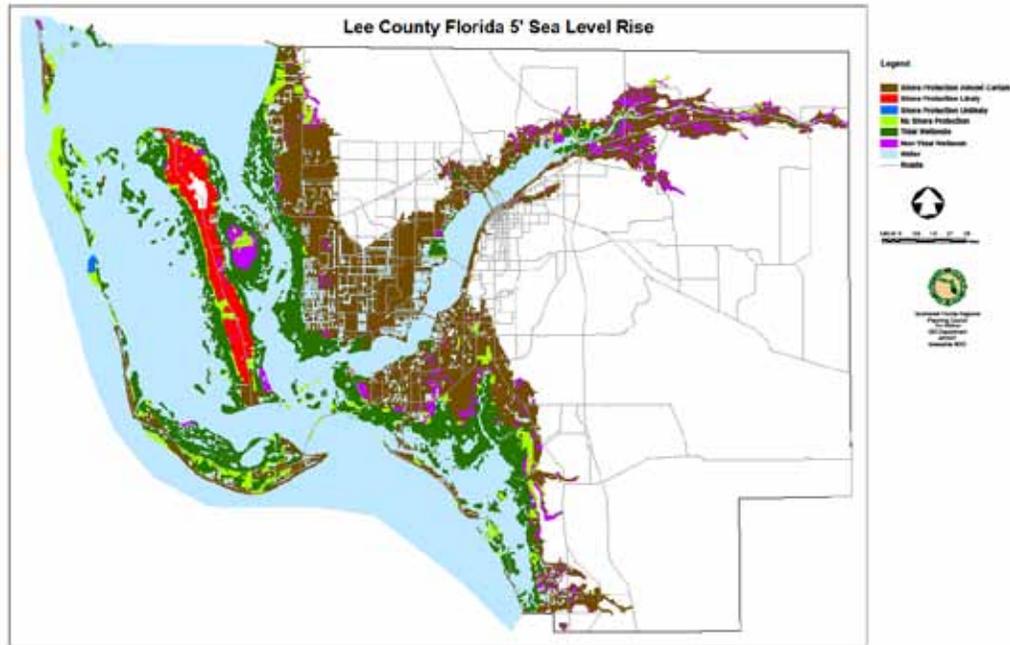


# Lee County Climate Change Resiliency Strategy (CCRS)



**Southwest Florida Regional Planning Council  
October 6, 2010**

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## **Acknowledgements**

This project has benefited from the contributions of numerous agencies and individuals that have contributed information, time, and opinion to the contents and recommendations, especially the Lee County Board of County Commissioners, the Lee County Office of the County Manager, the Lee County Department Directors, and the offices of the Constitutional Officers of Lee County.

Funding for this report was provided by Lee County through the Office of Sustainability.

The Southwest Florida Regional Planning Council has provided the venue and support for the entire project and regular input in the structure and function of the study.

The first draft was provided for technical review to the Lee County Board of County Commissioners, the Lee County Office of the County Manager, the Lee County Department Directors, and the Lee County Community Sustainability Advisory Committee. Thanks to Tessa LeSage, Office of Sustainability Director and Wayne Daltry as Smart Growth Director for support of this project.

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## Executive Summary

*Climate change resilience* is the capacity of an individual, community, or institution to dynamically and effectively respond to shifting climate impact circumstances while continuing to function at an acceptable level. It is the ability to survive, recover from, and/or live with the effects of climate change. It includes the ability to understand potential impacts and to take appropriate action before, during, and after a particular consequence to minimize negative effects and maintain the ability to respond to changing conditions.

On January 12, 2010 Lee County contracted with the Southwest Florida Regional Planning Council (SWFRPC) to develop a Climate Change Vulnerability Assessment (CCVA) for the unincorporated portions of the county. This was completed on March 18, 2010 and provided to the County for review.

That project included an assessment of significant potential effects of climate change on the human and native ecosystems of Lee County, including consequences for human and natural resources resulting from and related to (1) sea level rise, (2) aquatic and atmospheric temperature rise, (3) changes in rainfall patterns, (4) increased storm intensity, (5) waterbody chemistry, and (6) general weather instability.

A second part of the same contract was to develop the following Lee County Climate Change Resiliency Strategy (CCRS). The CCRS includes a process for identifying potential climate change resiliency strategies through coordination and consultation with local government leadership in 39 Lee County departments and divisions, including constitutional offices. Identification of resiliency strategies that could be utilized by Lee County to reduce the negative effects of climate change will also help in positioning the County to take advantage of potential climate prosperity opportunities. The CCRS is a toolbox that contains a wide variety of ideas and opportunities for the County to employ in climate change planning, energy savings, and cost savings. The CCRS informs the County of options and opportunities but it *does not prioritize those actions or direct County policy*. Prioritization would require a full public planning process incorporating public participation as part of a *full adaptation plan*.

Note that the CCRS is not an adaptation plan. In addition to a full public participation component that involves the total Lee County community in partnership with County leadership in setting adaptation goals and identifying the priority of adaptation actions to address the various climate change vulnerabilities, an adaptation plan also results in fully developed strategies for implementation. This extent of planning can be accomplished after the county determines an appropriate funding priority for the project.

Successful resilience and adaptation to climate change requires plans and strategies that respond to both the unique vulnerabilities and the priorities of the places they protect. Plans and strategies need to be flexible, to respond to changing conditions and information and to have realistic assessments of the degree of risk and cost that can be sustained. This document identifies the key elements of climate change resiliency for Lee County, and provides some of the information and resources that the County can use in climate change resiliency planning. There are several critical elements that are recommended by the EPA for climate ready adaptation plans and resiliency planning. These elements will be found in this report and include:

- § Description of specific implementation actions
- § A summary of considerations used to set priorities and select actions
- § Communication with stakeholders and decision makers; and
- § Monitoring and evaluation of results.

Following the completion of the CCVA, an online survey was sent to Lee County division heads, the Lee County Commission members and the Lee County constitutional officers. The purpose of the survey was to gather baseline data on key staff members' perceptions and experiences with respect to weather, climate, storm events and climate change. The survey results were compiled and used to inform follow-up in-person interviews. Results from both the surveys and the interviews provided a wealth of information *from Lee County personnel* about the ways in which County programs and assets might be made more resilient to the effects of climate change in the near-, middle- and long-term. Literature review pertinent to Lee County provided additional alternatives.

Resiliency strategies are alternatives to consider. In this document, resiliency strategies are organized according to groups of identified vulnerabilities. The strategies are not prioritized; prioritization should be the work of a full adaptation planning process. Some areas have many resiliency strategies, and some have few. It is noted throughout the resiliency strategy lists that Lee County has already made great strides in its efforts to increase energy efficiency, fuel economy, and water efficiency. These efforts are noted with a special symbol in the tables. None of the lists of possible strategies should be taken to be all inclusive, or exclusive, but should represent a place at which to begin discussion.

Resiliency strategy areas included in this document address the following:

- County buildings and infrastructure
- Policy and program-related resiliency strategies
- Coastal erosion and sea level rise
- Emergency and hazard planning
- Health and human services
- Land use planning
- Urban, suburban, and rural land use
- Public water supply and domestic self-supply projections of population
- Water and wastewater
- Waste management
- Natural systems and resources
- Renewable, green energy
- Transportation
- County vehicle fleet
- Education and outreach
- Historic preservation and historic districts

## Introduction

Changes in the climate of Lee County 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.

Successful resilience and adaptation to climate change requires plans and strategies that respond to both the unique vulnerabilities and the priorities of the places they protect. Plans and strategies need to be flexible, to respond to changing conditions and information and to have realistic assessments of the degree of risk and cost that can be sustained. This document identifies the key elements of climate change resiliency for Lee County, and provides some of the information and resources that the County can use in climate change resiliency planning.

There are several critical elements that are recommended by the EPA for climate ready adaptation plans and resiliency planning. These include:

- § An assessment of vulnerability;
- § Description of specific implementation actions;
- § A summary of considerations used to set priorities and select actions;
- § Communication with stakeholders and decision makers; and
- § Monitoring and evaluation of results.

A resiliency plan can be a stand-alone document or be incorporated as an additional or new element in an existing management plan, such as the Comprehensive Plan. Regardless of where the resiliency plan is housed, some of the key considerations include:

- § How the plan affects existing management goals;
- § Additional climate change-induced goals and objectives beyond the existing management goals;
- § Management actions associated with achieving those goals and objectives; and
- § Steps required for implementation (including the associated tools and resources that can be deployed).

Finally, any climate strategy or plan needs to be seen as a “living document” - one that allows for relatively easy revisiting and updating in response to changing conditions and lessons learned from monitoring and evaluation of results. Initial plans can be updated and enhanced as information changes regarding vulnerability, uncertainty, management priorities, technology, adaptation methods and costs.

## Elements of Resiliency Plan

In August of 2007, the Rockefeller Foundation launched its Building Climate Change Resilience initiative. While the global attention on climate change has been focused on mitigation through the reduction of greenhouse gases, in the long term there is a need to build resilience to the natural and enhanced climate changes that will come. The impacts of climate change have already begun to manifest and there are irreversible impacts that will continue and worsen within the span of a lifetime. Current and future consequences of climate change will result in significant costs in financial and human capital.

