karl, and L.O. Mearns. 2000. Climate extremes: observations, modeling and impacts. *Science*, v. 289, 2068-2074.
- Eaton M. A, Balmer D, Burton N, Grice PV, Musgrove AJ, Hearn R, Hilton G, Leech D, Noble DG, Ratcliffe N, Rehfish MM, Whitehead S, and Wotton S 2008. The state of the UK's birds 2007 RSPB, BTO, WWT, CCW, EHS, NE and SNH, Sandy, Bedfordshire.
- Ebi, Kristie L., Gerald A. Meehl, Dominique Bachelet (et al.), Robert R. Twilley, Donald F. Boesch (et al.). 2007. Arlington, VA: Pew Center on Global Climate Change. 80 pp.
- Echternacht, K. L. 1975. A study of the precipitation regimes of the Kissimmee River-Lake Okeechobee watershed. Fla. Dep. Environmental Reg., Tech. Ser. 1(3) 61 pp.
- Ehrhardt, N. M. and C. M. Legault (1999). "Pink Shrimp, *Farfantepenaeus duorarum*, Recruitment Variability as an Indicator of Florida Bay Dynamics." *Estuaries* 22(2, Part B: Dedicated Issue: Florida Bay: A Dynamic Subtropical Estuary): 471-483.
- Elsner, James B. 2006. Evidence in support of the climate change-Atlantic hurricane hypothesis. *Geophysical Research Letters* 33 (L16705): 1-3.
- Energy Information Administration (EIA) 2007. Annual Energy Outlook, Energy Information Administration. Environmental Protection Agency (1997). Climate Change and Florida. Washington D.C., EPA, Office of Policy, Planning and Evaluation: 4.
- Enfield, D.B., A.M. Mestas-Nuñez, and P.J. Trimble. 2001. The Atlantic multidecadal oscillation and its relation to rainfall and river flows in the continental U.S. *Geophysical Research Letters* 28 (10), 2077-2080.
- Epstein, P.R. 2005. Climate change and human health. *New England Journal of Medicine* 353: 1433-1436.
- Epstein, P.R., and E. Mills (Eds.). 2005. *Climate change futures: Health, ecological and economic dimensions*. A project of the Center for Health and the Global Environment, Harvard Medical School. CCF\_Report\_Final\_10.27.pdf. <http://www.climatechange-futures.org/pdf/>
- Estevez, E.D. 1988. Implications of sea level rise for wetlands creation and management in Florida. *Proceedings, Annual Conference on Wetlands Restoration and Creation* 103-113.

- Federal Emergency Management Agency. *Florida Disaster History*. June 12, 2009. [www.fema.gov/news/disasters\\_state.fema?id=12](http://www.fema.gov/news/disasters_state.fema?id=12) (accessed June 29, 2009).**
- Fields, P.A., J.B. Graham, R.H. Rosenblatt, and G.N. Somero. 1993. Effects of expected global climate change on marine faunas. *Trends in Ecology and Evolution* 8 (10):361-367.**
- Fletcher, Kristen 2009. Regional/State Sea Level Rise Initiatives. Coastal States Organization. Delaware Sea Level Rise workshop. 10 pp.**
- Florida Center for Environmental Studies, Florida Climate Change Conference, 9-11 May 2007. Climate Change Conference Summary. Tampa, Florida.**
- Florida Cooperative Fish and Wildlife Research Unit. 2000. "FLORIDA LAND COVER". gap\_lcov. Raster Digital Data. Florida: Florida Fish and Wildlife Conservation Commission. May 2000. (gap\_lcov).**
- Florida Department of Agriculture and Consumer Services 2003. Florida's Agricultural Water Policy: Ensuring Resource Availability. Tallahassee, Florida Department of Agriculture and Consumer Services: 40.**
- Florida Department of Agriculture and Consumer Services 2006a. Comprehensive Report on Citrus Canker Eradication Program in Florida Through 14 January 2006 Revised, Florida Department of Agriculture and Consumer Services—Division of Plant Industry.**
- Florida Department of Agriculture and Consumer Services 2006b. Florida Agriculture Statistical Directory. Tallahassee, Florida Department of Agriculture and Consumer Services: 178.**
- Florida Department of Agriculture and Consumer Services 2006c. Florida Agriculture Statistical Highlights. Tallahassee, Florida Department of Agriculture and Consumer Services.**
- Florida Department of Agriculture and Consumer Services 2007b). Florida Cattle Industry Brochure. Tallahassee, Florida Department of Agriculture and Consumer Services: 2.**
- Florida Department of Agriculture and Consumer Services 2007c. "Florida Wood Using Industry Directory." Retrieved 4 September, 2007, from [http://flame.fl-dof.com/apps/wood\\_using.php](http://flame.fl-dof.com/apps/wood_using.php).**
- Florida Department of Agriculture and Consumer Services 2007d. Wildfire report, July 10, 2007. Tallahassee, Florida Department of Agriculture and Consumer Services, Forestry Division.**
- Florida Department of Environmental Protection 1994. *Approach to the assessment of sediment quality in Florida coastal waters. Vol. 1, Chap. 2: Florida's coast: A national treasure*. Tallahassee, FL: Office of Water Policy. Prepared by MacDonald Environmental Sciences Ltd., British Columbia, Canada. [http://www.dep.state.fl.us/waste/uick\\_topics/publications/pages/default.htm](http://www.dep.state.fl.us/waste/uick_topics/publications/pages/default.htm).**
- Florida Department of Environmental Protection 2006. (FDEP) Critically Eroded Beaches in Florida, April 2006**

- Florida Department of Environmental Protection 2007a. Drinking Water Database, Florida DEP**
- Florida Department of Environmental Protection 2008. *Integrated water quality assessment for Florida: 2008 305(b) report and 303(d) list update.* Tallahassee, FL: Division of Environmental Assessment and Restoration, Bureau of Watershed Management.**  
[http://www.dep.state.fl.us/water/tmdl/docs/2006\\_Integrated\\_Report.pdf](http://www.dep.state.fl.us/water/tmdl/docs/2006_Integrated_Report.pdf).
- Florida Department of Environmental Protection 2008. LABINS<sup>SM</sup>. Land Boundary Information System.** <http://data.labins.org/2003/>
- Florida Department of Environmental Protection. 2004a. 15 June “Estuaries.” Retrieved 24 July, 2007, from**  
<http://www.dep.state.fl.us/coastal/habitats/estuaries.htm>.
- Florida Department of Environmental Protection. 2004b. 15 June). “Salt Marshes.” Retrieved 25 July, 2007, from**  
<http://www.dep.state.fl.us/coastal/habitats/saltmarshes.htm>.
- Florida Department of Environmental Protection. 2007b. 31 May). “Drought Conditions.” Retrieved 4 June, 2007, from**  
<http://www.dep.state.fl.us/drought/default.htm>.
- Florida Division of Emergency Management 2004. Hurricane Impact Report, A Summary, Florida Division of Emergency Management.**
- Florida Division of Emergency Management 2007. Draft Hurricane Impact Report, Florida Division of Emergency Management.**
- Florida Fish and Wildlife Conservation Commission 2005a. Economics of Fish and Wildlife Recreation Tallahassee, Fish and Wildlife Conservation Commission.**
- Florida Fish and Wildlife Conservation Commission 2005b. Florida’s Marine Fisheries: A Vision for the Future. Florida Fish and Wildlife Conservation Commission.**
- Florida Fish and Wildlife Conservation Commission 2007. Marine Fisheries Information System, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute,**
- Florida Fish and Wildlife Conservation Commission Florida’s Varied Marine Habitat. Tallahassee, Florida Fish and Wildlife Conservation Commission: 7.**
- Florida Fish and Wildlife Institute 2006 Florida Fish and Wildlife Conservation Commission Florida Statewide Environmental Sensitivity Index Maps,**  
<http://ocean.floridamarine.org/esimaps/>
- Florida Natural Areas Inventory 1989. Natural Communities. in Guide to the Natural Communities of Florida. 111 pp.**
- Florida Oceans and Coastal Council (FOCC) 2009. The effects of climate change on Florida’s ocean and coastal resources. A special report to the Florida Energy and Climate Commission and the people of Florida. Tallahassee, FL. 34 pp.**

- Florida Office of Insurance Regulation 2006. An Overview of Florida's Insurance Market Trends. Tallahassee, Florida Office of Insurance Regulation: 46.**
- Florida Office of Insurance Regulation 2007b. Presumed Rating Factors. Tallahassee, Florida Office of Insurance Regulation: 25.**
- Florida Office of Insurance Regulation. 2007a. "Compare Homeowner's Insurance Rates." Retrieved 12 July, 2007, from <http://www.shopandcomparerates.com/>.**
- Florida State Legislature 2006. The 2006 Florida Statutes.**
- Florida's Geological History and Geological Resources 1994. Florida Department of Environmental Protection, Florida Geological Survey, Special Publication No. 35, 1994, pages 17-26, including Figure 10, Sea level changes during the Cenozoic Era (after Haq et al., 1987) and Figure 16, Pleistocene Shoreline in Florida. Illustrated by Frank R. Rupert. .**
- Freed, R., J. Furlow, and S. Herrod Julius 2005. *Sea level rise and groundwater sourced community water supplies in Florida*. U.S. Climate Change Science Program Workshop, Arlington, VA, November 14–16, 2005. U.S. Environmental Protection Agency, Global Climate Research Program. [http://www.climatechange.gov/workshop2005/presentations/ppt/CO1.6\\_Free d.ppt](http://www.climatechange.gov/workshop2005/presentations/ppt/CO1.6_Free d.ppt).**
- Galbraith, H., R. Jones, R. A. Park, J. S. Clough, S. Herrod-Julius, B. Harrington, and G. Page 2003. Global climate change and sea level rise: potential losses of intertidal habitat for shorebirds. Pages 19-22 in N. J. Valette-Silver and D. Scavia, eds. *Ecological Forecasting: New Tools for Coastal and Marine Ecosystem Management*. NOAA, Silver Spring, Maryland.**
- Galbraith, H.R., Jones. R.A., J.S. Clough, S. Herrod-Julius, B. Harrinton and G. Page 2002. Global climate change and sea level rise: potential losses of intertidal habitat for shorebirds. *Waterbirds* 25: 173-183**
- Gazelles, B., M. Chavez, A. J. McMichael, and S. Hales. 2005. Non-stationary influence of El Nino on the synchronous dengue epidemics in Thailand. *PLoS Medicine* 2313-318.**
- GeoPlan Center at the University of Florida 2006. FLORIDA 2060: A POPULATION DISTRIBUTION SCENARIO. A Research Project Prepared for 1000 Friends of Florida by the GeoPlan Center at the University of Florida December 2006**
- Gilman, E.L Joanna Ellison b, Norman C. Duke c, Colin Field 2008. Threats to mangroves from climate change and adaptation options, *Aquatic. Bot.* doi:10.1016/j.aquabot.2007.12.009 14 pp.**
- Glick, P. 2006. Application of SLAMM 4.1 to Nine Sites in Florida, National Wildlife Federation, Climate Change Specialist, 6 Nickerson Street, Suite 200, Seattle, WA 98109, February 16, 2006. 27 pp.**
- Glick, P., and J. Clough. 2006. *An unfavorable tide: Global warming, coastal habitats and sportfishing in Florida*. National Wildlife Federation and Florida**

- Wildlife Federation. <http://www.nwf.org/news/story.cfm> page Id=867DBCA1-F1F6-7B10-369BEE5595525202.
- Goering, J.J. and P.L. Parker 1972. Nitrogen fixation by epiphytes of seagrasses. *Limnol. Oceanogr.* 17(2): 320-323.
- Goldenberg, S.B., C.W. Landsea, A.M. Mestaz-Nunez, and W.M. Gray. 2001. The recent increase in Atlantic hurricane activity: Causes and implications. *Science* 293, 474-479.
- Goodnough, A. 2007. Florida Is Slow to See the Need to Save Water *New York Times*, 19 June 2007.
- Gore, R.H. 1994a. Mangrove crab, *Aratus pisonii* (H. Milne Edwards). Pages 220-222 in M. Deyrup and R. Franz (eds.), Rare and endangered biota of Florida: Volume IV. Invertebrates. University Press of Florida, Gainesville, Florida.
- Gore, R.H. 1994b. Mangrove crab, *Goniopsis cruentata* (Latreille). Pages 222-224 in M. Deyrup and R. Franz (eds.), Rare and endangered biota of Florida: Volume IV. Invertebrates. University Press of Florida, Gainesville, Florida.
- Grace, M. F. and R.W. Klein 2006. After the Storms: Property Insurance Markets in Florida, Georgia State Center for Risk Management and Insurance Research.
- Gruber, A. 1969. Energy budget and climatology of the atmosphere over the Florida peninsula. Final rep. to the U.S. Army Elect. Commission. Tech. rep. ECOM-04367-F. 64 pp.
- Gutfreund, P. D. 1978. Florida sulfur oxides study no. 2 - dispersion, meteorology, and climatology. 3 vols. Prepared for: Fla. Sulfur Oxides Study, Inc. Dames and Moore, Atlanta, Ga.
- Gutowski, W.J., G.C. Hegerl, G.J. Holland, T.R. Knutson, L.O. Mearns, R.J. Stouffer, P.J. Webster, M.F. Wehner, and F.W. Zwiers 2008: Causes of observed changes in extremes and projections of future changes. In: *Weather and Climate Extremes in a Changing Climate: Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands* [Karl, T.R., G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray (eds.)]. Synthesis and Assessment Product 3.3. U.S. Climate Change Science Program, Washington, DC, pp. 81-116.
- Hansen, J.E., 2007. Scientific reticence and Sea Level Rise. *Environmental Research Letters*, Vol. 2, 024002. doi:10.1088/1748-9326/2/2/024002.
- Harvell, C. D., C. E. Mitchell, J. R. Ward, S. Altizer, A. Dobson, R. S. Ostfeld, and M. D. Samuel. 2002. Climate warming and disease risks for terrestrial and marine biota. *Science* 296:2158-2162.
- Harvell, C.D., C.E. Mitchell, J.R. Ward, S. Altizer, A.P. Dobson, R.S. Ostfeld, and M.D. Samuel. 2002. Climate warming and disease risks for terrestrial and marine biota. *Science* 296:2158-62.

- Harvell, C.D., K. Kim, J.M. Burkholder, R.R. Colwell, P.R. Epstein, D.J. Grimes, and E.E. Hofmann et al. 1999. Emerging marine diseases— Climate links and anthropogenic factors. *Science* 285, 1505-1510.
- Hatfield, J., K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, and D. Wolfe, 2008: Agriculture. In: *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* [Backlund, P., A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.)]. Synthesis and Assessment Product 4.3. U.S. Department of Agriculture, Washington, DC, pp. 21-74.
- Hauserman, J. 2007. The bottom line in the sand. *St. Petersburg Times*, January 28, 2007.
- Hay, S. I., I. Cox, D. J. Rogers, S. E. Randolph, D. I. Stern, G. D. Shanks, M. F. Myers, and R. W. Snow. 2002. Climate change and the resurgence of malaria in the East African highlands. *Nature* 415:905-909.
- Hela, I. 1952. Remarks on the climate of southern Florida. *Bull. Mar. Sci.* 2(2):438-447.
- Henderson-Sellers, A., H. Zhang, G. Berz et al. (1998). "Tropical Cyclones and Global Climate Change: A Post-IPCC Assessment." *Bulletin of the American Meteorological Society* 79(1).
- Hine, A.C., and D.F. Belknap. 1986. *Recent geological history and modern sedimentary processes of the Pasco, Hernando, and Citrus County coastlines: West central Florida*. Florida Sea Grant Report No. 79.
- Hodges, A. W., W. D. Mulkey, J. R. Alavalapati, D. R. Carter and C. F. Kiker 2005. *Economic Impacts of the Forest Industry in Florida, 2003: Final Report to the Florida Forestry Association*. Gainesville, FL, University of Florida, IFAS: 47.
- Hodges, A.W. and W. D. Mulkey 2003. *Regional Impacts of Florida's Agricultural and Natural Resource Industries*. Gainesville, FL, University of Florida: 20.
- Holman, B. 2008. *Options for Planning and Adapting to Impacts of Global Climate Change in North Carolina. Memorandum to North Carolina Legislative Commission on Global Climate Change*. Durham, NC
- Houghton, J.T. et al., eds. 2001. *Climate Change 2001: The Scientific Basis*. Technical report. Cambridge, U.K.: Cambridge University Press.
- Hughs, R. H. 1975. The native vegetation of south Florida related to month of burning. U.S. Dep. Agric. For. Serv. Res. Note SE-222, 8 p. Southeast For. Exp. Stn, Asheville, N. C.

- Humphrey, S.R. 1992. Southern Florida population of mink. Pages 319-327 in S.R. Humphrey (ed.), *Rare and endangered biota of Florida: Volume I. Mammals*. University Press of Florida. Gainesville, Florida.
- Humphrey, S.R., and H.W. Setzer. 1989. Geographic variation and taxonomic revision of mink (*Mustela vison*) in Florida. *Journal of Mammalogy* 70:241-252.
- Hundley, K. 2007. Premium profits for insurers; As skies cleared, the coffers filled in 2006 for Florida's home insurers *St. Petersburg Times* 18 Mar 2007.
- Hutchings, P., and P. Saenger. 1987. *Ecology of mangroves*. University of Queensland Press. Queensland, Australia.
- Indian River Lagoon Comprehensive Conservation and Management Plan (IRLCCMP). 1996. Final Draft. Indian River Lagoon National Estuary Program [IRLNEP], Melbourne, Florida.
- Intergovernmental Panel on Climate Change (IPCC) (2001a). *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. Cambridge UK, Cambridge University Press.
- Intergovernmental Panel on Climate Change (IPCC) (2007a). *Climate Change 2007: Summary for Policy Makers. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK, Cambridge University Press.
- Intergovernmental Panel on Climate Change (IPCC) 2001: *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp.
- Intergovernmental Panel on Climate Change (IPCC) 2007b. *Climate change 2007: The physical science basis. Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change* (S. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller, Eds.). Cambridge, UK, and New York: Cambridge University Press. <http://www.ipcc.ch>.
- Intergovernmental Panel on Climate Change (IPCC) 2007c. *Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (M.L. Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, eds.). Cambridge, UK: Cambridge University Press.
- Intergovernmental Panel on Climate Change. (IPCC) 2007a. *Climate change 2007: Synthesis report* (L. Bernstein, P. Bosch, O. Canziani, C. Zhenlin, R. Christ, O. Davidson, and W. Hare et al., Core Writing Team). Geneva, Switzerland. [http://www.ipcc.ch/pdf/assessmentreport/ar4/syr/ar4\\_syr.pdf](http://www.ipcc.ch/pdf/assessmentreport/ar4/syr/ar4_syr.pdf).