There is a need to build climate change resilience, and to be able to plan for, survive, recover from, and even thrive in changing climatic conditions, as a core part of the mission of local governments in southwest Florida. Climate change resilience is most critical in those places where vulnerability is high, such as Lee County, located in coastal southwest Florida.

In the field of ecology, resilience means building the capacity of a system to withstand perturbations and shocks and to rebuild and respond to change, including unanticipated change. The Resilience Alliance defines resilience as the capacity of a system to absorb disturbance, undergo change and still retain essentially the same function, structure, identity, and feedbacks (<http://www.resalliance.org/560.php>).

***Climate change resilience*** is the capacity of an individual, community, or institution to dynamically and effectively respond to shifting climate impact circumstances while continuing to function at an acceptable level. It is the ability to survive, recover from, and/or live with the effects of climate change. It includes the ability to understand potential impacts and to take appropriate action before, during, and after a particular consequence to minimize negative effects and maintain the ability to respond to changing conditions.

Historically, the term ***adaptation*** has been used to describe the individual actions required to respond to change. The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, an adjustment that moderates harm or exploits beneficial opportunities (IPCC 2007).

***Resilience***, on the other hand, refers to the *capacity over time* of a system, organization, community, or individual to create, alter, and implement *multiple* adaptive actions. Resilience is a more accurate, positive, and comprehensive term, describing the dynamic, systemic transformation that is needed to respond to the consequences of climate change, especially future impacts that are difficult to predict.

A **Climate Change Resilience Plan** should include the following elements:

***Flexibility*** at an individual, organizational, and systemic level, with each level able to respond and contribute to each situation, and to respond to shifting and unpredictable circumstances;

*A multi-faceted skill set*, including abilities that enable thorough preparation, such as comprehensiveness and detail-orientation; survival, such as quick decision-making and resourcefulness; or rapid recovery, such as innovation and diligence;

*Redundancy* of processes, capacities, and response pathways within an institution, community, or system, to allow for partial failure within a system or institution without complete collapse;

*Collaborative multi-sector approaches* to planning, execution, and recovery, since no one sector has a monopoly on a particular impact and thus understanding the overlaps and gaps between sectors is critical;

*Planning and foresight* to prepare for identified impacts and risks: While it is impossible to plan for every possible set of impacts, and in many cases the cumulative effect of impacts is unknown, the process of planning brings learning, builds skills, and helps to create resilience;

*Diversity and decentralization* of planning, response, and recovery activities: A diversity of options has greater potential to match the particular scenario of impacts that occurs, while decentralization allows for parts of the system to continue operations even if other parts of the system are down; and

*Plans for failure* so that break-downs happen gracefully, not catastrophically—for example, when flood gates break, they do so in a way that channels floodwaters to uninhabited flood zones, perhaps damaging property, but protecting human lives. Accepting that the unpredictability and uncertainty of climate risks and responses will ultimately lead to failure of some element of the system allows for failure-planning. In some cases returning to a pre-existing state will not be possible or will not be appropriate. Incremental failures and planning for failures will allow for real-time response and revision and will limit social, environmental, and economic costs. Total system failure limits response options and results in greater suffering.

**Resilience is a combination of activities that reduces risks and vulnerability to those risks, and provides a safety net or recovery path.**

A resilient system for storm events might include stronger building codes for homes (a risk reduction strategy), an evacuation plan (a risk reduction strategy), and catastrophe-bond insurance (a recovery strategy). In other cases, resilience might be possible only by increasing the overall strength of a system by removing or reducing other stressors—unrelated to climate change. For example, a coral reef might be able to recover from high-temperature related bleaching events faster if it is not stressed by polluted water. While it might be impossible to prevent coral bleaching events, it could be possible to reduce the level of pollution in the water (vulnerability reduction strategy).

The complexity of resilience requires the integration of strategies into the variety of *existing* activities and institutions. It is difficult to imagine a network of specialized institutions that could direct and manage the extent of complex changes required for climate change resilience without the involvement of the existing institutions. Indeed, climate change resilience must be a part of the plans, infrastructure, and day-to-day operations of existing institutions and systems.

Resilience is not simply the result of adding up resilient individuals. The uncertain nature of climate impacts means that no one individual or institution can possibly prepare for, or recover from, all of the potential scenarios. Therefore, resilient *systems* are required. Systems are combinations of resources, institutions, individuals, and processes that combine to accomplish a set of specific functions. To achieve resilience, systems build redundancies of resources, multiple response paths, and safety nets. Resilient systems survive a greater range of situations and, for extreme or unexpected impacts, fail gracefully, giving time to recover key functions.

**Effective response to climate change impacts will require action from multiple sectors.**

- Financial services and insurance companies will need to develop and distribute products that insure against new combinations and permutations of risk, as well as products that hedge against new types of risk.
- Agriculture, water, tourism, and energy businesses will need to understand the risks and impacts of climate change on business sustainability, and be prepared to react accordingly, including capitalizing on new business opportunities.
- Infrastructure will need to accommodate new standards and incorporate a new flexibility that can respond to climate change uncertainty.
- Health workers will need to build local response capacity for widespread events such as heat waves, while simultaneously extending the reach of efforts to mitigate climate-related diseases such as malaria, dengue fever, or schistosomiasis.
- Disaster relief organizations will need to plan for new types of disasters on a larger scale.

## **The Current Climate of Southwest Florida and Lee County**

The climate of southwest Florida is subtropical or tropical savanna (Hela 1952). This results in alternating wet season flooding and severe drought. There is an average of approximately 53 inches (135 cm) of annual rain (Bradley 1972). The dry season runs from November to April and the wet season from June to September (Riebsame et al. 1974). Typically, from 18 to 23% of annual rainfall occurs in the dry season and 60 to 72% of the rainfall occurs in the wet season (Drew and Schomer 1984). Seasonal wetlands, such as hydric pine flatwoods and wet prairies, usually become saturated and attain standing water in the middle to late wet season. 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 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).

Seventy-five percent of the thunderstorms occur in the summer (Jordan 1973, Duever et al. 1979). These short duration, high intensity thundershowers are the result of a cyclic land-sea breeze convection in a diurnal pattern peaking during late afternoon or early evening.

Thunderstorm rainfall can be very localized, resulting in differences of up to five inches per

month between areas less than five miles apart (Duever et al. 1979). It is this type of rainfall event that causes the highest volumes of stormwater runoff with the potential of spot flooding and damaging effects to the estuaries of Lee County and Charlotte Harbor. Individual cloud volumes during thunderstorms in south Florida can range from 200 to 2,000 acre-feet (Woodley 1970).

The wind patterns of south Florida are determined by the interactions 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 one degree Fahrenheit difference between Charlotte County and Collier County. Inland areas display a greater daily range in temperature than coastal habitats.

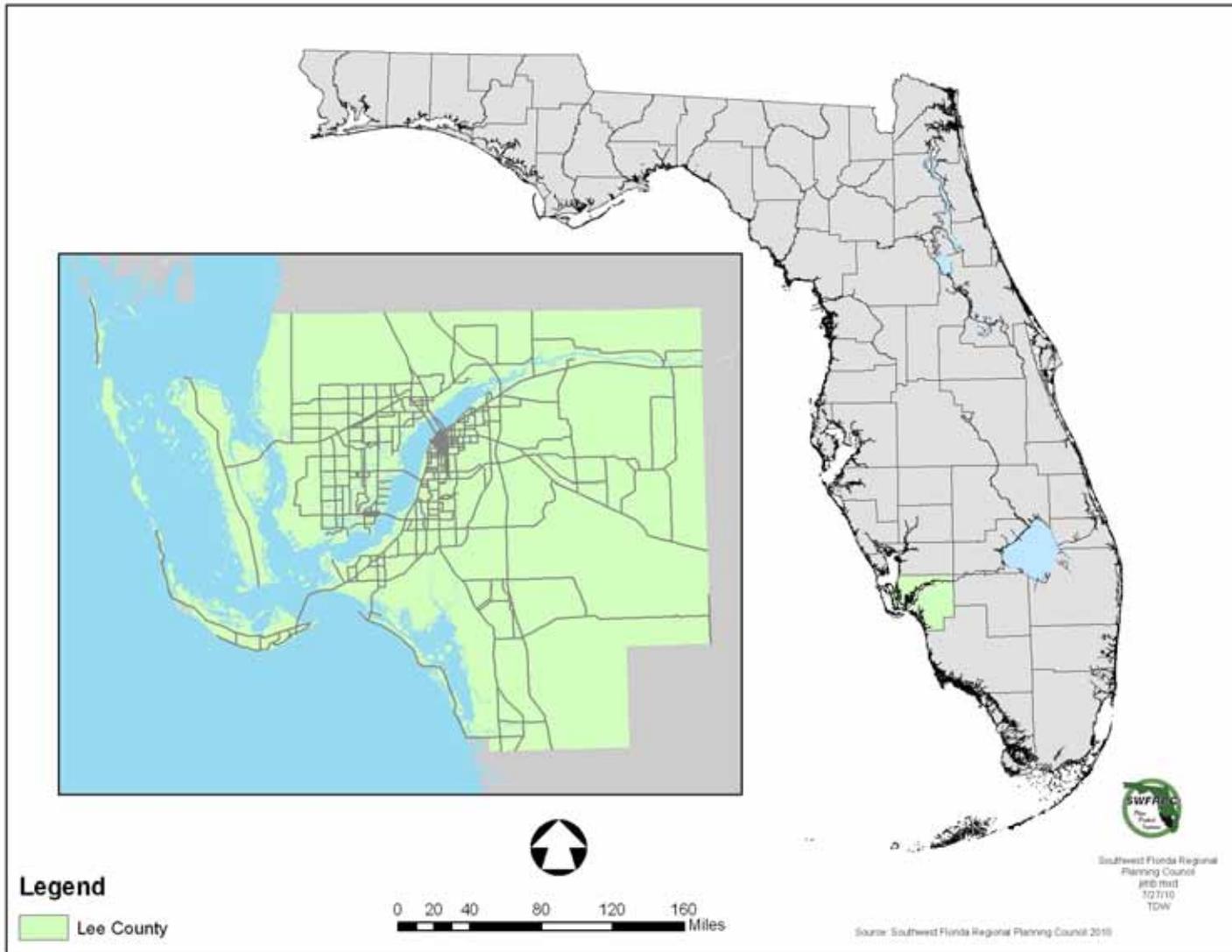
In winter, sharp drops in temperature occur following cold fronts containing cool, dry arctic air from Canada. Cooling begins after sunset and reaches the lowest temperatures at dawn. Temperature gradients of about six to 15 degrees F can occur between coastal and inland areas a few miles apart. A similar 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 alone, disaster declarations were made in Florida six times for freezing conditions (Federal Emergency Management Agency (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%).

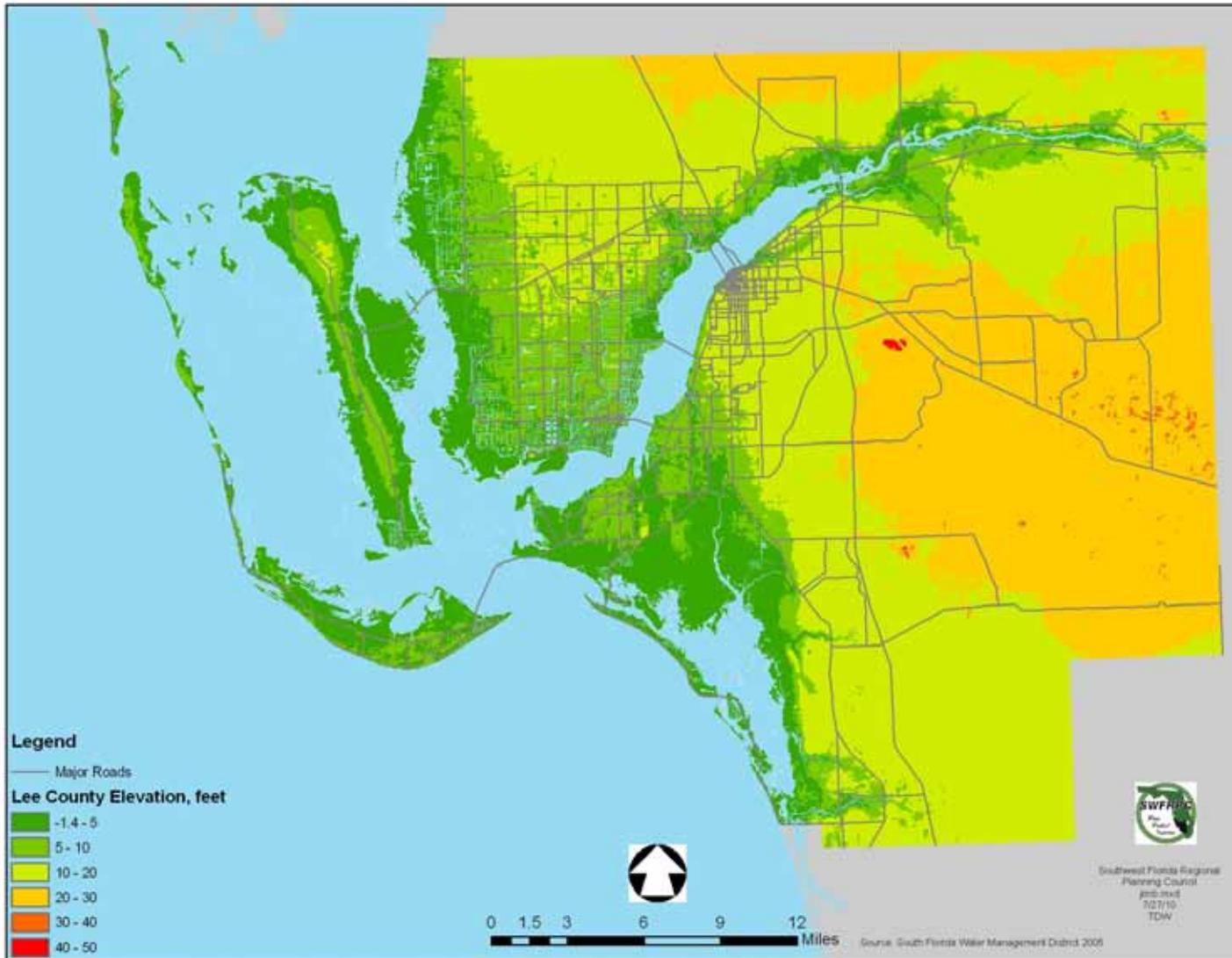
Evapotranspiration refers to the sum of evaporation and plant transpiration into the atmosphere. Evapotranspiration from wetland plants and saturated soils is an important control of sea breeze intensity and the formation of convective thunderstorms. Because evapotranspiration is a cooling phenomenon, 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).

South Florida is subject to more hurricanes than any other area of equal size in the United States (Drew and Schomer 1984). 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 about once every five years in the northern extents of the southwest Florida area (Bamberg 1980).

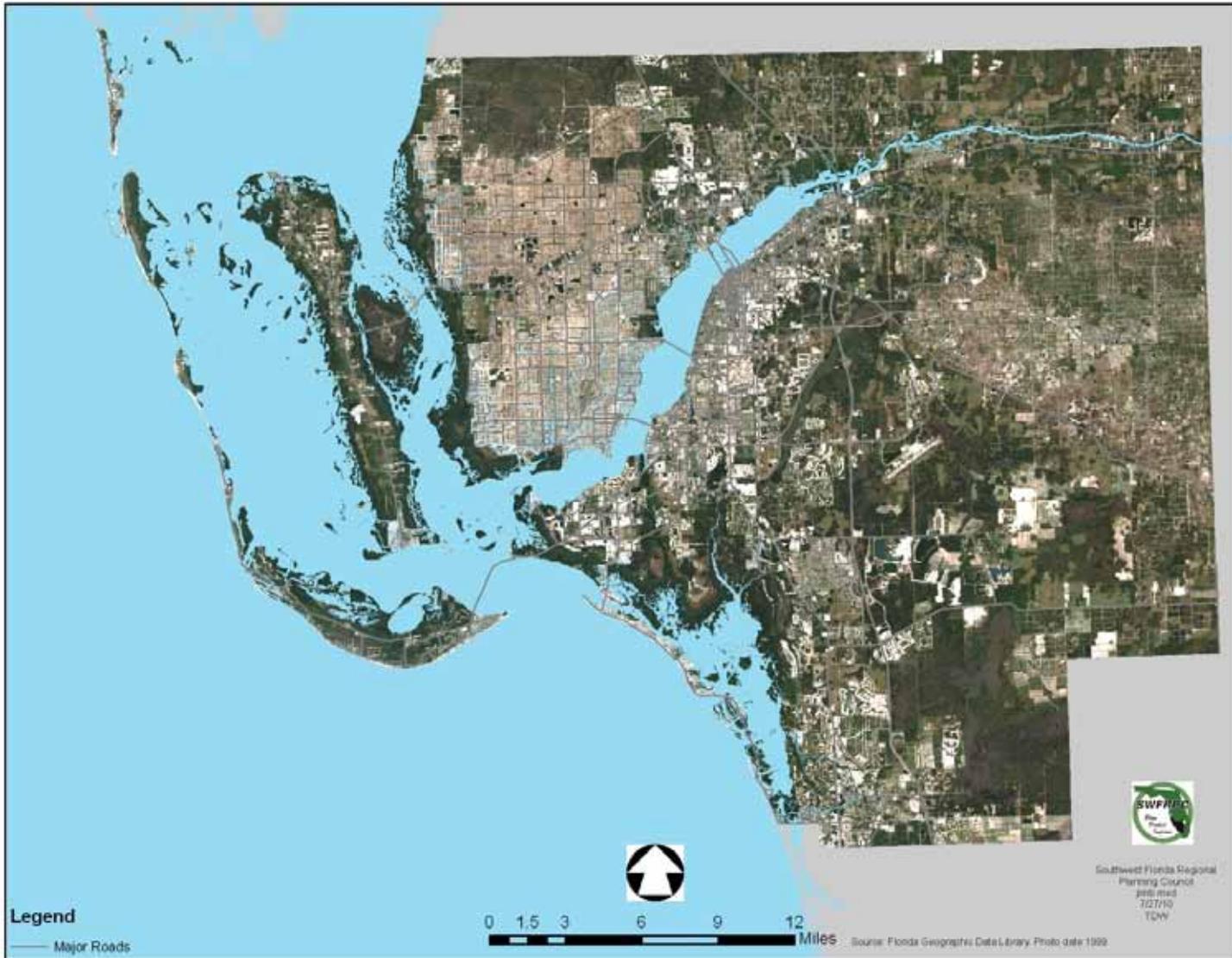
The three primary climatic effects of hurricanes are high wind, storm surge, and heavy rain. Wind force increases by the square of the wind speed such that a 93 mph wind exerts four times as much force as a 47 mph wind. Thus, when hurricane winds attain 249 mph, as reported for the 1935 Labor Day hurricane, the effects on forested ecosystems, including tree fall, substrate disturbance, and propagule (pinecone) distribution, can be considerable (Drew and Schomer 1984).