- Intergovernmental Panel on Climate Change. 2008. *About Intergovernmental Panel on Climate Change*. <http://www.ipcc.ch/about/index.htm>.
- Ishimatsu, A., M. Hayashi, K.-S. Lee, T. Kikkawa, and J. Kita. 2005. Physiological effects on fishes in a high-CO<sub>2</sub> world. *Journal of Geophysical Research* 110. <http://www.agu.org/pubs/crossref/2005/2004JC002564.shtml>press.
- Iverson, L. R. and A.M. Prasad 2001. "Potential Changes in Tree Species Richness and Forest Community Types Following Climate Change." *Ecosystems* 4(3): 186–199.
- Jimerfield, S., M. Waage, and W. Snape, 2007: *Global Warming Threats and Conservation Actions in Endangered Species Recovery Plans: a Preliminary Analysis*. Center for Biological Diversity.
- Jones, C.S., J.F. Shriver, and J.J. O'Brien. 1999. The effects of El Niño on rainfall and fire in Florida. *Florida Geographer* 30, 55-69.
- Jordan, C. L. 1973. Climate. Pages IIA-1 to IIA-14 in J. I. Jones, R. E. Ring, M. O. Rinkel, and R. E. Smith, (eds.) *A summary of knowledge of the eastern Gulf of Mexico*. State University System of Florida, Institute of Oceanography.
- Jordan, C.F. Jr. 1996. Spatial ecology of decapods and fishes in a northern Everglades wetland mosaic. PhD dissertation. University of Florida. 155 Pp.
- Kafalenos, R.S., K.J. Leonard, D.M. Beagan, V.R. Burkett, B.D. Keim, A. Meyers, D.T. Hunt, R.C. Hyman, M.K. Maynard, B. Fritsche, R.H. Henk, E.J. Seymour, L.E. Olson, J.R. Potter, and M.J. Savonis, 2008: What are the implications of climate change and variability for Gulf coast transportation? In: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I* [Savonis, M.J., V.R. Burkett, and J.R. Potter (eds.)]. Synthesis and Assessment Product 4.7. U.S. Department of Transportation, Washington, DC, pp. 4-1 to 4F-27 [104 pp.]
- Kale, H. W. II and D. S. Maehr 1990. Florida's birds: a handbook and reference. page 59 and 124. Pineapple Press, inc. Sarasota, Florida
- Kalkstein, L. and J. S. Greene (1997). "An Evaluation of Climate/Mortality Relationships in Large U.S. Cities and the Possible Impacts of a Climate Change." *Environmental Health Perspectives* 105(1) 84–93.
- Kalnay, E and M Cai. 2003. Impact of urbanization and land-use change on climate *Nature* 423:528.
- Karl, T. R., J. M. Melillo, and T. C. Peterson, (eds.) *Global Climate Change Impacts in the United States*, Cambridge University Press, 2009.
- Kaustuv, R., D. Jablonski, and J.W. Valentine. 2001. Climate change, species range limits and body size in marine bivalves. *Ecology Letters* 4 (4): 366-370.
- Kees, J. 2007. Personal communication with H. Scharber, 17 July 2007.

- Ketcham, D. E. and J. E. Bethune 1963. Fire resistances of south Florida slash pine. *J. Forestry* 61:529-530.
- Kilbourne, E.M. "Illness Due to Thermal Extremes," in *Maxcy-Rosenau-Last: Public Health & Preventive Medicine*, edited by Robert Wallace, (Stamford, Connecticut: Appleton & Lange, 1998).
- Kildow, J. (2006b). Phase I: Florida's Ocean and Coastal Economies Report. Moss Landing, CA, National Ocean Economics Program.
- Kildow, Judith 2006 Florida's Ocean and Coastal Economies Report Phase I California State University Monterey Bay June 2006 129 pp.
- Kleypas, J.A., R.A. Feely, V.J. Fabry, C. Langdon, C.L. Sabine, and L.L. Robbins. 2006. *Impacts of ocean acidification on coral reefs and other marine calcifiers: A guide for future research*. Report of a workshop held 18–20 April 2005, St. Petersburg, Florida, sponsored by the National Science Foundation, National Oceanic and Atmospheric Administration, and U.S. Geological Survey. [http://www.isse.ucar.edu/florida/report/Ocean\\_acidification\\_res\\_guide\\_compessed.pdf](http://www.isse.ucar.edu/florida/report/Ocean_acidification_res_guide_compessed.pdf).
- Knutson, T.R., J.J. Sirutis, S.T. Garner, G.A. Vecchi, and I.M. Held. 2008. Simulated reduction in Atlantic hurricane frequency under twenty-first-century warming conditions. *Nature Geoscience*, 18 May, doi: 10.1038/ngeo202.
- Koelle, K., X. Rodo, M. Pascual, M. Yunus, and G. Mostafa. 2005. Refractory periods and climate forcing in cholera dynamics, *Nature* 436:696-698.
- Komarek, R. 1963. Fire and changing wildlife habitat. Proc. Tall Timbers Fire Ecol. Conf. [Tallahassee, Fla. March 1963]2:35-43.
- Kriesel, Warren and Robert Friedman. 2002. Coastal hazards and economic externality: Implications for beach management policies in the American Southeast. Washington, DC: The H. John Heinz III Center for Science, Economics and the Environment.
- Kuffner, I.B., A.J. Andersson, P.L. Jokiel, K.S. Rodgers, and F.T. Mackenzie. 2008. Decreased abundance of crustose coralline algae due to ocean acidification. *Nature Geoscience*, v. 1, no. 2, pp. 114-117, doi: 10.1038/ngeo100.
- Kushlan, J.A. and T.E. Lodge 1974. Ecological and distributional notes on the freshwater fish of southern Florida. *Fla. Sci.* 37(2):110-128.
- LaDochy S et al. 2007. Recent California climate variability: spatial and temporal patterns in temperature trends. *Clim Res* 33:159.
- Lafferty, K.D. 2009 The ecology of climate change and infectious diseases. *Ecology* 90:888-900.
- Landsea, C.W., W.M. Gray, P.W. Mielke, Jr., and K.J. Berry. 1994. Seasonal forecasting of Atlantic hurricane activity. *Weather* 49, 273-284.
- Langdon, O. G. 1963. Growth patterns of Pinus elliottii var. densa. *Ecology* 44: 825-827.

- Lau, K.-M., and T. Wu. 2007. Detecting trends in tropical rainfall characteristics, 1979–2003. *International Journal of Climatology* 27, 979-988.
- Lawler, Joshua J., Sarah L. Shafer, Denis White, Peter Kareiva, Edwin P. Maurer, Andrew R. Blaustein, and Patrick J. Bartlein. 2009. Projected climate-induced faunal change in the Western hemisphere. *Ecology* 90(3), 2009, pp. 588-597.
- Layne, J. N. 1974. The land mammals of south Florida. Pages 386-413 in P. J. Gleason, (ed.) *Environments of South Florida: present and past*. Miami Geol. Soc. Mem. 2.
- Layne, J.N. and M.N. McCauley. 1976. Biological overview of the Florida panther. Pages 5-45 *in* P.C.H. Pritchard ed., *Proceedings of the Florida panther conference*. Florida Audubon Society. 121 pp.
- Lee County Visitor and Convention Bureau (LCVCB). 11 September 2008. "Beaches of Ft. Myers & Sanibel to Address Habitat Loss and Climate Change." Press release. Lee County, FL.
- Lee, J. K., R. A. Park, P. W. Mause, and R. C. Howe. 1991. GIS-related Modeling of Impacts of Sea Level Rise on Coastal Areas. Pages 356-367. *GIS/LIS '91 Conference*, Atlanta, Georgia.
- Lerner, B. R. 2006. Tomatoes Not Ripening? *Purdue Yard & Garden News*, September 17.
- Lessios, H.A., D.R. Robertson, and J.D. Cubit. 1984. Spread of *Diadema* mass mortality through the Caribbean. *Science* 226:335-337.
- Levina, E., J. S. Jacob, L. E. Ramos and I. Ortiz 2007. Policy Frameworks for Adaptation to Climate Change in Coastal Zones: The Case of the Gulf of Mexico. Paris, Organization for Economic Co-operation and Development:
- Lewis, C. E. 1964. Forage response to month of burning. U.S. Dept. Agric. For. Serv. Res. Note SE-35, 4p. Southeast For. Exp. Stn, Asheville, N. C.
- Lewis, R.R., R.G. Gilmore Jr., D.W. Crewz, and W.E. Odum. 1985. Mangrove habitat and fishery resources of Florida. Pages 281-336 *in* Florida aquatic habitat and fishery resources. W. Seaman, Jr. (ed.), American Fisheries Society.
- Liberto, J. 2007. Crist Freezes Rates for Citizens *St. Petersburg Times*, 27 June 2007.
- Lugo, A.E., and S.C. Snedaker. 1974. The ecology of mangroves. *Annual Review of Ecology and Systematics* 5:39-64.
- Maehr, D.S. 1984. Distribution of black bears in eastern North America. *Proceedings of the eastern workshop on black bear management research* 7:74.

- Maehr, D.S., and J.B. Wooding. 1992. Florida black bear. Pages 265-275 in S.R. Humphrey (ed.), *Rare and endangered biota of Florida: Volume I. Mammals*. University Press of Florida, Gainesville, Florida.
- Maehr, D.S., J.N. Layne, E.D. Land, J.W. McCowan, and J. Roof. 1988. Long distance movements of a Florida black bear. *Florida Field Naturalist* 16:1-6.
- Marella, R. L. 2004. *Water Withdrawals, Use, Discharge, and Trends in Florida, 2000: U.S. Geological Survey Scientific Investigations Report 2004-5151*. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey: 136.
- Marella, R. L. and M. P. Berndt 2005. *Water Withdrawals and Trends from the Floridan Aquifer System in the Southeastern United States, 1950-2000*. U. G. Survey.
- Marshall, C.H. Jr., R.A. Pielke Sr., and L.T. Steyaert. 2003. Crop freezes and land-use change in Florida. *Nature* 426, 29-30.
- Marshall, C.H. Jr., R.A. Pielke Sr., and L.T. Steyaert. 2004. Has the conversion of natural wetlands to agricultural land increased the incidence and severity of damaging freezes in south Florida? *Mon Weather Rev* 132:2243.
- Martin, S., J. M. Hall-Spencer, R. Rodolfo-Metalpa, and J. P. Gattuso. 2009. Effects of ocean acidification and global warming on Mediterranean coralline algae. ASLO Aquatic Sciences Meeting, January 25-30, 2009, Centre De Congre's Acropolis, Nice, France.
- Maul, G.A., and D.M. Martin. 1993. Sea level rise at Key West, Florida, 1846-1991: America's longest instrument record? *Geophysical Research Letters* 20 (18): 1955-1958.
- Maul, G.A., and H.J. Sims. 2007. Florida coastal temperature trends: Comparing independent datasets. *Florida Scientist* 70(1): 71-82.
- McNulty, S. G., J.M. Vose and W. T. Swank (1996). "Potential Climate Change Effects on Loblolly Pine Forest Productivity and Drainage across the Southern United States." *Ambio* 25(7).
- McPherson, B. F. 1969. Preliminary determination of hydrobiological and chemical conditions in the vicinity of the proposed jetport and other airports in South Florida. USGS Progress Report. 45 pp.
- Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver, and Z.-C. Zhao, 2007: Global climate projections. In: *Climate Change 2007: The Physical Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 747-845.
- Miller, T., J.C. Walker, G.T. Kingsley, and W.A. Hyman. December 1989. Impact of global climate change on urban infrastructure. In *Potential effects of global*

- climate change on the United States: Report to Congress. Appendix H: Infrastructure* (J.B. Smith and P.A. Tirpak, eds.), 2-2-2-37. Washington, DC: U.S. Environmental Protection Agency.
- Mitrovica, J.X., N. Gomez, and P.U. Clark, 2009: The sea level fingerprint of West Antarctic collapse. *Science*, 323(5915), 753.
- Moore, W. H. 1972. Managing bobwhites in the cutover pinelands of south Florida. In First natl. Bobwhite Quail Symp. Proc. 1972:56-65. [Stillwater, Oklahoma]
- Morton, J. (1987). Orange. *Fruits of warm climates*. J. F. Morton. Miami, FL: 134-142.
- Mulkey, S (ed.). 2006. Towards a sustainable Florida. Century Commission for a Sustainable Florida. [www.centurycommission.org](http://www.centurycommission.org)
- Mulkey, S. 2007. Climate Change and Land Use in Florida. Gainesville, FL: Century Commission.
- Mulkey, S. 2008. Climate Change and Land Use in Florida: Interdependencies and Opportunities. Century Commission for A Sustainable Florida. 2007. National Council for Science and the Environment 2008. Climate Change: Science and Solutions.
- Mulkey, W. D., A.W. Hodges, T. J. S. III, F. M. Roka and R. L. Degner 2005. Economic Impact of the C-43Reservoir in Southwest Florida: Final Report. Gainesville, FL, University of Florida, Institute of Food and Agricultural Studies: 47.
- Mulvania, M. 1931. Ecological survey of a Florida scrub. *Ecology* 12: 528-540.
- Murelio, C. 2003. Winter Peak Records Break across Eastern U.S., *Energy Vortex*, 2007.
- National Ocean Economics Program. (2007b). "Fisheries Statistics." Retrieved 27 July, 2007, from <http://noep.mbari.org/LMR/fishSearch.asp>.
- National Oceanic & Atmospheric Administration (2000a). The Potential Consequences of Climate Variability and Change on Coastal Areas and Marine Resources. *Decision Analysis Series*. D. Boesch, J. Field and D. Scavla. Silver Spring, MD, NOAA Coastal Ocean Program.
- National Oceanic & Atmospheric Administration (2000b). State, Territory, and Commonwealth Beach Nourishment Programs. Silver Spring, MD, National Oceanic and Atmospheric Administration.
- National Oceanic & Atmospheric Administration (2007a). Fisheries Statistics Database, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Fisheries Statistics Division.
- National Oceanic & Atmospheric Administration. (2007b). "National Climatic Data Center." 2007, from <http://www.ncdc.noaa.gov/oa/ncdc.html>.

- National Research Council 2000. **Ecological Indicators for the Nation**. National Academy Press, Washington, D.C. 180 pp.
- National Research Council. 2008. **Potential impacts of climate change on U.S. transportation**. Washington, D.C.: Transportation Research Board. 4 pp.
- National Wildlife Federation and Florida Wildlife Federation 2006. **An Unfavorable Tide: Global Warming, Coastal Habitats and Sportfishing in Florida**. Reston, VA, National Wildlife Federation and Florida Wildlife Federation.
- Natural Resources Defense Council and Florida Climate Alliance 2001. **Feeling the Heat in Florida: Global Warming on the Local Level**. New York Natural Resources Defense Council and the Florida Climate Alliance.
- Nobel Foundation. 2007. *The Nobel Peace Prize for 2007*. Press release. Oslo, Norway. [http://nobelprize.org/nobel\\_prizes/peace/laureates/2007/press.html](http://nobelprize.org/nobel_prizes/peace/laureates/2007/press.html).
- North American Electric Reliability Corporation 2006. **2006 Long-Term Reliability Assessment: The Reliability of the Bulk Power Systems In North America**, North American Electric Reliability Corporation.
- Nyman, J.A., R.D. DeLaune, H.H. Roberts, and W.H. Patrick, Jr. 1993. Relationship between vegetation and soil formation in a rapidly submerging coastal marsh. *Marine Ecology Progress Series* 96: 269-1993.
- O'Brien, J. and D. Zierden 2001. **Climate of Florida**. NCDC, NOAA.
- Odum, W.E., and C.C. McIvor. 1990. Mangroves. Pages 517-548 in R.L. Myers and J.J. Ewel, (eds.), **Ecosystems of Florida**. University Press of Florida, Gainesville, Florida.
- Odum, W.E., and E.J. Heald. 1972. Trophic analysis of an estuarine mangrove community. *Bulletin of Marine Science* 22:671-738.
- Odum, W.E., C.C. McIvor, and T.S. Smith. 1982. **The ecology of mangroves of South Florida: a community profile**. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS - 81/24.
- Oetting, J and T Hctor. 2007. **CLIP \_ Critical lands & waters Identification project**. Phase I report to the Century Commission for a Sustainable Florida. [www.centurycommission.org](http://www.centurycommission.org)
- Ogden, J. C. 1978a. Louisiana heron. pp. 77-78. in H. W. Kale II (ed.), **Rare and endangered biota of Florida**. Vol. II. Birds. University Presses of Florida, Gainesville, Florida.
- Ogden, J. C. 1978b. Roseate spoonbill. pp. 53-54. in H. W. Kale II (ed.), **Rare and endangered biota of Florida**. Vol. II. Birds. University Presses of Florida, Gainesville, Florida.
- Ogden, J. C. 1978c. Snowy egret. pp. 75-76. in H. W. Kale II (ed.), **Rare and endangered biota of Florida**. Vol. II. Birds. University Presses of Florida, Gainesville, Florida.

- Ogden, J. C. 1978d. Wood stork. pp. 3-4. *in* H. W. Kale II (ed.), Rare and endangered biota of Florida. Vol. II. Birds. University Presses of Florida, Gainesville, Florida.
- Ogden, J.D., J.A. Kushlan, and J.T. Tilmant. 1976. Prey selectivity by the wood stork *Condor* 78:324-330.
- Ogden, John C. and Steven M. Davis, eds. 1999. The use of conceptual ecological landscape models as planning tools for the south Florida ecosystem restoration programs. West Palm Beach, FL: South Florida Water Management District. 139 pp.
- Orr, J.C. et al. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* 437, 681-686. <http://www.nature.com/nature/journal/v437/n7059/full/nature04095.html>.
- Osterman, L.E., R.Z. Poore, and P.W. Swarzenski. 2007. The last 1000 years of natural and anthropogenic low-oxygen bottom water on the Louisiana shelf, Gulf of Mexico. *Marine Micropaleontology*, v. 66, no. 3-4, pp. 291-303, doi: 10.1016/j.marmicro. 2007.10.005. <http://www.sciencedirect.com/science/journal/03778398>.
- Ostfeld, R. 2009. Climate change and the distribution and intensity of infectious diseases *Ecology*, 90(14). 2009, pp. 903:905
- Paerl, H.W., and J. Huisman. 2008. Blooms like it hot. *Science* 320: 57-58.
- Park, R. A. 1991. Global Climate Change and Greenhouse Emissions. Pages 171-182. *Subcommittee on Health and Environment, U.S. House of Representatives*, Washington DC.
- Park, R. A., J. K. Lee, and D. Canning. 1993. Potential Effects of Sea Level Rise on Puget Sound Wetlands. *Geocarto International* 8: 99-110.
- Park, R. A., J. K. Lee, P. W. Mausel, and R. C. Howe. 1991. Using Remote Sensing for Modeling the Impacts of Sea Level Rise. *World Resource Review* 3: 184-205.
- Park, R. A., M. S. Trehan, P. W. Mausel, and R. C. Howe. 1989a. The Effects of Sea Level Rise on U.S. Coastal Wetlands. Pages 1-1 to 1-55. *in* J. B. Smith and D. A. Tirpak, eds. *The Potential Effects of Global Climate Change on the United States, Appendix B - Sea Level Rise*. U.S. Environmental Protection Agency, Washington, D.C.
- Park, R. A., M. S. Trehan, P. W. Mausel, and R. C. Howe. 1989b. The Effects of Sea Level Rise on U.S. Coastal Wetlands and Lowlands. Pages 48 pp. + 789 pp. *in* appendices. Holcomb Research Institute, Butler University, Indianapolis, Indiana.
- Park, R. A., T. V. Armentano, and C. L. Cloonan. 1986. Predicting the Effects of Sea Level Rise on Coastal Wetlands. Pages 129-152 *in* J. G. Titus, ed. *Effects of Changes in Stratospheric Ozone and Global Climate, Vol. 4: Sea Level Rise*. U.S. Environmental Protection Agency, Washington, D.C.

- Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology and Systematics* 37:637-669.
- Pascual, M., J. A. Ahumada, L. F. Chaves, X. Rodo, and M. Bouma. 2006. Malaria resurgence in the East African highlands: temperature trends revisited. *Proceedings of the National Academy of Sciences (USA)* 103:5829-5834.
- Patz, J.A., S.A. Olson and A.L. Gray. 2006. Climate change, oceans, and human health. *Oceanography* 19: 52-59.
- Peperzak, L. 2005. Future increase in harmful algal blooms in the North Sea due to climate change. *Water Science and Technology* 51: 31-36.
- Perry, Harriet and David Yeager. 2006. Invertebrate invaders: Established and potential exotics Gulf of Mexico region. Pamphlet. Ocean Springs, MS: Gulf Coast Research Laboratory.
- Peterson, C.H., R.T. Barber, K.L. Cottingham, H.K. Lote, C.A. Simenstad, R.R. Christian, M.F. Piehler, and J. Wilson. 2008. National estuaries. In *Preliminary review of adaptation options for climate-sensitive ecosystems and resources: A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*. Washington, DC: U.S. Environmental Protection Agency.
- Peterson, Charles H., Richard T. Barber, Kathryn L. Cottingham, Heike K. Lotze, Charles A. Simenstad, Robert R. Christian, Michael F. Piehler, and John Wilson. 2007. "National estuaries". SAP 4.4: Adaptation options for climate-sensitive ecosystems and resources. Washington D.C.: United States Environmental Protection Agency. 108 pp.
- Petit, J.R. et al. 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* 399(3 June):429-436.
- Pfeffer, W.T., J.T. Harper, and S. O'Neel, 2008: Kinematic constraints on glacier contributions to 21st-century sea level rise. *Science*, 321(5894), 1340-1343.
- Physicians for Social Responsibility. 2001. Death by Degrees. [www.psr.org](http://www.psr.org)
- Pielke, R (Sr.). 2005. Land use and climate change. *Science* 310:1625.
- Pielke, R.A., R.L. Walko, L. Steyaert, P.L. Vidale, G.E. Liston, and W.A. Lyons. 1999. The influence of anthropogenic landscape changes on weather in south Florida. *Monthly Weather Review* 127, 1663-1673.
- Pielke, RA et al. 2007. A new paradigm for assessing the role of agriculture in the climate system and in climate change. *Agric Forest Meteor* 142:234.
- Platts 2007. FRCC worries Florida may become too dependent on gas-fired power, 2007.
- Potter, J.R., V.R. Burkett, and M.J. Savonis, 2008: Executive summary. In: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I* [Savonis, M. J., V.R. Burkett, and J.R. Potter (eds.)]. Synthesis and Assessment Product 4.7. U.S. Department of Transportation, Washington, DC, pp. ES-1 to ES-10.

- Powers, W. 2003. Economic and environmental impacts associated with conversion of Indian Point Units 2 and 3 to a closed-loop condenser cooling water configuration. *Indian Point Fact Sheet*, New York State Department of Environmental Conservation.
- Precht, W.F., and R.B. Aronson. 2004. Climate flickers and range shifts of reef corals. *Frontiers in Ecology and Environment* 2(6): 307-314.
- Raabe, E.A., A.E. Streck, and R.P. Stumpf. 2004. *Historic topographic sheets to satellite imagery: A methodology for evaluating coastal change in Florida's Big Bend tidal marsh*. U.S. Geological Survey Open-File Report 02-211.
- Raabe, E.A., C.C. McIvor, J.W. Grubbs, and G.D. Dennis. 2007. *Habitat and hydrology: Assessing biological resources of the Suwannee River estuarine system*. U.S. Geological Survey Open-File Report 2007-1382. <http://pubs.usgs.gov/of/2007/1382/>.
- Rahmstorf, S. 2007. A semi-empirical approach to projecting future sea level rise. *Science* 315:368-370.
- Rail Network dataset 2006. *Federal Railroad Administration and Research and Innovative Technology Administration's Bureau of Transportation Statistics*.
- RAMSAR 2002 "Wetlands: water, life, and culture" 8th Meeting of the Conference of the Contracting Parties to the Convention on Wetlands (Ramsar, Iran, 1971) Valencia, Spain, 18-26 November 2002 Ramsar COP8 DOC. 11 Information Paper English only Climate Change and Wetlands: Impacts, Adaptation and Mitigation
- Reeves, T. 2007. In search of plentiful water for future *St. Petersburg Times (Florida)*, July 5, 2007.
- Reid, A. 2007. Seawater could help solve water woes, but at what price? *South Florida Sun-Sentinel*, July 24, 2007.
- Riebsame, W.E., W.L. Woodley, and F.D. Davis. 1974. Radar inference of Lake Okeechobee rainfall for use in environmental studies. *Weatherwise* 27(5):206-211.
- Ritchie, K.B. 2006. Regulation of marine microbes by coral mucus and mucus-associated bacteria. *Marine Ecology Progress Series* 322: 1-14.
- Rizou, M and F Nnadi. 2007. Land use feedback on clear sky downward longwave radiation: a land use adapted model. *Int J Climatol* (in press).
- Root, T.L., J.T. Price, K.R. Hall, S.H. Schneider, C. Rosenzweig, and J.A. Pounds. 2003. Fingerprints of global warming on wild animals and plants. *Nature* 421, 57-60.
- Rose, J.B., Epstein, P.R., Lipp, E.K., Sherman, B.H., Bernard, S.M., Patz, J.A. 2001. "Climate Variability and Change in the United States: Potential Impacts on Water and Food borne Diseases Caused by Microbiologic Agents," in *Environmental Health Perspectives*, Vol. 109, Supp. 2, 211-221.

- Royal Society. 2005. *Ocean acidification due to increasing atmospheric carbon dioxide*. Policy document 12/05. London, England.  
<http://royalsociety.org/displaypagedoc.asp?id=13314>.
- Rubinoff, Pamela, Nathan D. Vinhateiro, and Christopher Piecuch. 2008. Summary of coastal program initiatives that address sea level rise as a result of global climate change. Rhode Island: Rhode Island Sea Grant/Coastal Resources Center/ NOAA.
- Russell, J. B., W. M. Sharp et. al. 1979. The Effect of PH on Maximum Bacterial Growth Rate and its Possible Role as a Determinant of Bacterial Competition in the Rumen. *Journal of Animal Science*. 1979. American Society of Animal Science, Savoy, IL. 48:251-255.  
<http://jas.fass.org/cgi/content/abstract/48/2/251> accessed 3/31/09.
- Sallenger, A.H., C.W. Wright, and J. Lillycrop. 2005. Coastal impacts of the 2004 hurricanes measured with airborne Lidar; initial results. *Shore and Beach* 73(2&3), 10-14.
- Sallenger, A.H., C.W. Wright, and P. Howd. In review. Barrier island failure modes triggered by Hurricane Katrina and long-term sea level rise. Submitted to *Geology*.
- Sallenger, A.H., H.F. Stockdon, L. Fauver, M. Hansen, D. Thompson, C.W. Wright, and J. Lillycrop. 2006. Hurricanes 2004: An overview of their characteristics and coastal change. *Estuaries and Coasts* 29(6A), 880-888.
- Sato, S., M. M. Peet and J. F. Thomas 2000. "Physiological factors limit fruit set of tomato (*Lycopersicone sculentum* Mill.) under chronic, mild heat stress "Plant, *Cell & Environment* 23(7): 719-726.
- Savage T. 1972. Florida mangroves as shoreline stabilizers. Florida Department of Natural Resources professional paper 19.
- Savarese, M., L. P. Tedesco, C. Mankiewicz and L. Shrake 2002. *Late Holocene Sea Level Rise in Southwest Florida: Implications for Estuarine Management and Coastal Evolution*. Fifteenth Keck Research Symposium in Geology Proceedings, Amherst College, Amherst, Massachusetts.
- Scavia, D., J. Field, D. Boesch et al. 2002. "Climate Change Impacts on U.S. Coastal and Marine Ecosystems." *Estuaries Ecosystems.* *Estuaries* 25(2): 149-164.
- Schleupner, C. 2008. Evaluation of coastal squeeze and its consequences for the Caribbean island Martinique. *Ocean and Coastal Management* 51(5): 383-390.
- Schomer, N.S., and R.D. Drew. 1982. An ecological characterization of the lower Everglades, Florida Bay, and the Florida Keys. U.S. Fish and Wildlife Service, Office of Biological Services, Washington D.C. FWS/OBS-82/58.1.
- Schreiber, R.W. 1978. Eastern brown pelican. Pages 23-25 in H.W. Kale II, (ed.) Rare and endangered biota of Florida: Volume V. Birds. University Press of Florida, Gainesville, Florida.

- Schubert, R., H.-J. Schellnhuber, N. Buchmann et al. 2006. *The Future Oceans—Warming Up, Rising High, Turning Sour*. Berlin, German Advisory Council on Global Change (WBGU).
- Schubert, T. S., S. A. Rizvi, X. Sun et al. 2001. "Meeting the Challenges of Eradicating Citrus Canker in Florida—Again." *Plant Disease* 85(4): 340–356.
- Scott, R. 2007. Personal communication with H. Scharber, 18 July 2007.
- Seaman, W. 1985. Introduction to the aquatic resources of Florida. Pages 1-19 in W. Seaman (ed.), *Florida aquatic habitat and fishery resources*. American Fisheries Society.
- Selkowitz, S. and E.S. Lee., 1998. Advanced Fenestration Systems for Improved Daylight Performance. *Daylighting '98 Conference Proceedings*, May 11-13, 1998, Ottawa, Ontario, Canada: LBNL-41461
- Shay, L.K., G.J. Goni, and P.G. Black. 2000. Effects of a warm oceanic feature on Hurricane Opal. *Monthly Weather Review* 125(5), 1366-1383.
- Shepherd, J.M., A. Grundstein, and T.L. Mote. 2007. Quantifying the contribution of tropical cyclones to extreme rainfall along the coastal southeastern United States. *Geophysical Research Letters* 34: L23810, doi: 10.1029/2007GL031694.
- Shukman, David, 2009 Environment correspondent, BBC News, Copenhagen Sea rise 'to exceed projections' BBC World News. Page last updated at 14:38 GMT, Tuesday, 10 March 2009  
<http://news.bbc.co.uk/1/hi/sci/tech/7935159.stm>
- Simberloff, D.S., and E.O. Wilson. 1969. Experimental zoogeography of islands. The colonization of empty islands. *Ecology* 50(2):278-295.
- Smetacek, V., and J.E. Cloern. 2008. On phytoplankton trends. *Science* 319: 1346-1348.
- Smith, P.W. 1996. Mangrove cuckoo, *Coccyzus minor*. Pages 329-344 in J.A. Rodgers, Jr., H.W. Kale II, and H.T. Smith, (eds.) *Rare and endangered biota of Florida: Volume V. Birds*. University Press of Florida, Gainesville, Florida.
- Smyda, T.J. 1997. Marine phytoplankton blooms: their ecophysiology and general relevance to phytoplankton blooms in the sea. *Limnology and Oceanography* 42: 1137-1153.
- Snall, T., R. B. O'Hara, C. Ray, and S. K. Collinge. 2008. Climate-driven spatial dynamics of plague among prairie dog colonies. *American Naturalist* 171:238-248.
- Snedaker, S.C. 1982. Pages 111-125 in *Contributions to the ecology of halophytes*. D.N. Sen and K.S. Rajpurohit (eds.), Volume 2 The Hague: D.W. Junk.
- Sokolov, A., R. Prinn, P. H. Stone, C. E. Forest, S. Paltsev, A. Schlosser, S. Dutkiewicz, J. Reilly, M. Sarofim, C. Wang and H. D. Jacoby, M. Webster D. Kicklighter, B. Felzer and J. Melillo (2009) *Journal of Climate*, May In Press.

- Southeast Climate Change Partnership, Sustainable Development Round Table, and London Climate Change Partnership. 2005. Adapting to climate change: a checklist for development. London: Greater London Authority.**
- Southwest Florida Regional Planning Council (SWFRPC), 2001. Southwest Florida Regional Hurricane Evacuation Study 2001 Update, Table 2 Land falling Category 2 Storm Surge Vulnerable Population Estimates.**
- Southwest Florida Regional Planning Council (SWFRPC), 2008 Land Use Impacts SWFRPC**
- Southwest Florida Regional Planning Council (SWFRPC), 2009. Economic Views 2008: The year in Review, March 2009, 1926 Victoria Avenue, Fort Myers, Florida (<http://www.swfrpc.org/content/EcoDev/Views/2009/0309.pdf> )**
- Speybroeck, J., D. Bonte, W. Courtens et al. 2006. “Beach nourishment: an ecologically sound coastal defense alternative? A review.” *Aquatic Conservation: Marine and Freshwater Ecosystems* 16: 419–435.**
- Squillace, A. E. 1966. Geographic variation in the slash pine. For. Sci. Monogr. 10, 56p.**
- Stachowicz, J.J., J.R. Terwin, R.B. Whitlatch, and R.W. Osman.2002. Linking climate change and biological invasions: Ocean warming facilitates nonindigenous species invasions. *Proceedings of the National Academy of Sciences* 99: 15497-15500; published online as 10.1073/pnas.242437499.**
- Stanton, E.A., and F. Ackerman. 2007. *Florida and climate change: The costs of inaction*. Tufts University Global Development and Environment Institute and Stockholm Environment Institute–US Center.**
- Stenseth, N. C., et al. 2006. Plague dynamics are driven by climate variation. *Proceedings of the National Academy of Sciences (USA)* 103:13110-13115.**
- Stoddard, H. L. Sr. 1963. Bird habitat and fire. Second Annual Proc. Tall Timbers Fire Ecol. Conf. Tallahassee, Fla. March 1963]2:163-175.**
- Straile, D., and N.C. Stenseth. 2007. The North Atlantic Oscillation and ecology: Links between historical time-series, and lessons regarding future climate warming. *Climate Research* 34(3): 259-262.**
- Strong, A.M., R.J. Sawicki, and G.T. Bancroft. 1991. Effects of predator presence on the nesting destruction of white-crowned pigeons in Florida Bay. *Wilson Bulletin*103:414-425.**
- Taylor, D.S., and F.F. Snelson, Jr. 1992. Mangrove rivulus, *Rivulus marmoratus* (Poey).Pages 200-207 in *Rare and endangered biota of Florida: Volume II. Fishes*. University Press of Florida, Gainesville, Florida.**
- Telemeco, Rory S., Melanie J. Elphick, Richard Shine. 2009. *Nesting lizards (Bassiana duperreyi) compensate partly, but not completely, for climate change*. *Ecology*. Ecological Society of America. 90(1). Pp.17-22.**
- Thomas, T.M. 1974. A detailed analysis of climatological and hydrological records of south Florida, with reference to man's influence upon ecosystem evolution.**

- Pages 82-122 in P.J. Gleason, (ed.) *Environments of south Florida: present and past*. Miami Geol. Soc. Mem. 2.
- Titus, J. G. 1998. "Rising seas, coastal erosion, and the takings clause: how to save wetlands and beaches without hurting property owners". *Maryland Law Review* 57 (4) 1279-1399.
- Titus, J. G. 2000. Does the U.S. Government Realize that the Sea Is Rising? *Golden Gate University Law Review*, Vol. 30:4:717-778
- Titus, J. G. 2002. Does Sea Level Rise Matter to Transportation Along the Atlantic Coast? *The Potential Impacts of Climate Change on Transportation*, U.S. Department of Transportation, Center for Climate Change and Environmental Forecasting.
- Titus, J. G., R. A. Park, S. P. Leatherman, J. R. Weggel, M. S. Greene, P. W. Mausel, M. S. Trehan, S. Brown, C. Grant, and G. W. Yohe. 1991. Greenhouse Effect and Sea Level Rise: Loss of Land and the Cost of Holding Back the Sea. *Coastal Management* 19: 171-204.
- Titus, J.G. 1990. "Greenhouse Effect, Sea Level Rise, and Barrier Islands." *Coastal Management* 18:1:65-90.
- Titus, J.G. 2009 personal communication in first draft review of Southwest Florida/Charlotte Harbor Climate Change Vulnerability Assessment
- Titus, J.G. and C. Richman, 2001: Maps of lands vulnerable to sea level rise: modeled elevations along the U.S. Atlantic and Gulf coasts. *Climate Research*, 18(3): 205-228.
- Titus, J.G. and Narayanan, V.K. 1995. The Probability of Sea Level Rise. Washington D.C. Environmental Protection Agency.
- Tomlinson, P.B. 1986. The botany of mangroves. Cambridge University Press, New York, New York.
- Transportation Research Board 2008. Committee on Climate Change and U.S. Transportation 2008 *Potential Impacts of Climate Change on U. S. Transportation*. National Research Council 2008500 Fifth Street, NW, Washington, DC 20001
- Trescott, D. and T. Walker. 2009. Land use impacts and solutions to sea level rise in southwest Florida, Southwest Florida Regional Planning Council, Fort Myers, Florida. [www.swfrpc.org](http://www.swfrpc.org)
- Trimble, P.J., E.R. Santee, and C.J. Neidrauer. 1998. Preliminary estimate of impacts of sea level rise on the regional water resources of southeastern Florida. *Proceedings of the International Coastal Symposium, Journal of Coastal Research*, Special Issue No. 26.
- Turner, R.E, N.N. Rabalais, B. Fry, N. Atilla, C.S. Milan, J.M. Lee, and C. Normandeau et al. 2006. Paleo-indicators and water quality change in the Charlotte Harbor Estuary (Florida). *Limnology and Oceanography*, v. 51, no. 1, pp. 518-533.

- Twilley, R. 1980. Organic exports from black mangrove forests in south Florida. PhD dissertation (unpublished). University of Florida, Gainesville, Florida.**
- Twilley, R.R., E. Barron, H.L. Gholz, M.A. Harwell, R.L. Miller, D.J. Reed, J.B. Rose, E. Siemann, R.G. Welzel and R.J. Zimmerman. 2001. Confronting Climate Change in the Gulf Coast Region: Prospects for Sustaining Our Ecological Heritage. Union of Concerned Scientists, Cambridge, MA and Ecological Society of America, Washington, DC. 82 pp.**
- United States Department of Commerce (USDC), 1981. Local climatological data 1980 - Fort Myers - annual summary with comparative data. U.S. Dep. Comm., National Oceanic and Atmospheric Administration (NOAA).**
- United States Geological Survey, Biological Resources Division [USGS-BRD]. 1996. Classification of 1993/94 Landsat TM Imagery. Florida Cooperative Fish and Wildlife Research Unit, University of Florida; Gainesville, Florida.**
- Uhland, Angela Morrison. 2007. Global climate change policy developments in Florida. Presented at the Florida AWMA meeting, 29 October 2007, in Deerfield Beach, Florida.**
- United Nations Environment Programme. 2006. *GEO yearbook 2006*. Nairobi, Kenya: Division of Early Warning and Assessment. [www.unep.org/geo/yearbook/yb2006/PDF/Complete\\_pdf\\_GYB\\_2006.pdf](http://www.unep.org/geo/yearbook/yb2006/PDF/Complete_pdf_GYB_2006.pdf).**
- United States National Oceanic and Atmospheric Administration (USNOAA), Climatic Data Center. 2008. Draft Climate Change handbook. Asheville, NC: NOAA Climatic Data Center.**
- United States Army Corps of Engineers 2000. Lake Michigan Potential Damages Study—Task 3.3.2—Assess Costs of Higher and Lower Design Crest Elevations on Future Shore Protection. Detroit, United States Army Corps of Engineers: 23.**
- United States Census Bureau (2004a). State Interim Population Projections by Age and Sex: 2004 – 2030; Table 1: Interim Projections: Ranking of Census 2000 and Projected 2030 State Population and Change: 2000 to 2030. Washington DC, United States Census Bureau.**
- United States Census Bureau (2004b). U.S. Interim Projections by Age, Sex, Race, and Hispanic Origin; Table 1a. Projected Population of the United States, by Race and Hispanic Origin: 2000 to 2050, United States Census Bureau.**
- United States Census Bureau 2007. 2002 Economic Census, United States Census Bureau.**
- United States Climate Change Science Program (USCCSP). 2008. Coastal sensitivity to sea level rise: a focus on the mid-Atlantic region. Washington, DC: USEPA.**
- United States Climate Change Science Program and the Subcommittee on Global Change Research 2008. Adaptation Options for Climate-Sensitive**

- Ecosystems and Resources Final Report, Synthesis and Assessment Product 4.4, 550 pp**
- United States Congress, Office of Technology Assessment, 1993. Preparing for an Uncertain Climate--Volume I, OTA-O-567 (Washington, DC: U.S. Government Printing Office, October 1993).**
- United States Congress, Office of Technology Assessment, 1993. Preparing for an Uncertain Climate--Volume II, OTA-O-568 (Washington, DC: U.S. Government Printing Office, October 1993).**
- United States Department of Agriculture 2003. Florida Supplements to National Engineering Handbook, Part 652—Irrigation Guide. Washington, D.C., United States Department of Agriculture, Natural Resources Conservation Service.**
- United States Department of Agriculture 2005. Florida State Agriculture Overview—2005 United States Department of Agriculture: 2.**
- United States Department of Energy 2000. Interim report of the U.S. Department of Energy’s Power Outage Study Team, US DoE, Office of Policy and International Affairs.**
- United States Environmental Protection Agency 1997. Climate Change and Florida Office of Policy, Planning and Evaluation (2111) EPA 230-F-97-008i September 1997. 4 pp**
- United States Environmental Protection Agency Climate Ready Estuaries 2008. *Draft synthesis of adaptation options for coastal areas.* Distributed at NEP National Meeting, 26 February 2008. 26 pp.**
- United States Geological Survey 2000. National Assessment of Coastal Vulnerability to Future Sea level Rise. Washington, D.C., United States Geological Survey: 2.**
- United States Geological Survey 2007. *NOAA Medium Resolution Digital Vector Shoreline*, Coastal and Marine Geology Program Internet Map Server—Atlantic and East Coast USGS.**
- United States Global Change Research Program 2001. Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change. Washington D.C., National Assessment Synthesis Team, United States Global Change Research Program: Updated in 2004.**  
[www.usgcrp.gov/usgcrp/nacc/](http://www.usgcrp.gov/usgcrp/nacc/)
- United States Green Building Council (USGBC). 2007. Leadership in Energy and Environmental Design (LEED) New Construction & Major Renovation Version 2.2, Reference Guide, Third Edition October 2007. U.S. Green Building Council, Washington, D.C. 2006. 422 pp. website located at: <http://www.usgbc.org/DisplayPage.aspx?CMSPageID=222>**
- United States Streets Dataset. Environmental Systems Research Institute 200**

- University of Florida Bureau of Economic and Business Research, (UFBEBR)  
Warrington College of Business. 2008. Florida Statistical Abstract 2008.  
Gainesville, Florida: University of Florida.
- University of Florida: GeoPlan 2007 1:250,000 Digital Elevation Model
- University of Florida: GeoPlan 2007 Historic and Projected Populations of Florida  
Counties
- University of Washington Center for Science in the Earth System. 2007. Preparing  
for climate change: a guidebook for local, regional and state governments.  
King County, WA: The Climate Impacts Group. 186 pp.
- Vaclavicek, A. 2004. Sugar Cane: Cultivation, Breeding, Biotechnology. *Student  
Preparation Seminars: Costa Rica 2004*, Centre for Agriculture in the Tropics  
and Subtropics, University of Bodenheim.
- Van Arman, J., G.A. Graves, and D. Fike. 2005. Loxahatchee water-shed conceptual  
ecological model. *Wetlands* 25(4): 926-942.
- Van Dolah, F.M. 2000. Marine algal toxins: Origins, health effects, and their  
increased occurrence. *Environmental Health Perspectives* 108: 133-141.
- Vecchi, G.A., and B.J. Soden. 2007. Increased tropical Atlantic wind shear in model  
projections of global warming. *Geophysical Research Letters* 34, L08702, doi:  
10.1029/2006GL028905.
- Victorian Climate Change Program 2008. State of Victoria, Australia: Department  
of Sustainability and Environment. <http://www.climatechange.vic.gov.au>.
- Virmani, J.I., and R.H. Weisberg. 2006. The 2005 hurricane season: An echo of the  
past or a harbinger of the future? *Geophysical Research Letters* 33, L05707,  
doi: 10. 1029/2005GL025517.
- VISITFLORIDA 2007a. "Official Media Newsroom." Retrieved 12 June, 2007, from  
<http://media.visitflorida.org/about/research/>.
- VISITFLORIDA 2007b. Preliminary Visitor Estimates, Resident Pleasure Travel,  
and Industry Trend Indicators 2006Q4 and CY2006. Tallahassee, VISIT  
FLORIDA Research: 23.
- Volk, Michael. 2008a. An analysis of strategies for adaptation to sea level rise in  
Florida. Gainesville, FL: University of Florida. 143 pp.
- Volk, Michael. 2008b. Summary of research on strategies for adaptation to sea level  
rise in Florida. Gainesville, FL: University of Florida. 25 pp.
- Wade, D., J. Ewel, and R. Hofstetter 1980. Fire in South Florida Ecosystems.  
U.S.D.A. Forest Service General Technical Report SE-17, 125 pp.
- Walton, Todd L. Jr. 2007. Projected sea level rise in Florida, *Ocean Engineering* 34  
(2007) 1832–1840
- Wang, C., and D.B. Enfield et al. 1998. LEVITUS98: *World Ocean Atlas* 1998.

- Wang, C., and S.-K. Lee. 2008. Global warming and United States land falling hurricanes. *Geophysical Research Letters* 35, L02708, doi: 10.292007GL032396.
- Wanless, H.R. 1998. Mangroves, hurricanes, and sea level rise. South Florida Study Group, The Conservancy, Naples, Florida.
- Wanless, H.R., Parkinson, R., and Tedesco, L.P. 1994. Sea level control on stability of Everglades wetlands, in *Proceedings of Everglades Modeling Symposium*. St. Lucie Press, FL, p. 199-223.
- Webster, P.J., G.J. Holland, J.A. Curry, and H.-R. Chang. 2005. Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science* 309 (5742), 1844-1846.
- Wilkinson, C., and D. Souter (eds). 2008. *Status of Caribbean coral reefs after bleaching and hurricanes in 2005*. Townsville, Australia: Global Coral Reef Monitoring Network, and Reef and Rainforest Research Centre. [http://www.coris.noaa.gov/activities/caribbean\\_rpt/](http://www.coris.noaa.gov/activities/caribbean_rpt/).
- Williams, J.W., and S.T. Jackson. 2007. Novel climates, no-analog communities, and ecological surprises. *Frontiers in Ecology and Environment* 5(9): 475-482.
- Williams, K., K.C. Ewel, R.P. Stumpf, F.E. Putz, and T.W. Workman. 1999. Sea level rise and coastal forest retreat on the west coast of Florida, USA. *Ecology* 80 (6): 2045-2063.
- Wilson, C. 1997. Hurricane Andrew's Insurance Legacy Wearing Off *AP Business News*, February 27, 1997.
- Woodley, W. L., 1970: Precipitation results from pyrotechnic cumulus seeding experiment. *J. Appl. Meteor.*, 9, 109-122.
- Woodworth, P.L. and Player, R. 2003. The Permanent Service for Mean Sea Level: an update to the 21st century. *Journal of Coastal Research*, 19, 287-295
- Xian, G and M Crane. 2006. An analysis of urban thermal characteristics and associated land cover in Tampa Bay and Las Vegas using Landsat satellite data. *Remote Sensing of Environment* 104:147.
- Yohe, G., J. Neumann and P. Marshall 1999. The economic damage induced by sea level rise in the United States. *The Impact of Climate Change on the United States Economy*. R. Mendelsohn and J. E. Neumann. Cambridge, Cambridge University Press: 178–208.
- Yuhas, E. and T. Daniels 2006. "The USU.S. Freshwater Supply Shortage: Experiences with Desalination as Part of the Solution." *Journal of Environmental Planning and Management* 49(4): 571–585.
- Zillow.com 2009. U.S. Real Estate and Homes for Sale (<http://www.zillow.com/local-info>) Data on March 27, 2009.
- Zwick, P and M Carr. 2006. Florida 2060: A population distribution scenario for the state of Florida. 1000 Friends of Florida.

**Appendix 1: Critical Facilities by Coastal County**

**CHARLOTTE COUNTY CRITICAL FACILITIES SUBJECT TO SEA LEVEL RISE**

<b>FACILITY TYPE</b>	<b>FACILITY NAME</b>	<b>ADDRESS</b>	<b>ELEVATION/PROTECTION</b>
AIRPORT	Ranger Stadium		5'-10' Protection Definite
CLINIC	Inter-Medic Health Center	2885 TAMIAMI TR	5'-10' Protection Definite
CLINIC	Punta Gorda Senior Health	1401 TAMIAMI TR	5'-10' Protection Definite
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER	5060 PLACIDA RD	5'-10' Protection Definite
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER		5'-10' Protection Definite
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER		0' to 5' Protection Not Recommended
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER	3545 KENDALL RD	5'-10' Protection Definite
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER	4770 PLACIDA RD	0' to 5' Protection Not Recommended
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER	5201 LINWOOD RD	5'-10' Protection Definite
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER	5301 LINWOOD RD	5'-10' Protection Definite
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER	4195 KINGS HWY	5'-10' Protection Definite
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER	4291 BOCA ST	5'-10' Protection Definite
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER	22261 VICK ST	5'-10' Protection Definite
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER		0' to 5' Protection Not Recommended
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER	25097 MARION AV	5'-10' Protection Definite
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER		5'-10' Protection Definite
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER	417 COOPER ST	5'-10' Protection Definite
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER	701 DEAUVILLE DR	0' to 5' Protection Not Recommended
COMMUNICATIONS TOWER	COMMUNICATIONS TOWER	416 COOPER ST	5'-10' Protection Definite
COMMUNICATIONS TOWER	COMCAST CABLEVISION	22266 EDGEWATER DR	0' to 5' Protection Not Recommended
COMMUNICATIONS TOWER	GOLD 100 FM/WKII	3151 COOPER ST	0' to 5' Protection Not Recommended
COMMUNICATIONS TOWER	KIX 92.9 FM - WCVU 104.9 FM -	4810 DELTONA DR	0' to 5' Protection Not Recommended

COMMUNITY CENTER	NEIGHBORHOOD CENTER		5'-10' Protection Definite
COMMUNITY CENTER	COMMUNITY CENTER		5'-10' Protection Definite
COMMUNITY CENTER	NEIGHBORHOOD CENTER	4300 KINGS HWY	5'-10' Protection Definite
COMMUNITY CENTER	NEIGHBORHOOD CENTER	4200 TAMIAMI TR	5'-10' Protection Definite
COMMUNITY CENTER	NEIGHBORHOOD CENTER	4265 TAMIAMI TR	5'-10' Protection Definite
COMMUNITY CENTER	NEIGHBORHOOD CENTER		0' to 5' Protection Not Recommended
COMMUNITY CENTER	NEIGHBORHOOD CENTER		0' to 5' Protection Not Recommended
COMMUNITY CENTER	NEIGHBORHOOD CENTER		0' to 5' Protection Not Recommended
COMMUNITY CENTER	NEIGHBORHOOD CENTER	1139 BAL HARBOR BLVD	5'-10' Protection Definite
COMMUNITY CENTER	NEIGHBORHOOD CENTER	105 TAYLOR ST	5'-10' Protection Definite
COMMUNITY CENTER	NEIGHBORHOOD CENTER	317 NESBIT ST	5'-10' Protection Definite
COMMUNITY CENTER	NEIGHBORHOOD CENTER	3125 BAYNARD DR	0' to 5' Protection Not Recommended
COMMUNITY CENTER	COMMUNITY CENTER		5'-10' Protection Definite
COMMUNITY CENTER	COMMUNITY CENTER		5'-10' Protection Definite
ELECTRICAL FACILITY	ELECTRICAL FACILITY	155 BOUNDARY BLVD	5'-10' Protection Definite
ELECTRICAL FACILITY	ELECTRICAL FACILITY		5'-10' Protection Definite
ELECTRICAL FACILITY	ELECTRICAL FACILITY		5'-10' Protection Definite
ELECTRICAL FACILITY	ELECTRICAL FACILITY		5'-10' Protection Definite
ELECTRICAL FACILITY	ELECTRICAL FACILITY		5'-10' Protection Definite
ELECTRICAL FACILITY	ELECTRICAL FACILITY		5'-10' Protection Definite
ELECTRICAL FACILITY	ELECTRICAL FACILITY		0' to 5' Protection Not Recommended
ELECTRICAL FACILITY	ELECTRICAL FACILITY		0' to 5' Protection Not Recommended
ELECTRICAL FACILITY	ELECTRICAL FACILITY		0' to 5' Protection Not Recommended
ELECTRICAL FACILITY	ELECTRICAL FACILITY		0' to 5' Protection Not Recommended
ELECTRICAL FACILITY	ELECTRICAL FACILITY		0' to 5' Protection Not Recommended
ELECTRICAL FACILITY	ELECTRICAL FACILITY	122 E CHARLOTTE AV	5'-10' Protection Definite
ELECTRICAL FACILITY	ELECTRICAL FACILITY	615 DUPONT ST	5'-10' Protection Definite
ELECTRICAL FACILITY	ELECTRICAL FACILITY	391 TAMIAMI TR	5'-10' Protection Definite
ELECTRICAL FACILITY	ELECTRICAL FACILITY	11501 BURNT STORE RD	5'-10' Protection Definite
FIRE/EMS	FIRE/EMS	4322 EL JOBEAN RD	5'-10' Protection Definite
FIRE/EMS	FIRE/EMS	13600 MARATHON BLVD	5'-10' Protection Definite
FIRE/EMS	FIRE/EMS	3631 TAMIAMI TR	5'-10' Protection Definite
FIRE/EMS	FIRE/EMS	1501 TAMIAMI TR	5'-10' Protection Definite

FIRE/EMS	FIRE/EMS		5'-10' Protection Definite
FIRE/EMS	FIRE/EMS	403 BOUNDARY BLVD	5'-10' Protection Definite
FIRE/EMS	ENG #2 FIRE STATION	4780 PLACIDA RD	5'-10' Protection Definite
FIRE/EMS	FIRE/EMS	22429 EDGEWATER DR	5'-10' Protection Definite
FIRE/EMS	FIRE/EMS	3624 ASH ST	0' to 5' Protection Not Recommended
FIRE/EMS	FIRE/EMS	101 GASPARILLA WAY	0' to 5' Protection Not Recommended
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	750 W RETTA ESPLANADE	0' to 5' Protection Not Recommended
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	802 W RETTA ESPLANADE	0' to 5' Protection Not Recommended
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX		0' to 5' Protection Not Recommended
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	1001 W HENRY ST	0' to 5' Protection Not Recommended
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	719 W HENRY ST	0' to 5' Protection Not Recommended
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	260 W RETTA ESPLANADE	0' to 5' Protection Not Recommended
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	128 HERALD CT	5'-10' Protection Definite
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	126 HERALD CT	5'-10' Protection Definite
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	412 W MARION AV	5'-10' Protection Definite
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	520 KING ST	5'-10' Protection Definite
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	121 E MARION AV	0' to 5' Protection Not Recommended
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	1410 TAMIAMI TR	5'-10' Protection Definite
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	514 E GRACE ST	5'-10' Protection Definite
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	1501 COOPER ST	5'-10' Protection Definite
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX	808 CLEMENS AV	5'-10' Protection Definite
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX		5'-10' Protection Definite
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX		5'-10' Protection Definite
GOVERNMENT COMPLEX	GOVERNMENT COMPLEX		5'-10' Protection Definite
HOSPITAL	Charlotte Regional Medical Cen	809 E MARION AV	0' to 5' Protection Not Recommended
LOCK	LOCK	CATTLEDOCK LOCK	0' to 5' Protection Not Recommended
LOCK	LOCK	MIDWAY @ OHARE	0' to 5' Protection Not Recommended
LOCK	LOCK	ALLIGATOR CREEK	0' to 5' Protection Not Recommended
POLICE-SHERIFF	POLICE-SHERIFF		5'-10' Protection Definite
POLICE-SHERIFF	POLICE-SHERIFF	1410 TAMIAMI TR	5'-10' Protection Definite
POLICE-SHERIFF	POLICE-SHERIFF		5'-10' Protection Definite
POLICE-SHERIFF	POLICE-SHERIFF	1410 TAMIAMI TR	5'-10' Protection Definite
		12650 WILLMINGTON	
SCHOOL	Myakka River Elementary School	BLVD	5'-10' Protection Definite