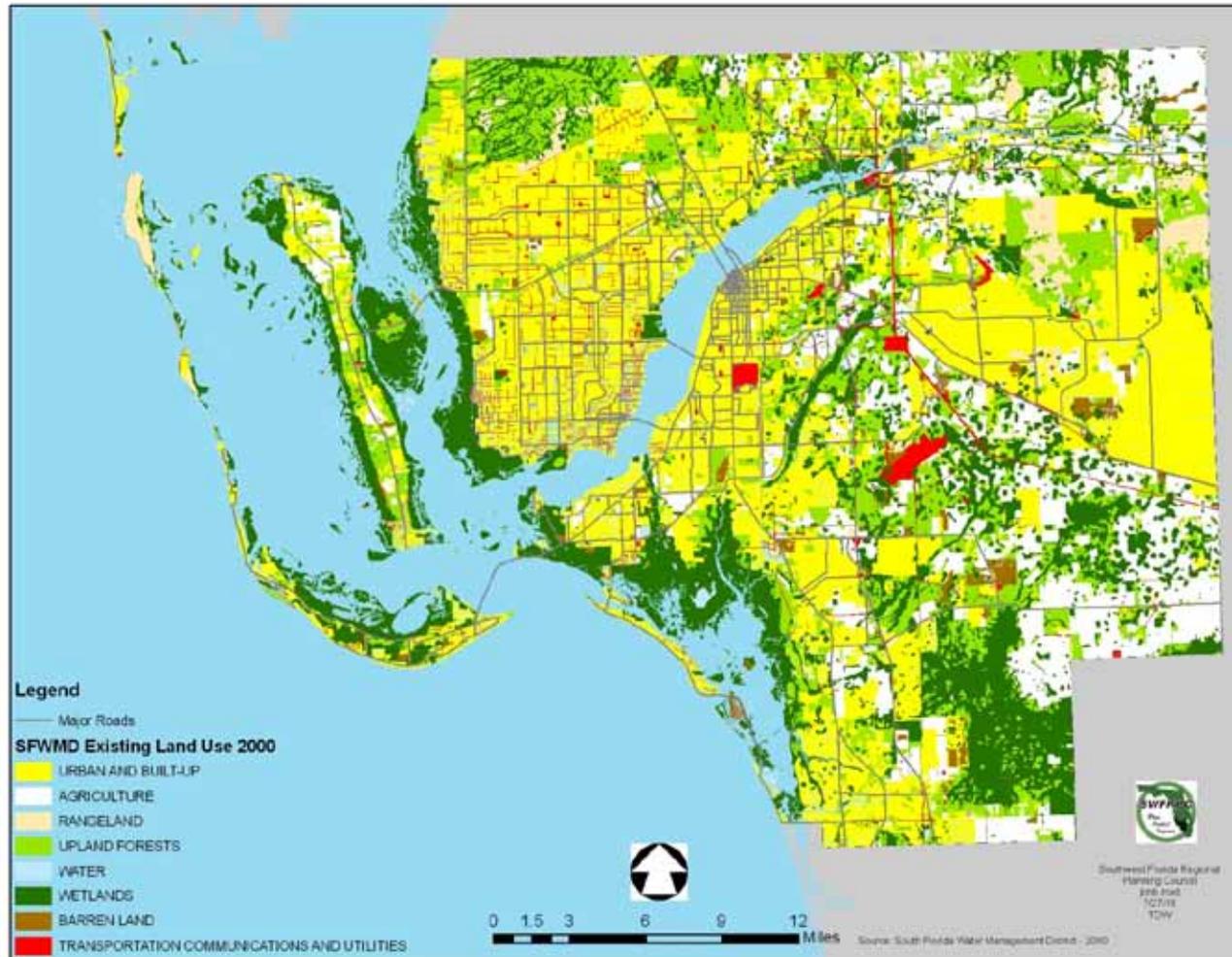
**Figure 1:** Lee County in relation to the State of Florida



**Figure 2:** USGS topographical map of Lee County



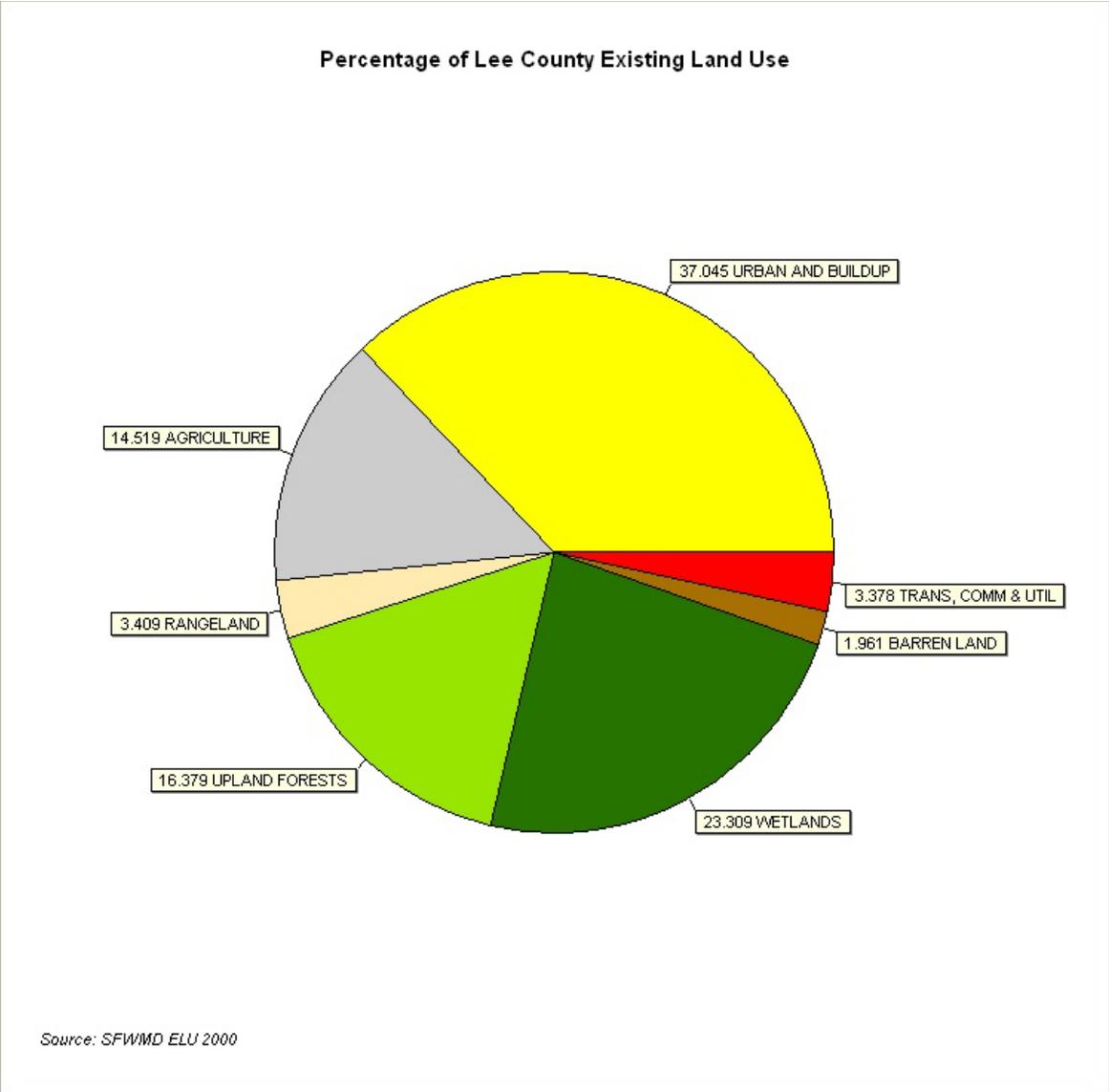
**Figure 3:** Aerial photograph of Lee County



**Figure 4:** Existing land uses of Lee County

<b>Land Use</b>	<b>FLUCCS Level 1</b>	<b>Area in acres</b>	<b>Percentage</b>
<b>Developed</b>	100	191,131.00	37.05
<b>Agriculture</b>	200	74,907.30	14.52
<b>Rangeland</b>	300	17,588.60	3.41
<b>Upland Forests</b>	400	84,505.10	16.38
<b>Wetlands</b>	600	120,258.00	23.31
<b>Barren Land</b>	700	10,119.70	1.96
<b>Transportation, Communications, and Utilities</b>	800	17,430.30	3.38

**Table 1.** Generalized existing land uses in lee county



**Figure 5:** Lee County's existing land uses  
Percent of total land uses

## Lee County Vulnerability Assessment

On January 12, 2010 Lee County contracted with the SWFRPC to develop a climate change vulnerability assessment (CCVA) for the unincorporated portions of the county. This was completed on March 18, 2010 and the draft provided to the County for review.