SCHOOL	Peace River Elementary School	22400 HANCOCK AV	5'-10' Protection Definite
SCHOOL	East Elementary School	27050 FAIRWAY DR	5'-10' Protection Definite
SCHOOL	Punta Gorda Middle School	825 CARMALITA ST	5'-10' Protection Definite
SCHOOL	Sallie Jones Elementary School	1221 COOPER ST	5'-10' Protection Definite
SCHOOL	Meadow Park Elementary School	3131 LAKEVIEW BLVD NW	5'-10' Protection Definite
SCHOOL	Charlotte High School	1250 COOPER ST	5'-10' Protection Definite
SCHOOL	Lemon Bay High School	2201 PLACIDA RD	5'-10' Protection Definite
SCHOOL	Charlotte Harbor School	22450 HANCOCK AV	5'-10' Protection Definite
SCHOOL	Edison Community College		0' to 5' Protection Not Recommended
SCHOOL	New Challenge School	16529 JOPPA AV	5'-10' Protection Definite
SCHOOL	Edison Community College - New	26300 AIRPORT RD	5'-10' Protection Definite
SCHOOL	Baker Elementary School	311 CHARLOTTE AV	5'-10' Protection Definite
TELEPHONE REMOTE BUILDING	GTE REMOTE BUILDING	2075 MANASOTA BEACH RD	5'-10' Protection Definite
TELEPHONE REMOTE BUILDING	GTE REMOTE BUILDING	2075 MANASOTA BEACH RD	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	SPRINT/UNITED PG CENTRAL OFC	113 W OLYMPIA AV	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	SPRINT/UNITED PC CENTRAL OFC	3391 TAMIAMI TR	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	GTE SWITCHING STATION	SAN CASA @ 776-SW COR	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	GTE SWITCHING STATION	BLUE HERON @ 776-NW	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	GTE SWITCHING STATION	ORIOLE @ 776 NW COR	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	GTE SWITCHING STATION	VIA DEL SOL @ 776 SE	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	GTE SWITCHING STATION	PLACIDA RD @ 776 SE	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	SPRINT/UNITED PG CENTRAL OFC	113 W OLYMPIA AV	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	SPRINT/UNITED PC CENTRAL OFC	3391 TAMIAMI TR	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	GTE SWITCHING STATION	SAN CASA @ 776-SW COR	5'-10' Protection Definite

TELEPHONE SWITCHING STATION	GTE SWITCHING STATION	BLUE HERON @ 776-NW	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	GTE SWITCHING STATION	ORIOLE @ 776 NW COR	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	GTE SWITCHING STATION	VIA DEL SOL @ 776 SE	5'-10' Protection Definite
TELEPHONE SWITCHING STATION	GTE SWITCHING STATION	PLACIDA RD @ 776 SE	5'-10' Protection Definite

## COLLIER COUNTY CRITICAL FACILITIES SUBJECT TO SEA LEVEL RISE

FACILITY TYPE	FACILITY NAME	ADDRESS	ELEVATION/PROTECTION
CLINIC	Naples Day Surgery	11161 Health Park Dr.	5'-10' Protection Definite
CLINIC	Ambulatory Surgery	1351 Pine Ridge Rd. 9732 Rattlesnake Hammock Rd.	5'-10' Protection Definite
CLINIC	E. Naples Medical Center	800 Goodlette Rd., N.	0' to 5' Protection Not Recommended
CLINIC	Collier Surgical Center	1084 Goodlette Rd., N.	0' to 5' Protection Not Recommended
CLINIC	Gulfshore Endoscopy	700 Neapolitan Way	5'-10' Protection Definite
CLINIC	Montgomery Eye Clinic	790 4th Street, N.	0' to 5' Protection Not Recommended
CLINIC	Naples Day Surgery	150 Tamiami Tr. N Suite 2 Naples	0' to 5' Protection Not Recommended
CLINIC	Endoscopy Center of Naples	2500 Airport Rd.	5'-10' Protection Definite
COMMUNICATION	WSGL Radio	301 Tower Rd.	0' to 5' Protection Not Recommended
COMMUNICATION	Media One Cable Co.	Crews Rd.	5'-10' Protection Definite
COMMUNICATION	WSGL Transmitter	28th Ave SE	0' to 5' Protection Not Recommended
COMMUNICATION	CCSO Repeater	401 Bald Eagle 34145	0' to 5' Protection Not Recommended
COMMUNICATION	Sprint Telephone	32020 Tamiami Tr. east	0' to 5' Protection Not Recommended
COMMUNICATION	800 MHz system Carnestown	2901 County Barn Rd.	5'-10' Protection Definite
COMMUNICATION	800 MHz system East Naples	520 S Collier Blvd	5'-10' Protection Definite
COMMUNICATION	800 MHz system Marco Island	SR 951	0' to 5' Protection Not Recommended
ELECTRICAL	Lee County Elec Company	Fiddlers Creek	0' to 5' Protection Not Recommended
ELECTRICAL	Fl Power & Light Sub-Station	Elcam Circle Marco Island	0' to 5' Protection Not Recommended
ELECTRICAL	Lee County Elec Company	Heathwood Dr. S.	0' to 5' Protection Not Recommended
ELECTRICAL	Lee County Elec Company	Highway 41	5'-10' Protection Definite
ELECTRICAL	Fl Power & Light Sub-Station	Golden Gate	5'-10' Protection Definite
EMERGENCY MEDICAL SERVICES	E. Naples EMS Center Medic 9	11121 E. Tamiami Trail	5'-10' Protection Definite
EMERGENCY MEDICAL SERVICES	Collier EMS 14/STN 90	7227 Isle of Capri Blvd	5'-10' Protection Definite

EMERGENCY MEDICAL SERVICES	CC Medflight	2375 Tower Dr.	5'-10' Protection Definite
EMERGENCY MEDICAL SERVICES	Collier County EMS # 11	201 Buckner Ave	0' to 5' Protection Not Recommended
EMERGENCY MEDICAL SERVICES	Collier County EMS medic 1	835 8th Ave South	0' to 5' Protection Not Recommended
EMERGENCY MEDICAL SERVICES	Collier County EMS Medic 15	977 26th Ave	5'-10' Protection Definite
EMERGENCY MEDICAL SERVICES	Collier County EMS Medic 2	2375 Tower Dr	5'-10' Protection Definite
EMERGENCY MEDICAL SERVICES	Collier County EMS Medic 4	1280 San Marco Rd	5'-10' Protection Definite
EMERGENCY OPERATION CENTER	CC EOC - Build - Build F	3301 E. Tamiami Trail	5'-10' Protection Definite
EMERGENCY OPERATION CENTER	Naples EOC	Fleishman Blvd.	5'-10' Protection Definite
FIRE STATION	N. Naples FD # 40	1441 Pine Ridge Rd.	5'-10' Protection Definite
FIRE STATION	E. Naples Fire Dept.	4798 Davis Blvd.	5'-10' Protection Definite
FIRE STATION	E Naples Sire Dept 23	SR 951	0' to 5' Protection Not Recommended
FIRE STATION	Isle of Capri FD	75 Capri Blvd	5'-10' Protection Definite
FIRE STATION	Ochopee Fire Control	U.S. 41	0' to 5' Protection Not Recommended
FIRE STATION	Naples Station 1	835 8th Ave, S.	0' to 5' Protection Not Recommended
FIRE STATION	Naples Station 2	977 26th Ave, S.	5'-10' Protection Definite
FIRE STATION	Naples Station 3	Naples Airport	5'-10' Protection Definite
FIRE STATION	Fire STA# 51	751 Elkcam Circle	5'-10' Protection Definite
FIRE STATION	Marco Island Fire STA # 50	1280 San Marco Rd.	5'-10' Protection Definite
FIRE STATION	East Naples Fire Dept ST 21	11121 East Tamiami Tr	5'-10' Protection Definite
FIRE STATION	North Naples Fire Control ST 45	1780 Immokalee Rd.	5'-10' Protection Definite
GOVERNMENT	Collier County Dev Services	2800 N. Horseshoe Dr.	5'-10' Protection Definite
GOVERNMENT	USPS - Annex	3573 Progress Ave	5'-10' Protection Definite
GOVERNMENT	Medical Examiner	3838 Domestic Ave	5'-10' Protection Definite
GOVERNMENT	CC Health Dept - Build H	3301 E. Tamiami Trail	5'-10' Protection Definite
GOVERNMENT	CC Courthouse - Build L	3301 E. Tamiami Trail	5'-10' Protection Definite
GOVERNMENT	Collier County Fleet Management	2901 County Barn Rd.	5'-10' Protection Definite
GOVERNMENT	Collier County Fleet Management	2901 County Barn Rd.	5'-10' Protection Definite

	Trailer		
GOVERNMENT	E. Naples Library	8787 E. Tamiami Trail	5'-10' Protection Definite
GOVERNMENT	Collier County Parks & Rec.	2901 County Barn Rd.	5'-10' Protection Definite
GOVERNMENT	Collier County Road & Bridge	2901 County Barn Rd.	5'-10' Protection Definite
GOVERNMENT	Collier County Stormwater Mgmt.	2901 County Barn Rd.	5'-10' Protection Definite
GOVERNMENT	Big Cypress Nat Preserve HQ	U.S. 41	0' to 5' Protection Not Recommended
GOVERNMENT	U.S. Post Office	427 Papaya St. Goodland	0' to 5' Protection Not Recommended
GOVERNMENT	U.S. Post Office	Hwy 29 Chokoloskee	5'-10' Protection Definite
GOVERNMENT	Marco Island - CAP	2005 Mainsail Dr.	0' to 5' Protection Not Recommended
GOVERNMENT	Marco Island - Beacon Shed	2005 Mainsail Dr.	0' to 5' Protection Not Recommended
GOVERNMENT	Marco Island - Maint #1	2005 Mainsail Dr.	0' to 5' Protection Not Recommended
GOVERNMENT	Marco Island - Maint #2	2005 Mainsail Dr.	0' to 5' Protection Not Recommended
GOVERNMENT	Marco Island - Trailer	2005 Mainsail Dr. B14	0' to 5' Protection Not Recommended
GOVERNMENT	USPS Ochopee	U.S. 41	0' to 5' Protection Not Recommended
GOVERNMENT	Naples City Hall	735 Eighth Street, S.	0' to 5' Protection Not Recommended
GOVERNMENT	Central Library	650 Central Ave.	5'-10' Protection Definite
GOVERNMENT	Marco Island Library	210 S. Heathwood Dr.	5'-10' Protection Definite
GOVERNMENT	CC Tax Collector	1041 Winterberry Dr.	5'-10' Protection Definite
GOVERNMENT	Marco Island City Hall	950 N. Collier Blvd. 34145	0' to 5' Protection Not Recommended
GOVERNMENT	USPS - Marco	600 Elkcarn Circle 34145	5'-10' Protection Definite
GOVERNMENT	Everglades City Garage	506 N. Buckner Ave	0' to 5' Protection Not Recommended
GOVERNMENT	Everglades City Control Building	200 S. Copeland Ave	0' to 5' Protection Not Recommended
GOVERNMENT	Everglades City Rec Building	101 Hibiscus St.	0' to 5' Protection Not Recommended
GOVERNMENT	Everglades City Storage Bldg	500 Buckner Ave	0' to 5' Protection Not Recommended
GOVERNMENT	Everglades City Hall	102 NE Copeland Ave	0' to 5' Protection Not Recommended
GOVERNMENT	Everglades City Comm Center	Buckner Ave	0' to 5' Protection Not Recommended
GOVERNMENT	USPS Everglades City	601 Collier Ave	0' to 5' Protection Not Recommended
HOSPITAL	Marco Island Health Care	40 Heathwood Dr. 34145	0' to 5' Protection Not Recommended
LANDFILL	Naples Transfer Station	Airport Rd.	5'-10' Protection Definite
LANDFILL	CC Solid Waste Trans	771 E. Elkcarn Cir	5'-10' Protection Definite
POLICE DEPARTMENT	Naples Police & EMS	355 Goodlette Rd.	0' to 5' Protection Not Recommended
SCHOOL	Naples Park Elementary	685 111th Ave N.	5'-10' Protection Definite
SCHOOL	Poinciana Elementary School	2825 Airport-Pulling Rd.	5'-10' Protection Definite

SCHOOL	Naples Christian Academy	3161 Santa Barbra Blvd	5'-10' Protection Definite
SCHOOL	Avalon Elementary School	3300 Thomason Dr.	5'-10' Protection Definite
SCHOOL	E. Naples Middle School	4100 Estey Ave.	5'-10' Protection Definite
SCHOOL	Shadowlawn Elementary	2161 Shadowlawn Dr.	5'-10' Protection Definite
SCHOOL	Edison Community College	7007 Lely Cultural Pkwy	5'-10' Protection Definite
SCHOOL	Lely Elementary School	8125 Lely Cultural Pkwy	5'-10' Protection Definite
SCHOOL	Lely High School	324 Lely Blvd	5'-10' Protection Definite
SCHOOL	Manatee Elementary School	1880 Manatee Rd.	5'-10' Protection Definite
SCHOOL	Manatee Middle School	1920 Manatee Rd.	5'-10' Protection Definite
SCHOOL	Gulfview Middle School	709 3rd Ave, S	0' to 5' Protection Not Recommended
SCHOOL	Lake Park Elementary	1295 14 Street, N	0' to 5' Protection Not Recommended
SCHOOL	Naples High School	1100 22nd Ave., N.	5'-10' Protection Definite
SCHOOL	St. Ann Catholic School	542 8th Ave., S.	0' to 5' Protection Not Recommended
SCHOOL	Tommie Barfield Elementary	101 Kirkwood St. 34145	5'-10' Protection Definite
SCHOOL	Everglades City School	School Dr.	0' to 5' Protection Not Recommended
SEWAGE TREATMENT	Wastewater Services	6027 Shirley Street	5'-10' Protection Definite
SEWAGE TREATMENT	South County WWTP	5600 Warren Street	5'-10' Protection Definite
SEWAGE TREATMENT	Everglades City WWTP	SR 29	0' to 5' Protection Not Recommended
SEWAGE TREATMENT	Marco Shores WW/WT	Mainsail Dr.	0' to 5' Protection Not Recommended
SEWAGE TREATMENT	Carnestown Transfer Station	U.S. 41 & SR 29	5'-10' Protection Definite
SEWAGE TREATMENT	Naples WWTP	275 13th St., N.	0' to 5' Protection Not Recommended
SHELTERS	Naples Park Elementary	685 111th Ave N.	5'-10' Protection Definite
SHELTERS	Poinciana Elementary School	2825 Airport-Pulling Rd.	5'-10' Protection Definite
SHELTERS	Naples Christian Academy	3161 Santa Barbra Blvd	5'-10' Protection Definite
SHELTERS	Avalon Elementary School	3300 Thomason Dr.	5'-10' Protection Definite
SHELTERS	E. Naples Middle School	4100 Estey Ave.	5'-10' Protection Definite
SHELTERS	Shadowlawn Elementary	2161 Shadowlawn Dr.	5'-10' Protection Definite
SHELTERS	Edison Community College	7007 Lely Cultural Pkwy	5'-10' Protection Definite
SHELTERS	Lely Elementary School	8125 Lely Cultural Pkwy	5'-10' Protection Definite
SHELTERS	Lely High School	324 Lely Blvd	5'-10' Protection Definite
SHELTERS	Manatee Elementary School	1880 Manatee Rd.	5'-10' Protection Definite
SHELTERS	Manatee Middle School	1920 Manatee Rd.	5'-10' Protection Definite
SHELTERS	Gulfview Middle School	709 3rd Ave, S	0' to 5' Protection Not Recommended

SHELTERS	Lake Park Elementary	1295 14 Street, N	0' to 5' Protection Not Recommended
SHELTERS	Naples High School	1100 22nd Ave., N.	5'-10' Protection Definite
SHELTERS	St. Ann Catholic School	542 8th Ave., S.	0' to 5' Protection Not Recommended
SHELTERS	Tommie Barfield Elementary	101 Kirkwood St. 34145	5'-10' Protection Definite
SHELTERS	Everglades City School	School Dr.	0' to 5' Protection Not Recommended
SHERIFF DEPARTMENT	CCSO Garage	4601 Arnold Ave	5'-10' Protection Definite
SHERIFF DEPARTMENT	CC Sheriff's Admin - Build	3301 E. Tamiami Trail	5'-10' Protection Definite
SHERIFF DEPARTMENT	CCSO Trailer - Airport	650 Airpark Rd.	0' to 5' Protection Not Recommended
SHERIFF DEPARTMENT	CCSO Station Everglades City	U.S. 41 & SR 29	0' to 5' Protection Not Recommended
SHERIFF DEPARTMENT	CCSO Sub-station	1401 N. Barfield	5'-10' Protection Definite
SHERIFF DEPARTMENT	CCSO - Marco - Sub	N. Barfield Dr. 34145	5'-10' Protection Definite
SHERIFF DEPARTMENT	CCSO Everglades City		0' to 5' Protection Not Recommended
SHERIFF DEPARTMENT	Collier County Sheriff, Golden Gate	11121 Tamiami Tr.	5'-10' Protection Definite
TRANSPORTATION	Everglades City Airport	650 Airport Dr.	0' to 5' Protection Not Recommended
TRANSPORTATION	Naples Airport	160 Aviation Dr.	5'-10' Protection Definite
TRANSPORTATION	Everglades City T Hangers	650 Airpark Rd.	0' to 5' Protection Not Recommended
TRANSPORTATION	Marco Island Exec Airport	2005 Mainsail Dr.	0' to 5' Protection Not Recommended
TRANSPORTATION	USPS (Main)	1200 Goodlette Rd., N.	0' to 5' Protection Not Recommended
WATER FACILITY	Carcia Road - Repump	Carcia & Goodlette Rd.	5'-10' Protection Definite
WATER TREATMENT	Manatee Re-Pump	1941 Manatee Rd.	0' to 5' Protection Not Recommended
WATER TREATMENT	Port of the Isle Until	Remunda Ranch Rd.	5'-10' Protection Definite
WATER TREATMENT	Goodland Re-Pump St	SR 92 (Goodland turn-off)	0' to 5' Protection Not Recommended
WATER TREATMENT	Everglades City Water Plant	Janes Scenic Dr.	0' to 5' Protection Not Recommended
WATER TREATMENT	Naples WTP	1000 Fleishman Blvd.	5'-10' Protection Definite
WATER TREATMENT	Florida Water Services	100 Windward Dr. 34145	0' to 5' Protection Not Recommended
WATER TREATMENT	FL Water WTP (Lime)	Lily Ct. 34145	0' to 5' Protection Not Recommended
WATER TREATMENT	Everglades City WTP	South Copeland Ave	0' to 5' Protection Not Recommended

## LEE COUNTY CRITICAL FACILITIES SUBJECT TO SEA LEVEL RISE

FACILITY TYPE	FACILITY	CITY	ELEVATION/PROTECTION
CHURCH	SAINT ANDREW CATHOLIC CHURCH IN CAPE CORAL	CAPE CORAL	5'-10' Protection Definite
CHURCH	METHODIST UNITED CH CAPE CORAL	CAPE CORAL	5'-10' Protection Definite
CHURCH	LUTHERAN CHRIST CHURCH	CAPE CORAL	5'-10' Protection Definite
CHURCH	BAPTIST CHURCH FIRST	CAPE CORAL	5'-10' Protection Definite
CHURCH	CHRISTIAN FIRST CHURCH OF	CAPE CORAL	5'-10' Protection Definite
CHURCH	BEACH UNITED METHODIST CHURCH	FORT MYERS	5'-10' Protection Definite
CHURCH	BETHANY EVANGELICAL LUTHERAN CHURCH	BEACH	5'-10' Protection Definite
CHURCH	BETHEL ASSEMBLY OF GOD	UNINCORPORATED	5'-10' Protection Definite
CHURCH	CHURCH ON THE ROCK	UNINCORPORATED	5'-10' Protection Definite
CHURCH	COVENANT PRESBYTERIAN CHURCH	CAPE CORAL	5'-10' Protection Definite
CHURCH	EDGEWOOD UNITED METHODIST CHURCH	FORT MYERS	5'-10' Protection Definite
CHURCH	EPIPHANY EPISCOPAL CHURCH	FORT MYERS	5'-10' Protection Definite
CHURCH	FIRST CHURCH OF CHRIST SCIENTIST - FORT MYERS	CAPE CORAL	5'-10' Protection Definite
CHURCH	GRACE LUTHERAN CHURCH - LCMS	FORT MYERS	5'-10' Protection Definite
CHURCH	HOLY TRINITY PRESBYTERIAN CHURCH	UNINCORPORATED	5'-10' Protection Definite
CHURCH	LIFE CHURCH	UNINCORPORATED	0' to 5' Protection Not Recommended
CHURCH	LIVING WORD MINISTRIES	FORT MYERS	5'-10' Protection Definite
CHURCH	LUTHERAN CHURCH OF THE GOOD SHEPHERD	UNINCORPORATED	5'-10' Protection Definite
CHURCH	MESSIAH LUTHERAN CHURCH	UNINCORPORATED	5'-10' Protection Definite
CHURCH	NEW TESTAMENT BAPTIST CHURCH	CAPE CORAL	5'-10' Protection Definite
CHURCH	NORTH FORT MYERS FIRST BAPTIST CHURCH	UNINCORPORATED	5'-10' Protection Definite
CHURCH	PENIEL SEVENTH DAY ADVENTIST CHURCH	UNINCORPORATED	5'-10' Protection Definite
CHURCH	SOUTHWEST BAPTIST CHURCH	FORT MYERS	5'-10' Protection Definite
CHURCH	TRINITY COMMUNITY CHURCH	UNINCORPORATED	0' to 5' Protection Not Recommended
		FORT MYERS	5'-10' Protection Definite

CHURCH	WINKLER ROAD BAPTIST CHURCH	UNINCORPORATED	5'-10' Protection Definite
CHURCH	CHABAD LUBAVITCH OF SOUTHWEST FLORIDA	UNINCORPORATED	5'-10' Protection Definite
CHURCH	TEMPLE BETH SHALOM	CAPE CORAL	5'-10' Protection Definite
CHURCH	ABIDING LOVE LUTHERAN CHURCH	CAPE CORAL	5'-10' Protection Definite
CHURCH	ALL SOULS EPISCOPAL CHURCH	UNINCORPORATED	5'-10' Protection Definite
CHURCH	BAYSHORE COMMUNITY CHAPEL	UNINCORPORATED	5'-10' Protection Definite
CHURCH	CAPE CORAL CHURCH OF CHRIST	CAPE CORAL	5'-10' Protection Definite
CHURCH	CENTRO CRISTIANO EL BUEN SAMARITANO	UNINCORPORATED	5'-10' Protection Definite
CHURCH	CHURCH OF GOD OF PROPHECY	FORT MYERS	5'-10' Protection Definite
CHURCH	CHURCH OF THE RESURRECTION OF OUR LORD	UNINCORPORATED	5'-10' Protection Definite
CHURCH	CYPRESS LAKE BAPTIST CHURCH	UNINCORPORATED	5'-10' Protection Definite
CHURCH	CYPRESS LAKE PRESBYTERIAN CHURCH	UNINCORPORATED	5'-10' Protection Definite
CHURCH	CYPRESS LAKE UNITED METHODIST	UNINCORPORATED	5'-10' Protection Definite
CHURCH	FAITH ASSEMBLY OF GOD	UNINCORPORATED	5'-10' Protection Definite
CHURCH	FAITH UNITED METHODIST CHURCH	UNINCORPORATED	5'-10' Protection Definite
CHURCH	FIRST UNITED METHODIST CHURCH	FORT MYERS	5'-10' Protection Definite
CHURCH	GULF COAST CHRISTIAN FELLOWSHIP	UNINCORPORATED	5'-10' Protection Definite
CHURCH	HOPE PARSONAGE	CAPE CORAL	5'-10' Protection Definite
CHURCH	IGLESIA EL BUEN PASTOR	UNINCORPORATED	5'-10' Protection Definite
CHURCH	LIVING HOPE CHURCH OF GOD	UNINCORPORATED	5'-10' Protection Definite
CHURCH	NORTH FORT MYERS UNITED METHODIST CHURCH	UNINCORPORATED	5'-10' Protection Definite
CHURCH	OUR LADY OF LIGHT CATHOLIC COMMUNITY	UNINCORPORATED	5'-10' Protection Definite
CHURCH	SAN JOSE CATHOLIC MISSION	UNINCORPORATED	5'-10' Protection Definite
CHURCH	SOUTHSIDE CHRISTIAN CHURCH	UNINCORPORATED	5'-10' Protection Definite
CHURCH	TEMPLO LUZ EN EL DESIERTO	UNINCORPORATED	5'-10' Protection Definite
CHURCH	WESTMINSTER PRESBYTERIAN CHURCH	UNINCORPORATED	0' to 5' Protection Not Recommended
CHURCH	ZION LUTHERAN CHURCH	UNINCORPORATED	5'-10' Protection Definite
CHURCH	TEMPLE BETH-EL	UNINCORPORATED	5'-10' Protection Definite
CHURCH	TEMPLE JUDEA - CONSERVATIVE	UNINCORPORATED	0' to 5' Protection Not Recommended
CHURCH	BETH SHILOH MESSIANIC SYNAGOGUE	UNINCORPORATED	0' to 5' Protection Not Recommended

CLINIC	CAPE CORAL SURGERY CENTER	CAPE CORAL	5'-10' Protection Definite
CLINIC	PONDELLA HEALTH DEPT. (SUBCENTER)	UNINCORPORATED	5'-10' Protection Definite
COMMUNICATION	CAPE CORAL POLICE DEPARTMENT TOWER	CAPE CORAL	5'-10' Protection Definite
COMMUNICATION	FT MYERS BROADCASTING CO	CAPE CORAL	5'-10' Protection Definite
COMMUNICATION	G T E MOBELNET OF TAMPA INC	CAPE CORAL	5'-10' Protection Definite
COMMUNICATION	G T E MOBILNET OF TAMPA INC	CAPE CORAL	5'-10' Protection Definite
COMMUNICATION	SPRINT-FLORIDA INC	CAPE CORAL	5'-10' Protection Definite
COMMUNICATION	UNITED TELEPHONE CO OF FL	CAPE CORAL	5'-10' Protection Definite
COMMUNICATION	VANDERLINDEN DIRK TR	CAPE CORAL	5'-10' Protection Definite
COMMUNICATION	UNITED STATES POSTAL SERVICE	CAPE CORAL	5'-10' Protection Definite
COMMUNICATION	TOWER CITY POLICE	CAPE CORAL	5'-10' Protection Definite
ELECTRICAL	LEE CO ELECTRIC COOP EL DORADO BL SUBSTATION	CAPE CORAL	5'-10' Protection Definite
ELECTRICAL	LEE CO ELECTRIC COOP DEL PRADO SUBSTATION	CAPE CORAL	5'-10' Protection Definite
ELECTRICAL	LEE CO ELECTRIC COOP BURNT STORE SUBSTATION	CAPE CORAL	5'-10' Protection Definite
ELECTRICAL	LEE CO ELECTRIC COOP INDUSTRIAL SUBSTATION	CAPE CORAL	5'-10' Protection Definite
ELECTRICAL	LEE CO ELECTRIC COOP CC SUBSTATION	CAPE CORAL	5'-10' Protection Definite
ELECTRICAL	LEE CO ELECTRIC COOP WEST CC SUBSTATION	CAPE CORAL	5'-10' Protection Definite
ELECTRICAL	LEE CO ELECTRIC COOP SOUTH CAPE SUBSTATION	CAPE CORAL	5'-10' Protection Definite
ELECTRICAL	PINE ISLAND	UNINCORPORATED	0' to 5' Protection Not Recommended
ELECTRICAL	GLADIOLUS SUBSTATION	UNINCORPORATED	0' to 5' Protection Not Recommended
ELECTRICAL	IONA	UNINCORPORATED	5'-10' Protection Definite
ELECTRICAL	SANIBEL	SANIBEL	0' to 5' Protection Not Recommended
ELECTRICAL	PINEY	UNINCORPORATED	5'-10' Protection Definite
ELECTRICAL	TICE SWITCHING STATION	UNINCORPORATED	5'-10' Protection Definite
ELECTRICAL	EDISON	UNINCORPORATED	5'-10' Protection Definite
EMERGENCY MEDICAL SERVICES	EMERGENCY MEDICAL SERVICE- AMBULANCE MEDIC 4	CAPE CORAL	5'-10' Protection Definite
EMERGENCY MEDICAL SERVICES	EMERGENCY MEDICAL SERVICE- AMBULANCE MEDIC 12	CAPE CORAL	5'-10' Protection Definite

EMERGENCY MEDICAL SERVICES	EMERGENCY MEDICAL SERVICE- AMBULANCE MEDIC 14	CAPE CORAL	5'-10' Protection Definite
FIRE STATION	BAYSHORE FIRE DEPARTMENT	UNINCORPORATED	5'-10' Protection Definite
FIRE STATION	CAPTIVA FIRE DEPARTMENT	UNINCORPORATED	0' to 5' Protection Not Recommended
FIRE STATION	FLORIDA DIVISION OF FORESTRY	UNINCORPORATED	5'-10' Protection Definite
FIRE STATION	FT MYERS BEACH FIRE DEPARTMENT 1	FORT MYERS BEACH	5'-10' Protection Definite
FIRE STATION	FT MYERS BEACH FIRE DEPARTMENT 2	UNINCORPORATED	5'-10' Protection Definite
FIRE STATION	FT MYERS SHORES FIRE DEPARTMENT	UNINCORPORATED	5'-10' Protection Definite
FIRE STATION	IONA MCGREGOR FIRE (STATION #2)	UNINCORPORATED	5'-10' Protection Definite
FIRE STATION	IONA MCGREGOR FIRE (STATION #1)	UNINCORPORATED	5'-10' Protection Definite
FIRE STATION	IONA MCGREGOR FIRE (STATION #3)	UNINCORPORATED	0' to 5' Protection Not Recommended
FIRE STATION	MATLACHAPINE ISLAND FIRE (STATION 1)	UNINCORPORATED	5'-10' Protection Definite
FIRE STATION	N FT MYERS FIRE (STATION #2)	UNINCORPORATED	5'-10' Protection Definite
FIRE STATION	N FT MYERS FIRE (STATION #3)	UNINCORPORATED	5'-10' Protection Definite
FIRE STATION	N FT MYERS FIRE (STATION #1)	UNINCORPORATED	5'-10' Protection Definite
FIRE STATION	SAN CARLOS FIRE (STATION # 2)	UNINCORPORATED	5'-10' Protection Definite
FIRE STATION	SANIBEL FIRE STATION 1	SANIBEL	0' to 5' Protection Not Recommended
FIRE STATION	SANIBEL FIRE STATION 2	SANIBEL	0' to 5' Protection Not Recommended
FIRE STATION	CAPE CORAL FIRE STATION #1	CAPE CORAL	5'-10' Protection Definite
FIRE STATION	CAPE CORAL FIRE STATION #3	CAPE CORAL	5'-10' Protection Definite
FIRE STATION	CAPE CORAL FIRE STATION #4	CAPE CORAL	5'-10' Protection Definite
FIRE STATION	CAPE CORAL FIRE STATION #6	CAPE CORAL	5'-10' Protection Definite
FIRE STATION	CAPE CORAL FIRE STATION #7	CAPE CORAL	5'-10' Protection Definite
FIRE STATION	MATLACHA-PINE ISLAND FIRE DISTRICT #2	UNINCORPORATED	0' to 5' Protection Not Recommended
FIRE STATION	UPPER CAPTIVA FIRE PROTECTION AND RESCUE	UNINCORPORATED	0' to 5' Protection Not Recommended
FIRE STATION	ALVA FIRE CONTROL DISTRICT #2	UNINCORPORATED	5'-10' Protection Definite
FIRE STATION	BOCA GRANDE FIRE CONTROL	UNINCORPORATED	0' to 5' Protection Not Recommended
FIRE STATION	MATLACHA-PINE ISLAND FIRE DISTRICT #3	UNINCORPORATED	5'-10' Protection Definite
GOVERNMENT BUILDING	ST. JAMES CITY POST OFFICE	UNINCORPORATED	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	PINE ISLAND PUBLIC LIBRARY	UNINCORPORATED	5'-10' Protection Definite
GOVERNMENT BUILDING	CAPTIVA POST OFFICE	UNINCORPORATED	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	CAPTIVA MEMORIAL PUBLIC LIBRARY	UNINCORPORATED	0' to 5' Protection Not Recommended

GOVERNMENT BUILDING	U.S. COAST GUARD	UNINCORPORATED FORT MYERS	5'-10' Protection Definite
GOVERNMENT BUILDING	FORT MYERS BEACH PUBLIC LIBRARY	BEACH FORT MYERS	5'-10' Protection Definite
GOVERNMENT BUILDING	FORT MYERS BEACH POST OFFICE	BEACH	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	SANIBEL ISLAND POST OFFICE	SANIBEL	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	SANIBEL GOVERNMENT	SANIBEL	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	RIVERDALE PUBLIC LIBRARY	UNINCORPORATED	5'-10' Protection Definite
GOVERNMENT BUILDING	SANIBEL ISLAND PUBLIC LIBRARY	SANIBEL	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	PINELAND POST OFFICE	UNINCORPORATED	5'-10' Protection Definite
GOVERNMENT BUILDING	BOKEELIA POST OFFICE	UNINCORPORATED	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	MATLACHA POST OFFICE	UNINCORPORATED	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	LEE COUNTY ANNEX, CAPE CORAL	CAPE CORAL	5'-10' Protection Definite
GOVERNMENT BUILDING	LEE COUNTY UTILITIES	FORT MYERS	5'-10' Protection Definite
GOVERNMENT BUILDING	CAPE CORAL POST OFFICE	CAPE CORAL	5'-10' Protection Definite
GOVERNMENT BUILDING	FLORIDA DEP, SOIL CONSERVATION	FORT MYERS	5'-10' Protection Definite
GOVERNMENT BUILDING	FEDERAL COURTHOUSE	FORT MYERS	5'-10' Protection Definite
GOVERNMENT BUILDING	FORT MYERS POST OFFICE	FORT MYERS	5'-10' Protection Definite
GOVERNMENT BUILDING	CAPE CORAL PUBLIC LIBRARY	CAPE CORAL	5'-10' Protection Definite
GOVERNMENT BUILDING	CAPE CORAL POST OFFICE	CAPE CORAL	5'-10' Protection Definite
GOVERNMENT BUILDING	IONA CARRIER ANNEX POST OFFICE	UNINCORPORATED	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	RUTENBERG PUBLIC LIBRARY	UNINCORPORATED	5'-10' Protection Definite
GOVERNMENT OFFICES	LEE COUNTY COMMUNITY DEVELOPMENT LEE COUNTY COURT HOUSE/JUSTICE CENTER (NEW)	FORT MYERS	5'-10' Protection Definite
GOVERNMENT OFFICES	CAPE CORAL CITY HALL BONITA BAY PROPERTIES: BONITA BAY GOLF MAINT.	CAPE CORAL	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	BONITA BAY PROPERTIES: RES.CONSERVATION SYSTEM	UNINCORPORATED	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	CITY OF CAPE CORAL-UTILITIES COLLECTIONS DIST.	UNINCORPORATED	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	CITY OF CAPE CORAL YACHT CLUB COMPLEX	CAPE CORAL	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	CITY OF FT MYERS CENTRAL AWWT	FORT MYERS	5'-10' Protection Definite

	FACILITY		
HAZARDOUS MATERIAL SITE	CITY OF SANIBEL SEWER SYSTEM	SANIBEL	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	CITY OF SANIBEL WULFERT WATER RECLAMATION	SANIBEL	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	CYPRESS LAKE COUNTRY CLUB	UNINCORPORATED	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	FLORIDA CITIES COLLEGE PKWY WTP	UNINCORPORATED	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	FLORIDA CITIES FIESTA VILLAGE AWWT PLANT	UNINCORPORATED	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	FLORIDA CITIES WATERWAY ESTATES WTP	UNINCORPORATED	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	FLORIDA CITIES WATERWAY ESTATES WWTP	UNINCORPORATED	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	GASPARILLA ISLAND WATER ASSOC SUB STATION	UNINCORPORATED	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	GASPARILLA ISLAND WATER ASSOCIATION WWTP	UNINCORPORATED	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	GREATER PINE ISLAND WATER WTP	UNINCORPORATED	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	GULF UTILITY CASCADE STORAGE BOOSTER STATION	UNINCORPORATED	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	ISLAND WATER ASSOCIATION RO PLANT	SANIBEL	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	K MART STORE 7277	CAPE CORAL	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	LEE COUNTY UTILITIES IONA MCGREGOR WWTP	UNINCORPORATED	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	LEE COUNTY UTILITIES- MATLACHA WWTP	UNINCORPORATED	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	LEE COUNTY UTILITIES OLGA WATER PLANT	UNINCORPORATED	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	SOUTH SEAS UTILITY	UNINCORPORATED	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	SPRINT CAPE CORAL CENTRAL OFFICE	CAPE CORAL	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	SPRINT FORT MYERS CENTRAL OFFICE	FORT MYERS	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	SPRINT FORT MYERS BEACH CENTRAL OFFICE	FORT MYERS BEACH	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	SPRINT N FORT MYERS CENTRAL OFFICE	UNINCORPORATED	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	SPRINT PINE ISLAND CENTRAL OFFICE	UNINCORPORATED	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	SPRINT SANIBEL CAPTIVA CENTRAL OFFICE	SANIBEL	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	SUN COAST POOL CHEMICAL	UNINCORPORATED	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	SUN TECH CHEMICAL	UNINCORPORATED	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	TWEEN WATERS INN	UNINCORPORATED	0' to 5' Protection Not Recommended