The vulnerability of a county is a function both of the county's sensitivity to changes in climate as well as its adaptive capacity to adjust to changes in climate (either reactively or proactively through planning decisions). To assess its vulnerability, the county should describe the specific effects from climate change that are likely to affect key management goals. Climate change impacts will vary regionally, as will the approach taken to identify the most significant vulnerabilities. There are many different approaches to completing an assessment, from simple back-of-the-envelope approaches based on effects that are already occurring, to more sophisticated approaches that examine the links between multiple effects using predictive modeling or other tools to help project changes. Although a general understanding of vulnerability may be enough of a basis to inform adaptation actions in coastal areas, most counties may need and develop county-specific information that better characterizes the spatial distribution, intensity, and frequency of projected impacts. A more detailed and descriptive assessment may also be necessary to better inform stakeholders and to prioritize and gain support for actions. Additionally, the time frame for effects will vary according to the selected planning horizon for the county. Regardless, a vulnerability assessment could include: a description of the approach used, a summary of the most significant effects, the timeframe for the predicted effects, and any considerations for uncertainties or other factors needed to set priorities.

The primary focus of the CCVA was the vulnerability of the coastal regions of Lee County to climate change. The project included an assessment of significant potential effects of climate change on the human and native ecosystems of Lee County, 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. The CCVA lays the groundwork for the development of a resiliency plan for the local government, local government guidance resolutions, and comprehensive planning.

From the CCVA, it can be stated that, in the absence of effective avoidance, mitigation, minimization and adaptation, climate-related failures will appear in all of the important management goals identified by Lee County in its comprehensive plan.

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

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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.

Beach and mangrove ecosystems of Lee County 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 and 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 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 allow 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 is already being done by the Charlotte Harbor National Estuary Program (CHNEP) and will 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
- a. 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.”

Lee County’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 Lee County 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 Lee County (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 benefit from 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 across north Lee County through four landscape scale acquisitions, including the Yucca Pen Creek, Yucca Pens Unit of the Charlotte Harbor Flatwoods, Pinelands Preserve, and Babcock Ranch.

The likely effects of climate change and particularly sea level rise on Lee County and 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.

## **Risk Analysis**

Natural hazards are a threat the people and property of Lee County face on a daily basis, and most analyses project that these hazards are likely to increase in intensity and/or frequency with climate change. The level of risk differs by hazard type, time of year, and location of the person or piece of property. Risk analysis is an essential first step in helping the people of Lee County prepare to face these risks. This risk analysis includes four main components: hazard identification, profiling hazard events, asset inventory, and estimation of potential loss.

An important step in the risk analysis process is to identify those hazards that are most likely to impact Lee County. While there is a long list of natural hazards that have the potential of occurring in Lee County, the majority of these hazards have a low probability of occurring. Thus, the hazards that have been identified for analysis in this plan because of their potential to impact the county include (in no particular order): flooding, coastal storms, wildfire, tornadoes, thunderstorms and high wind events, coastal erosion, drought, winter storms and freezes, and exotic pests and diseases.

Profiling hazard events describes the causes and characteristics of each hazard, how the hazard has impacted Lee County in the past, and what part of Lee County has been vulnerable to each specific hazard. A profile of each hazard that is covered in the Unified Local Mitigation Strategy for Lee County, Florida was adopted in February 2007. This plan has a section on each individual hazard. For a full description of the history of hazard events, please see the appropriate hazard chapter and Appendix B of that report.

The asset inventory is a way to assess vulnerability from each hazard by looking at the types and numbers of existing buildings, infrastructure, and critical facilities located in each identified hazard area. In order to assign a monetary value for each structure, the structure's replacement value, content value, and functional use value were determined. Appendix A in this document explains the methodology used to determine these values.

"Replacement value" is the current cost of returning a physical asset to its pre-damaged condition. It reflects present day cost of labor and materials to construct a building of particular size, type, and quality. For this analysis, value of the building, as listed in the property appraiser's records, was used. In instances when the building value was not available, the total value of the property was used.

## **Summary of Priority Considerations**

Planning typically requires some narrowing of the scope to focus efforts on managing risk where most needed. Determining the greatest needs for a particular county will likely entail both quantitative and qualitative analyses of risk and vulnerability, as well as discussion and agreement among key estuary managers, stakeholders, and collaborators. Quantitative and qualitative climate change risk and vulnerability assessments need to be balanced with the county's management goals and objectives. In many cases, climate change will not necessitate creation of new management goals or initiatives, but rather consideration of how existing

programs will be able to address or be impacted by a changing climate. A summary of this information in an adaptation plan should describe the approach taken, decisions on priorities and any uncertainties or other considerations that may affect the selection of specific activities.

Key considerations in assessing management priorities and risk include:

1. Timing of projected impacts (e.g., short-term, mid-term, long-term) relative to the timing of management decisions and actions;
2. Severity of projected impacts (e.g., catastrophic, severe, major, minor, insignificant), and geographic scale (i.e., localized vs. county-wide);
3. Probability of the occurrence of different impacts;
4. Economic or social significance/value of economic, social or environmental assets (i.e., what is being protected); and
5. Capacity of the community to undertake the action compared to the scale of the impacts, which could include:
  - a. Costs associated with implementing adaptation actions (e.g., budget availability, funding opportunities);
  - b. Information availability, including ongoing monitoring and research (e.g., LIDAR, GIS, mapping, indicators);
  - c. Availability of adaptation options suitable for addressing risks;
  - d. Timing and time horizon (e.g., decision frequency, planning horizon, implementation period);
  - e. Linkage to other decisions (i.e., will adaptation actions impact other decisions within the county or externally);
  - f. Regulatory, operational, political, and legal constraints;
  - g. Public awareness, support, and concern about the issue; and
  - h. Ability to act under uncertainty (of either the likely impacts or the effectiveness of the actions).

## Lee County Resiliency Strategy

### Communication with Stakeholders and Decision Makers

Resiliency actions will require consent from the decision makers who will have to provide approval, and funding in carrying out the selected actions, as well as the Lee County staff that live, work, and play in the county. Local governments tend to be very experienced with appropriate communication tools for their locales, and should be able to readily incorporate climate adaptation planning into ongoing information and education programs. However, in many places communication for climate change resiliency may demand either a different approach or new expertise for the county. In particular, some plans will involve trying to develop alternatives to prevent future negative outcomes that are either uncertain or unimagined. Rather than returning to historic conditions of water quality or ecosystem health, staff and officials may have to anticipate conditions that, as yet, have not manifested in the system.

A “multi-modal” communication strategy may be necessary to address some of these unfamiliar concerns and to provide specific information on the actions that will be necessary in the watershed.

Climate change resiliency strategy (CCRS) planning must be a cooperative effort involving all stakeholders: citizens; construction, business, real estate, and agricultural interests; retirees; families; emergency services; city and county government and more. The effort should be done in cooperation with the county government, preferably as a part of the comprehensive plan update and other existing planning processes. This enables the resulting CCRS to take on the authority necessary to make sure recommended actions are eventually implemented and an ongoing process for adaptive planning is put in place. Comprehensive plan amendments, land development regulations and community initiatives should result, informed by the people on the ground, and approved by decision makers.

Communication efforts should stress the transparency of the process and the accountability of the entity leading the effort, whether it is the County government, a contractor, a state agency, or a citizen group. The planning effort should involve as much of the public as possible, increasing responsiveness of the plan to local citizenry and resulting in public buy-in.

For Lee County, staff was approached initially by CHNEP and SWFRPC staff to gauge interest in developing a CCRS. Fortunately, this progressive local government had already included climate change planning and greenhouse gas mitigation in several programs including a bio-fuel initiative utilizing *Jatropha*, support for algenol development and support for solar field development. Also, Policy 4.3.3 of the Lee County Comprehensive Plan states that architectural and landscape design based on local climate and history and natural methods of cooling and heating will be encouraged and that Green Building techniques will be considered in construction.

The next step in the development of the CCRS was a survey devised to gauge the awareness, attitudes and experience of high level Lee County staff members, County Commissioners, and constitutional officers regarding climate change. The survey was sent out via the web-based service, SurveyMethods.com. Introductory information included a link to the draft Vulnerability Study. The survey (Figure 6) was sent via email to 50 potential respondents; 26 participated.

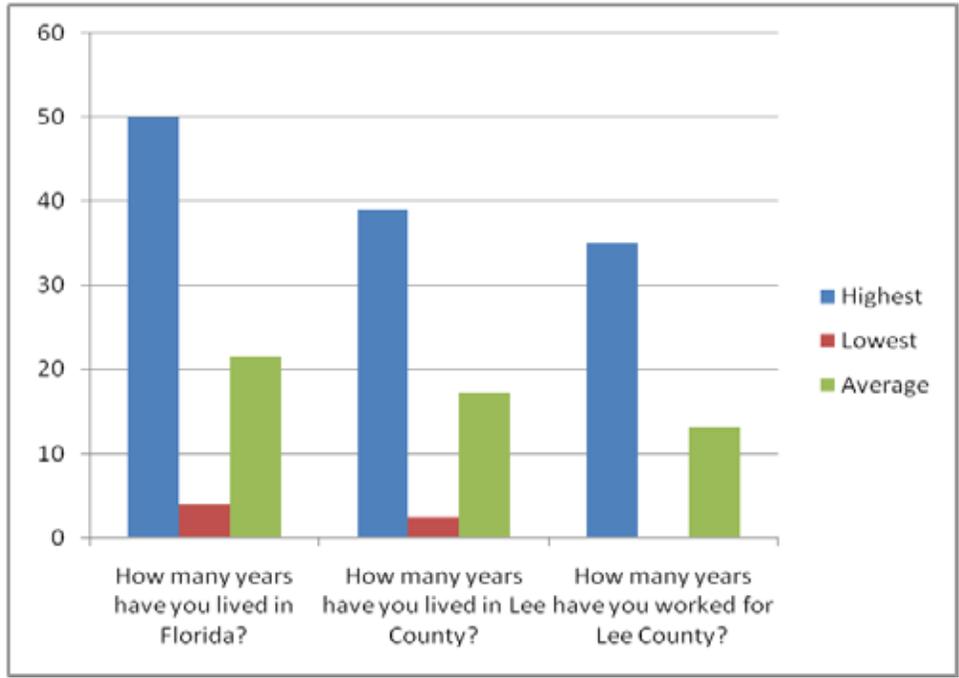
Lee County Climate Change Resiliency Planning  
Lee County Staff Survey

1. How many years have you lived in Florida?
2. How many years have you lived in Lee County?
3. How many years have you worked for Lee County?
4. Winter in Florida is typically the dry, cool season.
  - Do you think winters have been wetter, drier, or the same since you began living in Florida?
  - Do you think winters have been cooler, warmer, or the same since you began living in Florida?
5. Summer here is typically the warm, rainy season.
  - Do you think summers have been wetter, drier, or the same since you began living in Florida?
  - Do you think summers have been cooler, warmer, or the same since you began living in Florida?
6. Do you think fishing around Lee County is improving, declining, or about the same, or are you not sure?
7. Do you think water quality in Lee County lakes and rivers is improving, declining, or about the same, or are you not sure?
8. Do you think water quality in Lee County's salt water environments is improving, declining, or about the same, or are you not sure?
9. Do you think the presence of wildlife in Lee County increasing, decreasing, or about the same, or are you not sure?
10. Have you noticed any changes in the weather generally in the time you've lived in Lee County?
11. Do you think storms are getting more severe? More frequent?
12. Do you expect the weather generally to be better, worse or about the same in the future?
13. What impacts, if any, did Hurricane Charley have on your department/responsibilities?
  - ÿ Damage to or loss of facilities
  - ÿ Damage to or loss of equipment
  - ÿ Damage to or loss of non-tangible assets, such as data, etc.
  - ÿ Loss of personnel from any storm-related cause
  - ÿ Spending/budget impact
  - ÿ Change of goals/objectives/focus
14. In what ways did Hurricane Charley affect your department's goals and operations for the 2003-2004 fiscal year?
15. In what ways did Hurricane Charley affect your department's goals and operations for the 2004-2005 fiscal year?

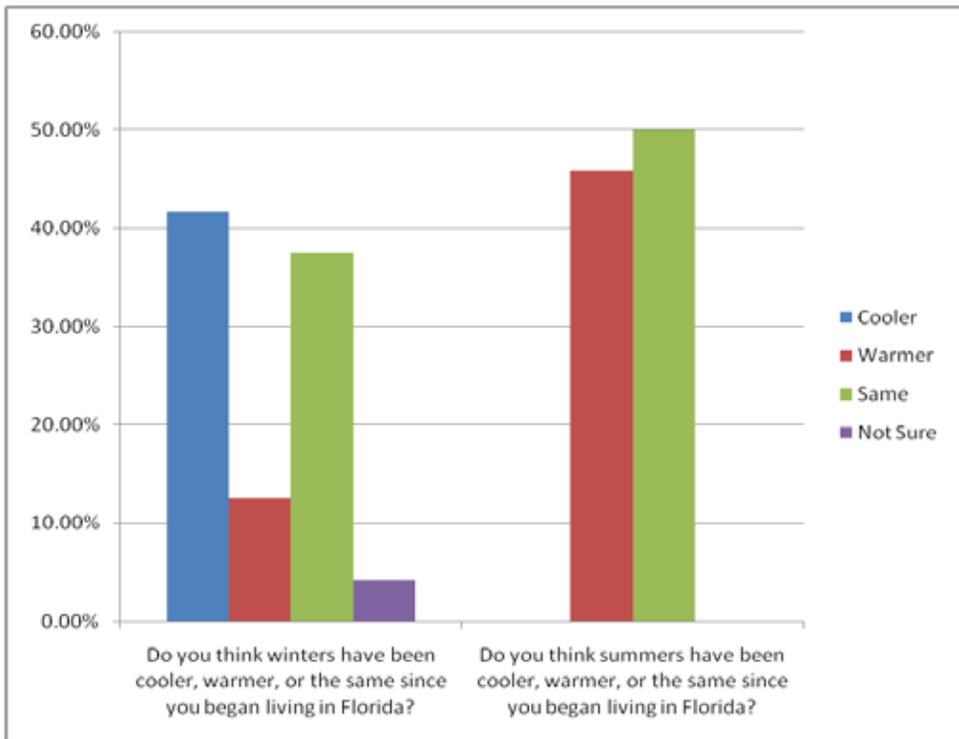
16. Did Hurricane Charley change the way your department “did business”? In what ways?
17. Does your department have assets in a flood zone?
18. Does your department have assets in any storm surge zones? Which zones?
19. What percentage of your department’s activities would you say are weather-dependent?
20. Has weather ever impacted your department’s activities in the past?
21. Given that climate change has the potential to result in a 5” rise in sea level by the year 2025, how do you think your department/facilities might be impacted? How do you think other departments/facilities might be impacted?
22. Given that climate change has the potential to result in a 2.4°F increase in average temperatures in Lee County by the year 2025, how do you think your department/facilities might be impacted? How do you think other departments/facilities might be impacted?
23. Are there any energy-saving changes that could be made to your department’s facilities?
24. Do you encourage any energy-saving activities in your department/facilities, such as turning off lights in unused rooms or programming thermostats for energy efficient settings?
25. Are there any changes that could be made to your department’s facilities that would make them more wind- or rain-resistant?
26. How old are your facilities?
27. Do any of your employees carpool? Job share? Telecommute? Use public transit? Have flexible hours?
28. Do you encourage carpooling, job sharing, telecommuting, use of public transit, or flexible hours in your department? In what ways?
29. What do you think is the most important thing Lee County could do to prepare for potential climate change over the next 25 years?
30. What do you think would be the worst thing Lee County could do to prepare for potential climate change over the next 25 years?

**Figure 6:** The on-line survey

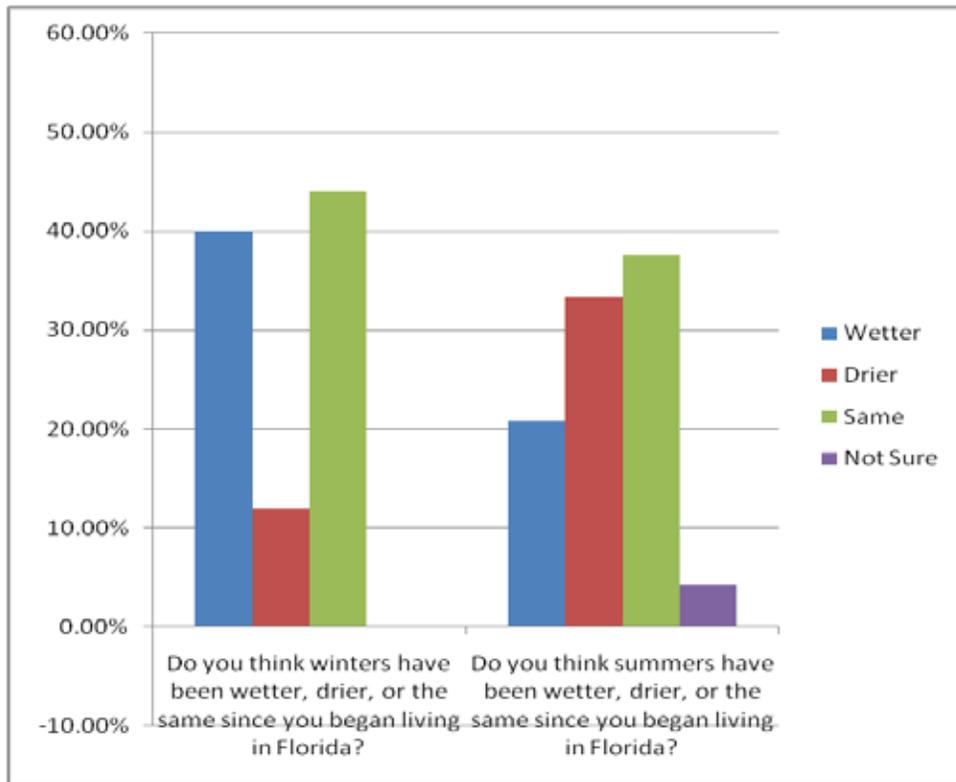
The first few questions gathered information about the respondents' history in Lee County, and their perceptions of weather and climate conditions.