HAZARDOUS MATERIAL SITE	CAPE CORAL GOLF AND TENNIS RESORT LIME PLANT	CAPE CORAL	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	EVEREST WASTEWATER RECLAMATION FACILITY	CAPE CORAL	5'-10' Protection Definite
HAZARDOUS MATERIAL SITE	SW WASTEWATER TREATMENT FACILITY	CAPE CORAL	5'-10' Protection Definite
HOSPITALS	HEALTH PARK MEDICAL CENTER	UNINCORPORATED	0' to 5' Protection Not Recommended
HOSPITALS	CAPE CORAL HOSPITAL	CAPE CORAL	5'-10' Protection Definite
LANDFILL	BROWNING FERRIS INDUSTRIES	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDFILL	BOCA GRANDE TRANSFER SITE	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	BOCA GRANDE HELISTOP	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	BOKEELIA HELISTOP	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	BOWMANS BEACH HELISTOP	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	CAPTIVA HELISTOP/PLANTATION INC.	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	PINE ISLAND HELISTOP	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	PINE RIDGE HELISTOP	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	ST JAMES HELISTOP	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	TRANQUILITY BAY AIRFIELD	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	WINKLER HELISTOP	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	CAPE CORAL HOSPITAL HELISTOP	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	CIPRIANI HELISTOP	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	HEALTHPARK HOSPITAL HELISTOP	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	NORTH CAPTIVA AIRFIELD	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	STRAYHORN AIRFIELD	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	KELLY ROAD COMMUNITY	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	PHILLIPS COMMUNITY	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	TROPICAL	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	STORM FOOTBALL COMPLEX	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	MULTI SPORTS COMPLEX	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	CAMELOT	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	MUSEUM OF THE ISLANDS	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	BONITA SPRINGS DEPOT	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	BONITA SPRINGS COMMUNITY PARK AND RECREATION CENTER	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	BONITA BEACH PARK	UNINCORPORATED	5'-10' Protection Definite

LANDING ZONE	EVERGLADES WONDER GARDENS	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	CARL E. JOHNSON WAYSIDE	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	CARL E. JOHNSON	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	LYNN HALL MEMORIAL PARK	FORT MYERS BEACH	5'-10' Protection Definite
LANDING ZONE	BAY OAKS COMMUNITY CEN.	FORT MYERS BEACH	5'-10' Protection Definite
LANDING ZONE	LOVERS KEY RECREATION	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	BODWITCH POINT	FORT MYERS BEACH	5'-10' Protection Definite
LANDING ZONE	MATANZAS PASS PRESERVE	FORT MYERS BEACH	0' to 5' Protection Not Recommended
LANDING ZONE	BOWMANS REGIONAL PARK	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	J.N. DING DARLING WILDLIFE	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	SANIBEL-CAPTIVA CONSERVATION AREA.	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	TARPON BAY BEACH ACCESS	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	SANIBEL COMPLEX EAST*	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	TURNER BEACH REGIONAL	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	GULFSIDE CITY PARK	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	ISLAND HISTORICAL MUSEUM	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	ROADSIDE CITY PARK	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	DIXIE BEACH	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	SANIBEL PARK & BOAT RAMP	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	LIGHTHOUSE PARK	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	SANIBEL CAUSEWAY	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	SANIBEL HISTORIC VILLAGE	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	FORT MYERS SHORES	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	OLGA COMMUNITY CENTER	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	FRANKLIN LOCKS SOUTH	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	FRANKLIN LOCKS NORTH	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	SANIBEL COMPLEX WEST*	SANIBEL	0' to 5' Protection Not Recommended
LANDING ZONE	CAYO COSTA STATE PARK*	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	BOCA GRANDE COM. CENTER	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	GASPARILLA ISLAND	UNINCORPORATED	0' to 5' Protection Not Recommended

LANDING ZONE	BOCA GRANDE COM. PARK	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	MATLACHA COMM. PARK	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	NORTHWEST SOFTBALL	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	CITY HALL	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	EDISON SAILING CLUB	FORT MYERS	0' to 5' Protection Not Recommended
LANDING ZONE	JUDD PARK	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	CALOOSAHATCHEE BRIDGE PARK	FORT MYERS	0' to 5' Protection Not Recommended
LANDING ZONE	WATERWAY ESTATES	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	HENLEY RIVERVIEW	FORT MYERS	5'-10' Protection Definite
LANDING ZONE	FORD WINTER HOME	FORT MYERS	5'-10' Protection Definite
LANDING ZONE	TARPON POINT FISHING PIER	FORT MYERS	0' to 5' Protection Not Recommended
LANDING ZONE	SHADY OAKS PARK	FORT MYERS	5'-10' Protection Definite
LANDING ZONE	FREMONT	FORT MYERS	5'-10' Protection Definite
LANDING ZONE	BILLY BOWLEGS PARK	FORT MYERS	5'-10' Protection Definite
LANDING ZONE	LEE COUNTY CIVIC CENTER	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	ROYAL PALM	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	PARK OF PALMS	FORT MYERS	5'-10' Protection Definite
LANDING ZONE	CENTENNIAL PARK	FORT MYERS	0' to 5' Protection Not Recommended
LANDING ZONE	BURROUGHS HOME	FORT MYERS	0' to 5' Protection Not Recommended
LANDING ZONE	PROPOSED MANATEE REGIONAL	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	JASON VERDOW MEMORIAL	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	PELICAN FIELDS	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	PELICAN SOCCER	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	VETERANS PARK	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	FOUR FREEDOMS	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	JAYCEE	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	CAPE CORAL BRIDGE PARK	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	CAPE CORAL YACHT CLUB & ROTINO		
LANDING ZONE	SENIOR CENTER	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	ECOLOGY PARK	CAPE CORAL	0' to 5' Protection Not Recommended
LANDING ZONE	HORTON	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	BARBARA B. MANN PERFORMING	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	RUTENBURG COMM. PARK	UNINCORPORATED	5'-10' Protection Definite
LANDING ZONE	HARLEM HEIGHTS	UNINCORPORATED	0' to 5' Protection Not Recommended

LANDING ZONE	LAKES REGIONAL PARK	UNINCORPORATED	0' to 5' Protection Not Recommended
LANDING ZONE	KOZA/SALADINO	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	ADMIN. & ART STUDIO	CAPE CORAL	5'-10' Protection Definite
LANDING ZONE	HARBORSIDE CONVENTION	FORT MYERS	5'-10' Protection Definite
MISCELLANEOUS	AMTEL MARINA HOTEL & SUITES	FORT MYERS	5'-10' Protection Definite
MISCELLANEOUS	BEST WESTERN BEACH RESORT	FORT MYERS	5'-10' Protection Definite
MISCELLANEOUS	CAPE CORAL GOLF & TENNIS	BEACH	5'-10' Protection Definite
MISCELLANEOUS	CASA LOMA MOTEL	CAPE CORAL	5'-10' Protection Definite
MISCELLANEOUS	CASA YBEL RESORT	CAPE CORAL	5'-10' Protection Definite
MISCELLANEOUS	CHAPEL BY THE SEA	SANIBEL	5'-10' Protection Definite
MISCELLANEOUS	DAYS INN NORTH	FORT MYERS	5'-10' Protection Definite
MISCELLANEOUS	EVANGELICAL PRESBYTERIAN CHURCH	BEACH	5'-10' Protection Definite
MISCELLANEOUS	HOLIDAY INN SUNSPREE RESORT	UNINCORPORATED	5'-10' Protection Definite
MISCELLANEOUS	QUALITY INN	CAPE CORAL	5'-10' Protection Definite
MISCELLANEOUS	RADISSON INN SANIBEL GATEWAY	FORT MYERS	0' to 5' Protection Not Recommended
MISCELLANEOUS	SANIBEL COMMUNITY CHURCH	CAPE CORAL	5'-10' Protection Definite
MISCELLANEOUS	SUNDIAL BEACH RESORT	UNINCORPORATED	0' to 5' Protection Not Recommended
MISCELLANEOUS	TAKIKI MOTEL	SANIBEL	0' to 5' Protection Not Recommended
MISCELLANEOUS	TEMPLE JODEA	SANIBEL	5'-10' Protection Definite
MISCELLANEOUS	LEE EXPO BUILDING (LEE CIVIC CENTER)	FORT MYERS	0' to 5' Protection Not Recommended
NURSING/CONVALESCENT CENTERS	CALUSA HARBOR RETIREMENT COMMUNITY	UNINCORPORATED	0' to 5' Protection Not Recommended
NURSING/CONVALESCENT CENTERS	CAPE CHATEAU	FORT MYERS	0' to 5' Protection Not Recommended
NURSING/CONVALESCENT CENTERS	CHATEAU CHARLEMAGNE	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	COURTYARD VILLAS	UNINCORPORATED	0' to 5' Protection Not Recommended
NURSING/CONVALESCENT CENTERS	FAMILY HOME CARE II	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	THE MILLER HOME	UNINCORPORATED	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	MILLIE'S CONVALESCENT CARE	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	OUR HOUSE ALF	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	PERIDOT PLACE OF CAPE CORAL	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	PERIDOT PLACE OF CAPE CORAL	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	RIVERSIDE VILLAGE	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	SHELL POINT VILLAGE- KING'S CROWN	FORT MYERS	0' to 5' Protection Not Recommended
		UNINCORPORATED	5'-10' Protection Definite

NURSING/CONVALESCENT CENTERS	SPRINGWOOD COURT	UNINCORPORATED	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	SUNNYSIDE OF LIFE ALF	UNINCORPORATED	0' to 5' Protection Not Recommended
NURSING/CONVALESCENT CENTERS	VILLA PALMS	UNINCORPORATED	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	WESTBAY ASSISTED LIVING	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	SUNRISE #12	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	SUNRISE CAPE CORAL CLUSTER	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	CALUSA HARBOUR HEALTH CENTER	FORT MYERS	0' to 5' Protection Not Recommended
NURSING/CONVALESCENT CENTERS	HEALTH PARK CARE CENTER	UNINCORPORATED	0' to 5' Protection Not Recommended
NURSING/CONVALESCENT CENTERS	IHS OF FORT MYERS	UNINCORPORATED	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	SHELL POINT NURSING PAVILION REHABILITATION AND HEALTHCARE	UNINCORPORATED	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	CENTER OF CAPE CORAL	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	STERLING HOUSE	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	HEARTLAND HEALTH CARE	CAPE CORAL	5'-10' Protection Definite
NURSING/CONVALESCENT CENTERS	FORT MYERS CARE CENTER	UNINCORPORATED	5'-10' Protection Definite
POLICE DEPARTMENT	SANIBEL CITY HALL/PD	SANIBEL	0' to 5' Protection Not Recommended
POLICE DEPARTMENT	CAPE CORAL POLICE DEPARTMENT	CAPE CORAL	5'-10' Protection Definite
POLICE DEPARTMENT	CAPE CORAL POLICE DEPARTMENT SOUTH SUB.	CAPE CORAL	5'-10' Protection Definite
RED CROSS	WESTMINSTER PRESBYTERIAN CHURCH	UNINCORPORATED	5'-10' Protection Definite
REFUGES OF LAST RESORT	SANIBEL CONGREGATIONAL CHURCH OF CHRIST	SANIBEL	0' to 5' Protection Not Recommended
SCHOOL	CAPE ELEMENTARY	CAPE CORAL	5'-10' Protection Definite
SCHOOL	GULF ELEMENTARY	CAPE CORAL	5'-10' Protection Definite
SCHOOL	PELICAN ELEMENTARY	CAPE CORAL	5'-10' Protection Definite
SCHOOL	GULF MIDDLE SCHOOL	CAPE CORAL	5'-10' Protection Definite
SCHOOL	TRAFALGAR MIDDLE SCHOOL	CAPE CORAL	5'-10' Protection Definite
SCHOOL	CAPE CORAL HIGH SCHOOL	CAPE CORAL	5'-10' Protection Definite
SCHOOL	PINE ISLAND	UNINCORPORATED	0' to 5' Protection Not Recommended
SCHOOL	BONITA SPRINGS	UNINCORPORATED	5'-10' Protection Definite
SCHOOL	FORT MYERS BEACH	BEACH	0' to 5' Protection Not Recommended
SCHOOL	SANIBEL	SANIBEL	0' to 5' Protection Not Recommended
SCHOOL	RIVERDALE	UNINCORPORATED	5'-10' Protection Definite

SCHOOL	HANCOCK CREEK	UNINCORPORATED	0' to 5' Protection Not Recommended
SCHOOL	CAPE CORAL	CAPE CORAL	5'-10' Protection Definite
SCHOOL	EDISON COMMUNITY COLLEGE	UNINCORPORATED	5'-10' Protection Definite
SCHOOL	UNIVERSITY OF SOUTH FLORIDA	UNINCORPORATED	5'-10' Protection Definite
SCHOOL	CYPRESS LAKE	UNINCORPORATED	5'-10' Protection Definite
SCHOOL	CYPRESS LAKE	UNINCORPORATED	5'-10' Protection Definite
SCHOOL	HEIGHTS	UNINCORPORATED	0' to 5' Protection Not Recommended
SCHOOL	INTERNATIONAL COLLEGE	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	EVEREST RECLAMATION FACILITY METER #153472	CAPE CORAL	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	SOUTHWEST WATER RECLAMATION FACILITY P MCC-1 BUILDING	CAPE CORAL	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	SOUTHWEST WATER RECLAMATION FACILITY P MCC-2 BUILDING	CAPE CORAL	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	SOUTHWEST WATER RECLAMATION FACILITY P BIO-SOLIDS BUILDING	CAPE CORAL	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	SOUTHWEST WATER RECLAMATION FACILITY P MAINTENANCE BUILDING	CAPE CORAL	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	MATLACHA PACKAGE PLANT	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	PINE ISLAND SHOPPING CENTER	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	PINE ISLAND COVE	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	CHERRY ESTATES	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	PINE ISLAND KOA	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	SOUTHSEAS PLANTATION	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	TWEEN WATERS INN	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	SUNSET CAPTIVA W.W.T. PLANT	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	BAY HARBOR CLUB	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	THREE S DISPOSAL	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	VANDERBILT LAKES	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	BONITA SPRINGS MIDDLE SCHOOL	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	FORT MYERS CAMPGROUND	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	RIVERWOODS PLANTATION	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	SHADY ACRES MHP	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	SPRING CREEK VILLAGE	UNINCORPORATED	5'-10' Protection Definite

SEWAGE TREATMENT FACILITY	FOUNTAIN LAKES	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	BLACK ISLAND RESORT	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	FORT MYERS BEACH	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	SANIBEL BAYOUS UTILITIES	SANIBEL	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	DONAX WATER RECLAMATION FACILITY	SANIBEL	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	WULFERT POINT REGIONAL (FUTURE)	SANIBEL	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	SHADY ACRES TRAVEL PARK	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	GULF PINES SUBDIVISION	SANIBEL	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	USEPPA INN	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	GASPARILLA ISLAND	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	FOUR WINDS MARINA	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	BOCILLA ISLAND CLUB	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	CAPTAIN'S COVE	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	BLUE CRAB KEY	UNINCORPORATED	0' to 5' Protection Not Recommended
SEWAGE TREATMENT FACILITY	TWISTY TREET	CAPE CORAL	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	WATERWAY ESTATES	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	PALM FROND CONDOMINIUM	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	PIONEER VILLAGE	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	FOREST PARK	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	FORT MYERS CENTRAL	FORT MYERS	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	UP RIVER CAMPGROUND	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	BAY POINTE CONDOMINIUM	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	JAMAICA BAY WEST	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	LAUREL OAKS	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	FOREST UTILITIES	UNINCORPORATED	5'-10' Protection Definite
SEWAGE TREATMENT FACILITY	CAPE CORAL WATER RECLAMATION	CAPE CORAL	5'-10' Protection Definite
SHELTERS	ABIDING LOVE LUTHERAN CHURCH	CAPE CORAL	5'-10' Protection Definite
SHELTERS	BAY OAKS COMMUNITY CENTER	FORT MYERS	5'-10' Protection Definite
SHELTERS	BAY OAKS RECREATION CENTER	BEACH	0' to 5' Protection Not Recommended
SHELTERS	BOCA GRANDE COMMUNITY CENTER	FORT MYERS	0' to 5' Protection Not Recommended
SHELTERS	CAPE CORAL FIRST UNITED METHODIST CHURCH	UNINCORPORATED	0' to 5' Protection Not Recommended
SHELTERS		CAPE CORAL	5'-10' Protection Definite

SHELTERS	CHURCH OF GOD OF PROPHECY	FORT MYERS	5'-10' Protection Definite
SHELTERS	FIRST CHURCH OF CHRIST SCIENTIST	FORT MYERS	5'-10' Protection Definite
SHELTERS	LEE CIVIC CENTER (MAIN BUILDING)	UNINCORPORATED	0' to 5' Protection Not Recommended
SHELTERS	MATLACHA COMMUNITY CENTER	UNINCORPORATED	0' to 5' Protection Not Recommended
SHELTERS	OLGA COMMUNITY CENTER	UNINCORPORATED	5'-10' Protection Definite
SHELTERS	SANIBEL RECREATIONAL COMPLEX	SANIBEL	0' to 5' Protection Not Recommended
SHELTERS	ST ISABEL PARISH	SANIBEL	0' to 5' Protection Not Recommended
SHELTERS	HEIGHTS ELEMENTARY	UNINCORPORATED	0' to 5' Protection Not Recommended
SHERIFF DEPARTMENT	LEE COUNTY SHERIFFS (WEST DISTRICT)	UNINCORPORATED	5'-10' Protection Definite
SHERIFF DEPARTMENT	FORT MYERS BEACH SUBSTATION	FORT MYERS	5'-10' Protection Definite
SHERIFF DEPARTMENT	BOCA GRANDE SUBSTATION	BEACH	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	PUBLIX SUPER MARKETS	UNINCORPORATED	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	PUBLIX SUPER MARKETS	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	PUBLIX SUPER MARKETS	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	PUBLIX SUPER MARKETS	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	PUBLIX SUPER MARKETS	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	PUBLIX SUPER MARKETS	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	PUBLIX SUPER MARKETS	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WALMART CORPORATION	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WALMART CORPORATION	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH SEAS RESORTS	UNINCORPORATED	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	SOUTH SEAS RESORTS	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH SEAS RESORTS	UNINCORPORATED	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	SOUTH SEAS RESORTS	UNINCORPORATED	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	WINN DIXIE STORES INC	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WINN DIXIE STORES INC	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WINN DIXIE STORES INC	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WINN DIXIE STORES INC	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WINN DIXIE STORES INC	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WINN DIXIE STORES INC	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	WINN DIXIE STORES INC	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WINN DIXIE STORES INC	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SPRINT	FORT MYERS	5'-10' Protection Definite
TOP 100 BUSINESS	NATIONS BANK	FORT MYERS	5'-10' Protection Definite
TOP 100 BUSINESS		BEACH	5'-10' Protection Definite