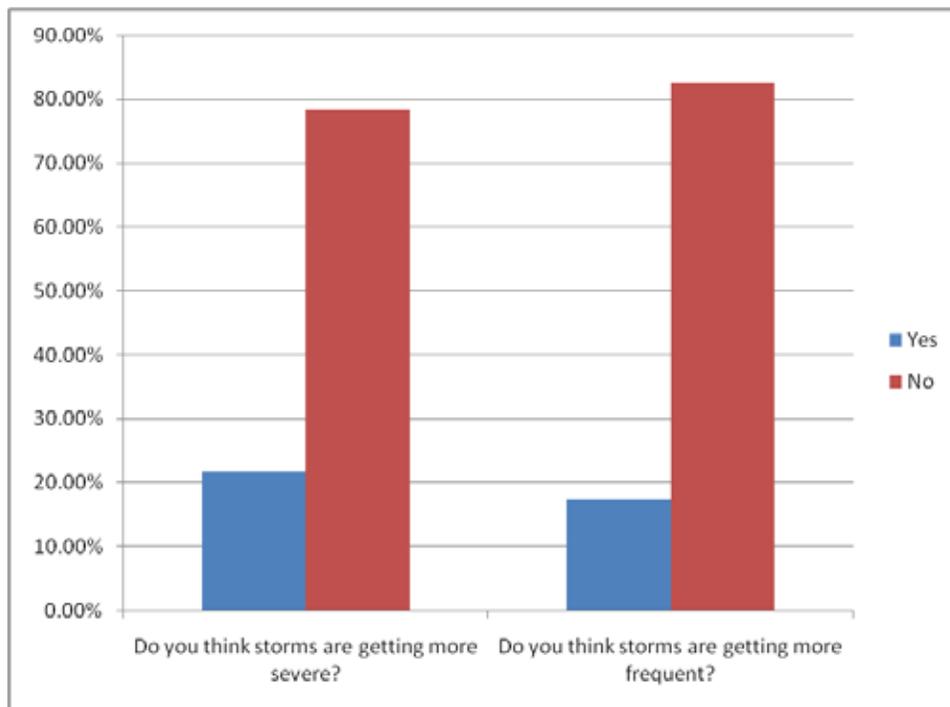
**Figure 7: Demographic information**



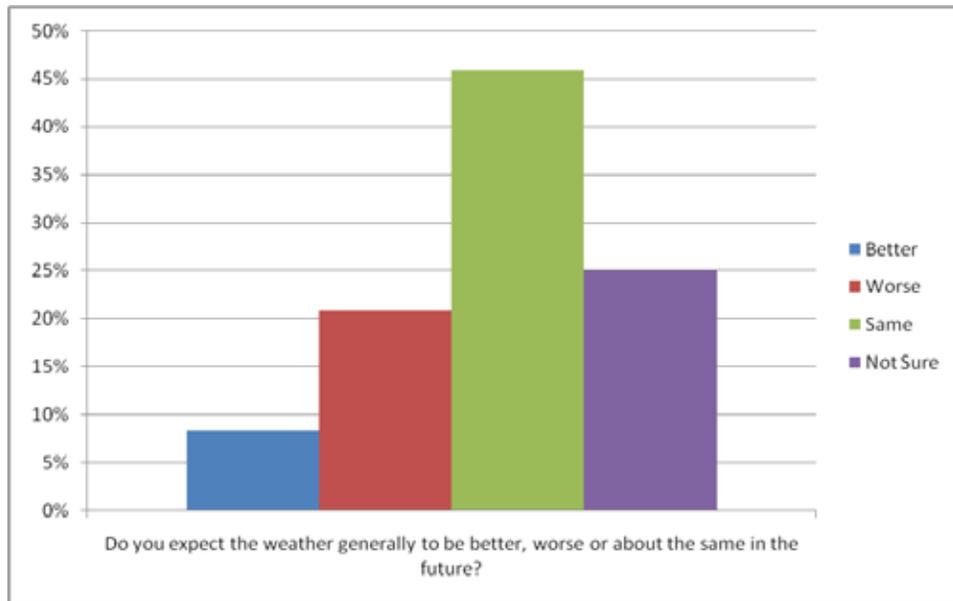
**Figure 8: Perceptions of temperature changes**