TOP 100 BUSINESS	SUNTRUST/SW FL NA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SUNTRUST/SW FL NA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SUNTRUST/SW FL NA	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	SUNTRUST/SW FL NA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SUNTRUST/SW FL NA	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	SUNTRUST/SW FL NA	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	SUNTRUST/SW FL NA	SANIBEL	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	SUNTRUST/SW FL NA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SUNTRUST/SW FL NA	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	FT MYERS LINCOLNMERCURY	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	FT MYERS LINCOLNMERCURY	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	RUTH COOPER CTR	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	BEALLS DEPT STORES	UNINCORPORATED	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	BEALLS DEPT STORES	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	BEALLS DEPT STORES	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	BEALLS DEPT STORES	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	BEALLS DEPT STORES	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	GASPARILLA INN INC	UNINCORPORATED	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	J C PENNEY COMPANY	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	KREHLING IND INC	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	KASH N KARRY FOOD	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	KASH N KARRY FOOD	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WACHOVIA NTL BANK	UNINCORPORATED	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	WACHOVIA NTL BANK	FORT MYERS	
TOP 100 BUSINESS	WACHOVIA NTL BANK	BEACH	5'-10' Protection Definite
TOP 100 BUSINESS	WACHOVIA NTL BANK	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	WACHOVIA NTL BANK	FORT MYERS	5'-10' Protection Definite
TOP 100 BUSINESS	WACHOVIA NTL BANK	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WACHOVIA NTL BANK	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WACHOVIA NTL BANK	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WACHOVIA NTL BANK	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	WACHOVIA NTL BANK	FORT MYERS	
TOP 100 BUSINESS	WACHOVIA NTL BANK	BEACH	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	WACHOVIA NTL BANK	UNINCORPORATED	0' to 5' Protection Not Recommended

TOP 100 BUSINESS	WACHOVIA NTL BANK	SANIBEL	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	WACHOVIA NTL BANK	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	WACHOVIA NTL BANK	FORT MYERS	
TOP 100 BUSINESS	WACHOVIA NTL BANK	BEACH	5'-10' Protection Definite
TOP 100 BUSINESS	FREELAND MOTORS	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	FREELAND MOTORS	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	JOHN SCANLON AUTO	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH TRUST BANK NA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH TRUST BANK NA	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH TRUST BANK NA	FORT MYERS	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	SOUTH TRUST BANK NA	FORT MYERS	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH TRUST BANK NA	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH TRUST BANK NA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH TRUST BANK NA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH TRUST BANK NA	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH TRUST BANK NA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH TRUST BANK NA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH TRUST BANK NA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	SOUTH TRUST BANK NA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	TARGET	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	TARGET	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	GULF COAST DODGE	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	BREEZE CORP	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	EYE CENTERS OF FLORIDA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	EYE CENTERS OF FLORIDA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	EYE CENTERS OF FLORIDA	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	EYE CENTERS OF FLORIDA	SANIBEL	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	EYE CENTERS OF FLORIDA	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	HOLIDAY INN SELECT	FORT MYERS	
TOP 100 BUSINESS	HOLIDAY INN SELECT	BEACH	5'-10' Protection Definite
TOP 100 BUSINESS	CC GOLF & TENNIS	SANIBEL	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	THE FURST GROUP	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	SUNRISE COMM FOR RETARDED	UNINCORPORATED	5'-10' Protection Definite
		CAPE CORAL	5'-10' Protection Definite

TOP 100 BUSINESS	WINK/CBS CABLE 5	FORT MYERS	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	CHICO'S INC	SANIBEL	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	CHICO'S INC	UNINCORPORATED	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	CHICO'S INC	SANIBEL	0' to 5' Protection Not Recommended
TOP 100 BUSINESS	CSR RINKER MATERIALS	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	OLGA WATER PLANT - UTILITIES	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	PINE ISLAND LIBRARY	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	DEPOT 1 SIGN SHOP/MAINT/BRIDGES	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	HEALTHDEPT/HUMANSVCADMN/SOCIALSVC	UNINCORPORATED	5'-10' Protection Definite
TOP 100 BUSINESS	COMMUNITY DEVT PUBLIC WORKS CTR	FORT MYERS	5'-10' Protection Definite
TOP 100 BUSINESS	LEE CO COMPLEX AT CAPE CORAL	CAPE CORAL	5'-10' Protection Definite
TOP 100 BUSINESS	FMB SEWAGE PLANT	UNINCORPORATED	5'-10' Protection Definite
TRANSPORTATION FACILITIES	PORT BOCA GRANDE	UNINCORPORATED	0' to 5' Protection Not Recommended
WATER TREATMENT FACILITY	SW R/O PLANT	CAPE CORAL	5'-10' Protection Definite
WATER TREATMENT FACILITY	LIME PLANT STORAGE AND REPUMP STATION	CAPE CORAL	5'-10' Protection Definite
WATER TREATMENT FACILITY	REVERSE OSMOSIS WATER TREATMENT FACILITY METER #150940	CAPE CORAL	5'-10' Protection Definite
WATER TREATMENT FACILITY	SHADY ACRES TRAILER PARK	UNINCORPORATED	5'-10' Protection Definite
WATER TREATMENT FACILITY	ISLAND WATER ASSOCIATION	SANIBEL	0' to 5' Protection Not Recommended
WATER TREATMENT FACILITY	ALVA MOTEL AND TRAILER PARK	UNINCORPORATED	5'-10' Protection Definite
WATER TREATMENT FACILITY	LEE COUNTY UTILITIES, ALVA	UNINCORPORATED	5'-10' Protection Definite
WATER TREATMENT FACILITY	SPRING CREEK VILLAGE	UNINCORPORATED	0' to 5' Protection Not Recommended
WATER TREATMENT FACILITY	USEPPA INN	UNINCORPORATED	0' to 5' Protection Not Recommended
WATER TREATMENT FACILITY	GREATER PINE ISLAND WATER	CAPE CORAL	5'-10' Protection Definite
WATER TREATMENT FACILITY	BAYSHORE UTILITIES	UNINCORPORATED	0' to 5' Protection Not Recommended
WATER TREATMENT FACILITY	ORANGE HARBOR MHP	UNINCORPORATED	5'-10' Protection Definite
WATER TREATMENT FACILITY	FLORIDA CITIES WATER, MIRACLE MILE	UNINCORPORATED	5'-10' Protection Definite

## SARASOTA COUNTY CRITICAL FACILITIES SUBJECT TO SEA LEVEL RISE

FACILITY TYPE	FACILITY NAME	ADDRESS	ELEVATION/PROTECTION
302 FACILITY	ENGLEWOOD WATER OSMOSIS PLANT	SELMA AVENUE UNIVERSITY	5'-10' Protection Definite
302 FACILITY	FLORENTINE MARBLE MAUFACTURING	PARKWAY	5'-10' Protection Definite
302 FACILITY	MIDCO PETROLEUM- SARASOTA	6 TH STREET	5'-10' Protection Definite
302 FACILITY	GTE OF FLORIDA- NORTH PORT EAX CO	TAMIAMI TRAIL	5'-10' Protection Definite
302 FACILITY	GTE OF FLORIDA- SIESTA KEY EAX CO	MIDNIGHT PASS RD.	0' to 5' Protection Not Recommended
302 FACILITY	MIDCO PETROLEUM- VENICE	WARFIELD AVE.	5'-10' Protection Definite
302 FACILITY	CITY OF VENICE- ISLAND BEACH WWTP	SOUTH HARBOR DR.	5'-10' Protection Definite
302 FACILITY	NORTH PORT WATER TREATMENT PLANT	NORTH PORT BLVD.	5'-10' Protection Definite
CITY BUILDING	NORTH PORT- CITY HALL		5'-10' Protection Definite
CITY BUILDING	NORTH PORT- PLANNING DEPARTMENT		5'-10' Protection Definite
CITY BUILDING	NORTH PORT- POLICE DEPARTMENT	NORTH PORT BLVD.	5'-10' Protection Definite
COMMUNICATIONS	NORTH PORT- POLICE DEPARTMENT	NORTH PORT BLVD.	5'-10' Protection Definite
	NORTH PORT POLICE DEPARTMENT HOLDING CELL	NORTH PORT BLVD.	5'-10' Protection Definite
CORRECTIONAL FACILITY			
EMERGENCY MEDICAL SERVICES	NORTH PORT- FIRE RESCUE STATION 82	NORTH PORT BLVD.	5'-10' Protection Definite
FIRE STATION	CITY OF VENICE STATION #2-(#52)	GROVE STREET	5'-10' Protection Definite
FIRE STATION	SCFD-STATION 4	OLD BRADENTON RD.	5'-10' Protection Definite
FIRE STATION	LONGBOAT KEY FIRE DEPARTMENT	GULF OF MEXICO DR.	0' to 5' Protection Not Recommended
FIRE STATION	NORTH PORT- FIRE RESCUE STATION 82	NORTH PORT BLVD.	5'-10' Protection Definite
FIRE STATION	SCFD-STATION 3	N ADAMS DR.	5'-10' Protection Definite
FIRE STATION	SCFD-STATION 37-VFD #2-(#52)	GROVE STREET OLD ENGLEWOOD RD.	5'-10' Protection Definite
FIRE STATION	ENGLEWOOD FIRE STATION #3-(#73)		5'-10' Protection Definite
FIRE STATION	LONGBOAT KEY FIRE DEPARTMENT		0' to 5' Protection Not Recommended
FIRE STATION	SCFD-STATION 36	TAMIAMI TRAIL	5'-10' Protection Definite
FIRE STATION	SCFD-STATION 2	WALDEMERE ST.	5'-10' Protection Definite
FIRE STATION	ENGLEWOOD STATION #2	PLACIDA RD.	5'-10' Protection Definite

FIRE STATION	NORTH PORT- FIRE RESCUE STATION 82	NORTH PORT BLVD.	5'-10' Protection Definite
FIRE STATION	NORTH PORT- FIRE RESCUE STATION 82	NORTH PORT BLVD.	5'-10' Protection Definite
FIRE STATION	SCFD-STATION 36	TAMIAMI TRAIL	5'-10' Protection Definite
GOVERNMENT BUILDING	CRIMINAL JUSTICE CENTER	Ringling BLVD.	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	CRIMINAL JUSTICE CENTER SERVICES BUREAU	Ringling BLVD.	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	HISTORICAL RESOURCES/CHIDSEY BUILDING	Plaza De Santo Domingo	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	CATTLEMEN ROAD COMPLEX, Bldg. C	Cattlemen RD.	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	CATTLEMEN ROAD COMPLEX, Bldg. E	Cattlemen RD.	5'-10' Protection Definite
GOVERNMENT BUILDING	CENTRAL STORES	Ashton RD.	5'-10' Protection Definite
GOVERNMENT BUILDING	Knights Trail Criminal Justice Bldg	Rustic RD.	0' to 5' Protection Not Recommended
GOVERNMENT BUILDING	MEDICAL EXAMINER	Hawthorne BLVD.	5'-10' Protection Definite
GOVERNMENT BUILDING	POLICE DEPT./ TOWN COMMISSION CHAMBERS	BAY ISLES RD.	0' to 5' Protection Not Recommended
HAZARDOUS MATERIAL SITE	NORTH PORT WATER TREATMENT PLANT	NORTH PORT BLVD.	5'-10' Protection Definite
HELIPORT	NORTH PORT- HELIPORT	NORTH PORT BLVD.	5'-10' Protection Definite
HOSPITAL	ENGLEWOOD COMMUNITY HOSPITAL	MEDICAL BLVD.	5'-10' Protection Definite
LANDING ZONES	HELIPAD (STATION 82)	NORTH PORT BLVD.	5'-10' Protection Definite
LAW ENFORCEMENT	LONGBOAT KEY POLICE DEPARTMENT	BAY ISLES	0' to 5' Protection Not Recommended
LAW ENFORCEMENT	Community Policing 2- SIESTA KEY	Ocean BLVD.	5'-10' Protection Definite
LAW ENFORCEMENT	Community Policing 4	N Tamiami TRAIL	5'-10' Protection Definite
LAW ENFORCEMENT	NORTH PORT- POLICE DEPARTMENT	NORTH PORT BLVD.	5'-10' Protection Definite
MAINTENANCE BUILDING	Facilities Maintenance- Bldg. 'A'	17Th ST.	5'-10' Protection Definite
NEXTEL TOWER SITES	F0439	MIDNIGHT PASS RD.	5'-10' Protection Definite
POTABLE WATER	NORTH PORT WATER TREATMENT PLANT	NORTH PORT BLVD.	5'-10' Protection Definite
POTABLE WATER	NORTH PORT WATER TREATMENT PLANT	NORTH PORT BLVD.	5'-10' Protection Definite
PUBLIC BUILDINGS & INFRASTRUCTURE	DEEP INJECTION WELL (AT LUDLOW AVENUE)	CAMPBELL DR.	0' to 5' Protection Not Recommended
PUBLIC BUILDINGS & INFRASTRUCTURE	FLOOD PRONE AREA (AT EAGER STREET)	US 41	5'-10' Protection Definite
PUBLIC BUILDINGS & INFRASTRUCTURE	FLOOD PRONE AREA (AT GROBE STREET)	US 41	5'-10' Protection Definite
PUBLIC BUILDINGS & INFRASTRUCTURE	NORTH PORT CITY HALL	NORTH PORT BLVD.	5'-10' Protection Definite
PUBLIC UTILITIES	Island Beach WWTP	1800 Harbor Dr S	5'-10' Protection Definite
REP LOSS	HISTORICALLY DAMAGED SECTION OF S. R. 789	GULF OF MEXICO DR.	0' to 5' Protection Not Recommended

SCHOOL	MANATEE COMMUNITY COLLEGE	S. TAMIAMI TRAIL	5'-10' Protection Definite
SCHOOL	MANATEE COMMUNITY COLLEGE	TAMIAMI TRAIL	5'-10' Protection Definite
SCHOOL	RINGLING SCHOOL OF ART AND DESIGN	TAMIAMI TRAIL	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	CARRIAGE HOUSE RESTAURANT	N INDIANA AVE.	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	DEER CREEK MHP- AND MICHIGAN AVE	HORTON AVE.	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	FAIR WINDS CONDOMINIUM	ALBEE RD.	0' to 5' Protection Not Recommended
SEWAGE TREATMENT PLANT	FIELD CLUB	FIELD RD.	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	FLIGHT DECK RESTAURANT- AT U.S. 41	VAMO WAY	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	LAKE VILLAGE MHP	LAKE N. DR.	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	LAKE VILLAGE MOBILE HOME COMMUNITY	LAKE DR.	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	LYONS COVE CONDO	LOUELLA LANE	0' to 5' Protection Not Recommended
SEWAGE TREATMENT PLANT	OAK HAMMOCK PROF.CTR.(BENEVA CREEK)	BEE RIDGE RD.	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	OUR LADY OF PERPETUAL HELP WWTP	SOUTH MOON DR.	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	PALM & PINES MHP WWTP	N. TAIMIAMI TRAIL	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	RAMBLERS REST RESORT WWTP	NORTH RIVER RD.	0' to 5' Protection Not Recommended
SEWAGE TREATMENT PLANT	SARASOTA BAY MHP - R/O PLANT	WEST OAK	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	SARA MEM. HOSP. 1 1/2 MI. WEST OF RIVER RD	U.S.HWY 41	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	SIESTA KEY UTILITIES AUTHORITY	OAKMONT PLACE	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	SORRENTO UTILITIES - R/O & EDR	MONTANA DR.	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	SOUTH GATE AWWTP	PINE VALLEY DR.	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	SOUTHBAY UTILITIES	YACHT HARBOR DR.	0' to 5' Protection Not Recommended
SEWAGE TREATMENT PLANT	VENICE CAMPGROUND WWTP	EAST VENICE AVE.	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	FL0020508	Harbor DR.	5'-10' Protection Definite
SEWAGE TREATMENT PLANT	FL0025755	OAKMONT PLACE	5'-10' Protection Definite
		SOUTH MCINTOSH RD.	5'-10' Protection Definite
SHELTER	SARASOTA JEWISH FEDERATION		
TELEPHONE AND CELLULAR FACILITY	GTE BUILDING	BISCAYNE @ 41	5'-10' Protection Definite
WATER STORAGE FACILITY	SOUTH KEY WATER STORAGE FACILITY	GULF OF MEXICO DR.	5'-10' Protection Definite
WATER TREATMENT	CASPERSONS BEACH	Harbor DR.	5'-10' Protection Definite
WATER TREATMENT	DISABLED AMERICAN VE		5'-10' Protection Definite
WATER TREATMENT	ENGLEWOOD WATER DISTRICT		5'-10' Protection Definite
WATER TREATMENT	KINGS GATE RV PARK		5'-10' Protection Definite
WATER TREATMENT	NORTH PORT UTILITIES		0' to 5' Protection Not Recommended

WATER TREATMENT	RAMBLERS REST RESORT		5'-10' Protection Definite
WATER TREATMENT	SPANISH LAKES MHP		5'-10' Protection Definite
WATER TREATMENT	CASPERSEN BEACH		5'-10' Protection Definite
WATER TREATMENT	ENGLEWOOD WATER DISTRICT		5'-10' Protection Definite
WATER TREATMENT	KINGS GATE RV PARK		5'-10' Protection Definite
WATER TREATMENT	NORTH PORT UTILITIES		0' to 5' Protection Not Recommended
WATER TREATMENT	SARASOTA CO SPECIAL		5'-10' Protection Definite
WATER TREATMENT	SARASOTA CO SPECIAL		5'-10' Protection Definite
WATER TREATMENT	NORTH PORT WATER TREATMENT PLANT	NORTH PORT BLVD.	5'-10' Protection Definite
WATER TREATMENT	NORTH PORT- CITY WATER PLANT	NORTH PORT BLVD.	5'-10' Protection Definite
WATER TREATMENT	SIESTA KEY UTILITIES	MIDNIGHT PASS RD.	5'-10' Protection Definite
WATER TREATMENT	VENICE GARDENS UTILITIES		5'-10' Protection Definite
WATER TREATMENT	WOODBRIIDGE DR 921		5'-10' Protection Definite
WELL	WELL NO 1	22ND ST.	5'-10' Protection Definite
WELL	WELL NO 1	22ND ST.	5'-10' Protection Definite
WELL	WELL NO 7	12TH ST.	5'-10' Protection Definite
WELL	WELL NO 7	12TH ST.	5'-10' Protection Definite