**Figure 9: Perceptions of precipitation changes**

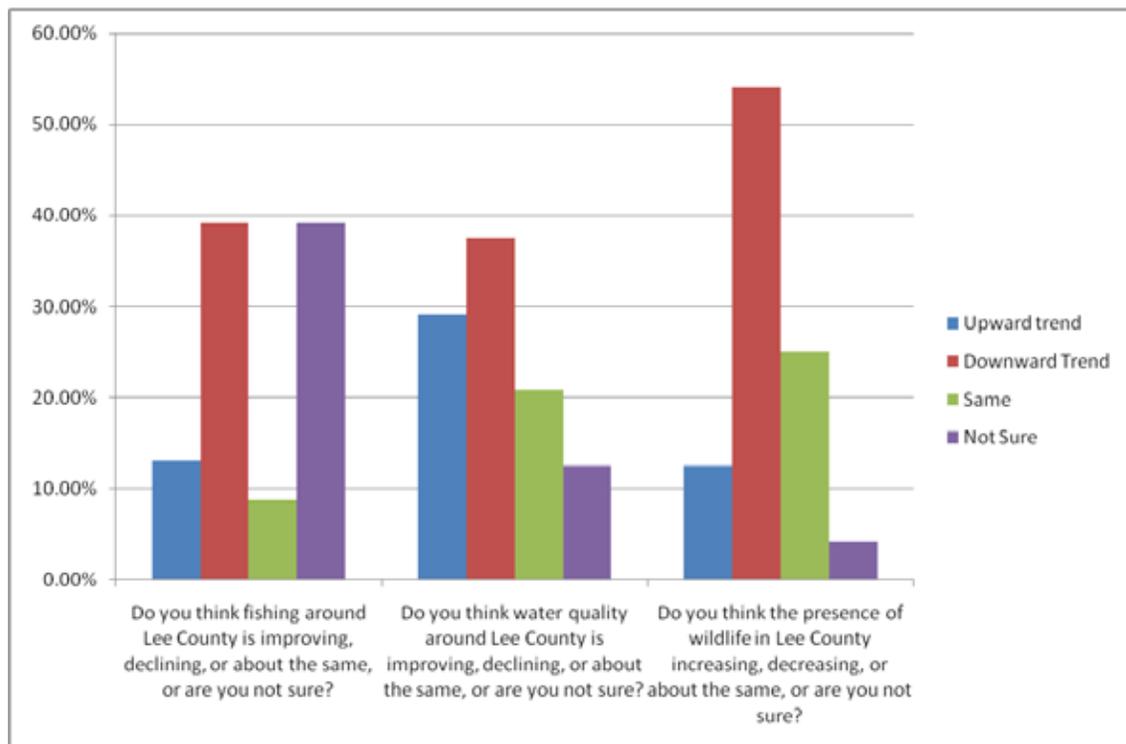


**Figure 10: Perceptions of storm severity and frequency**



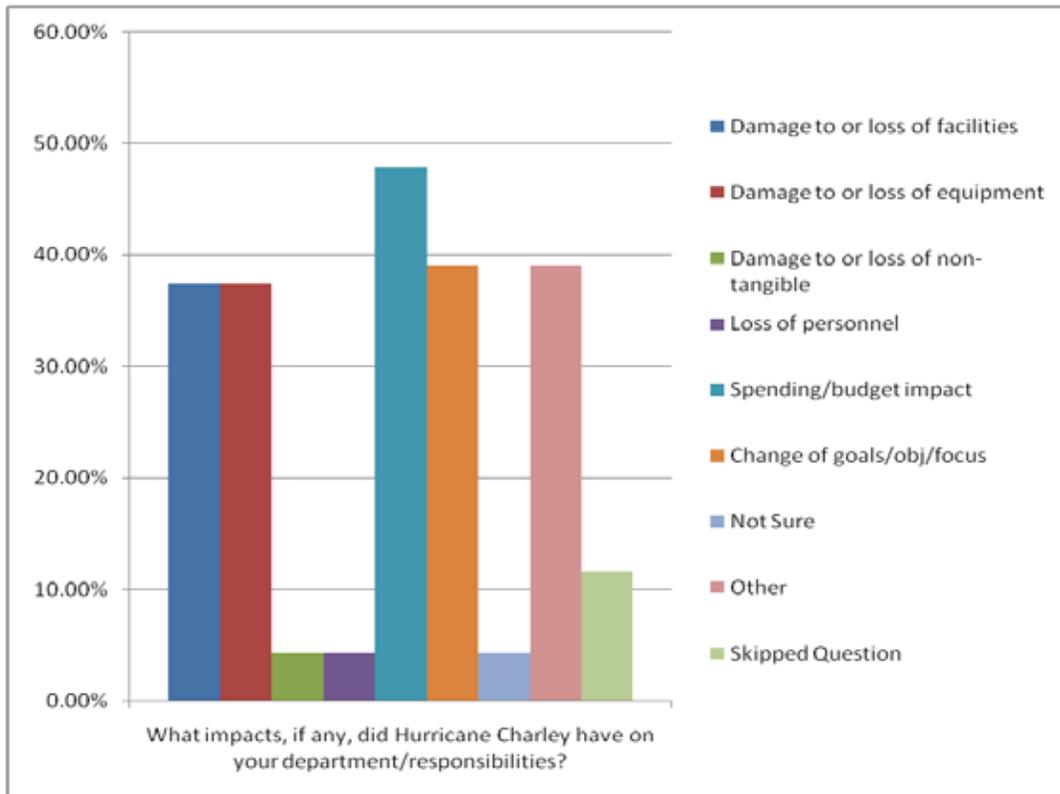
**Figure 11:** Perceptions of weather/climate

Participants were also asked about their perceptions of natural resources in the area.

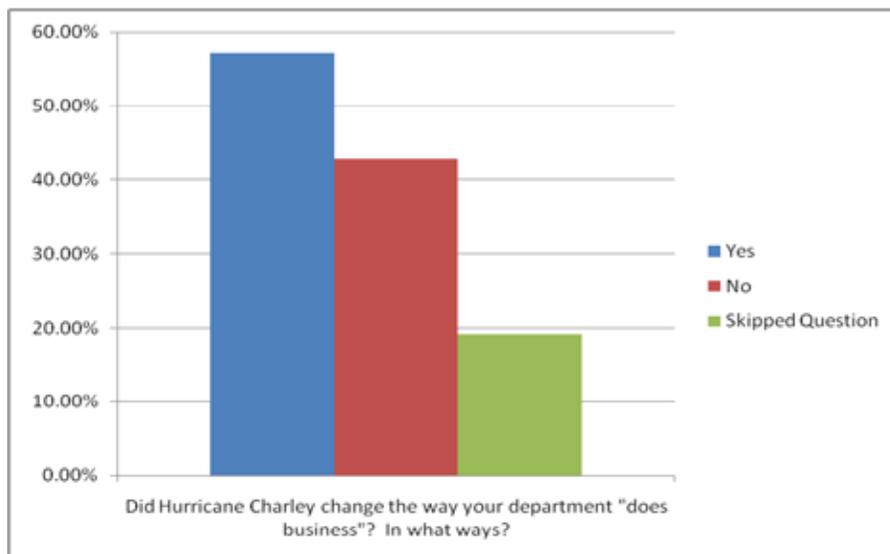


**Figure 12:** Perceptions of natural resources

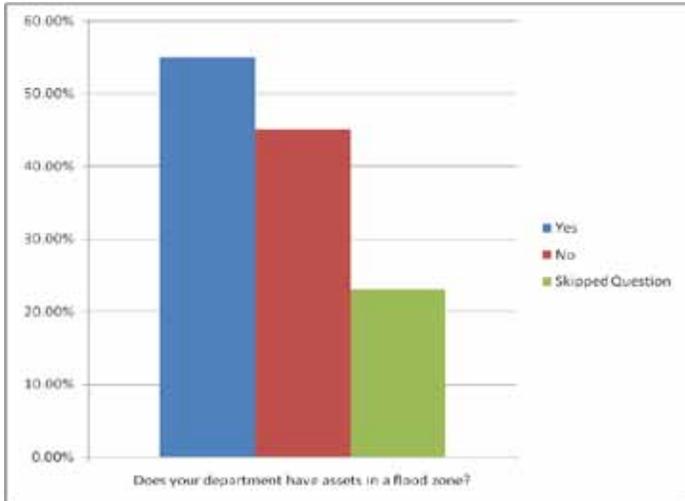
Survey questions then turned to the effects of Hurricane Charley in 2004 on county departments – facilities, personnel, processes, and activities – and on any changes that may have resulted. Many effects of climate change have results analogous, in the long term, to the short term consequences of major tropical storms, such as flooding, damage from storm winds, electrical power surges and problems with personnel transportation.



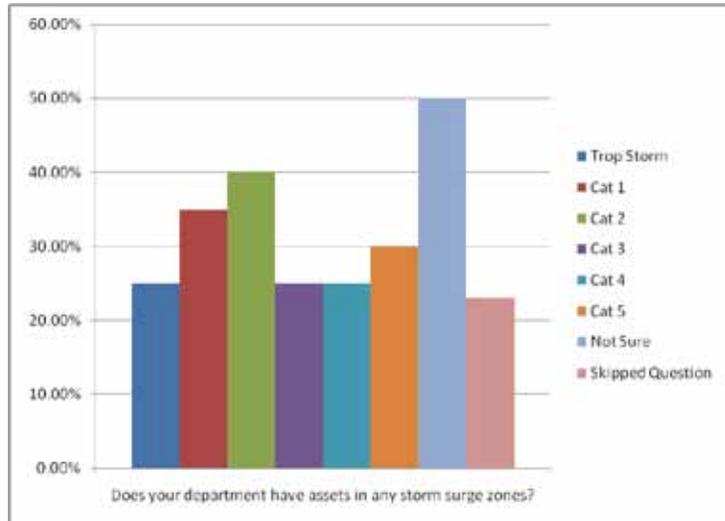
**Figure 13:** Impacts of Hurricane Charley on County departments



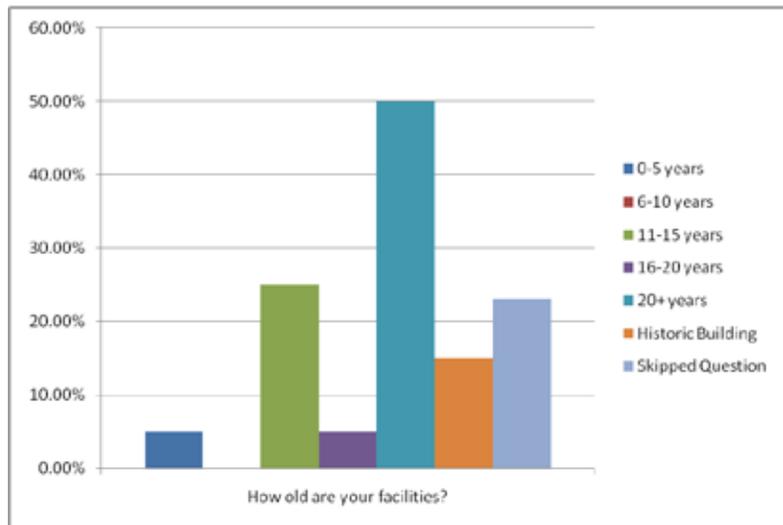
**Figure 14:** Changes resulting from Hurricane Charley



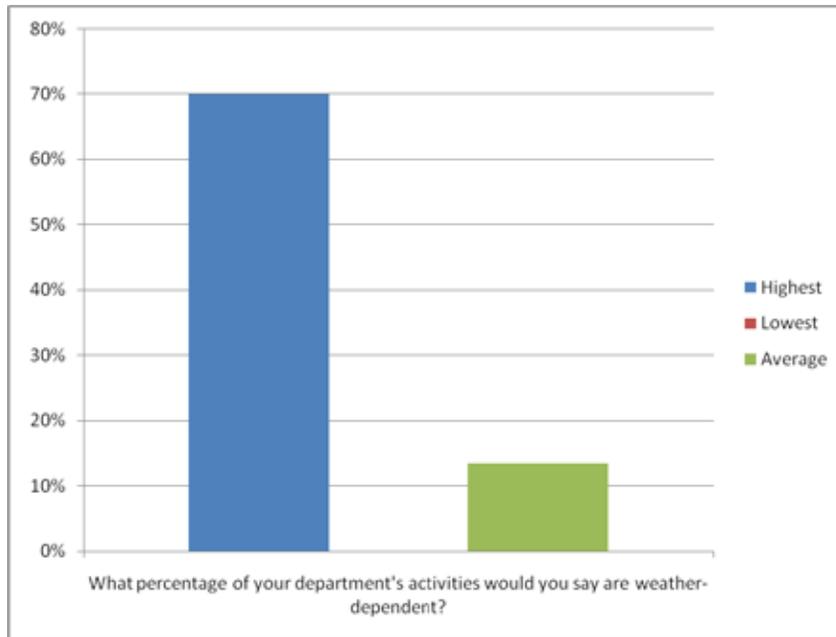
**Figure 15:** County assets in flood zones



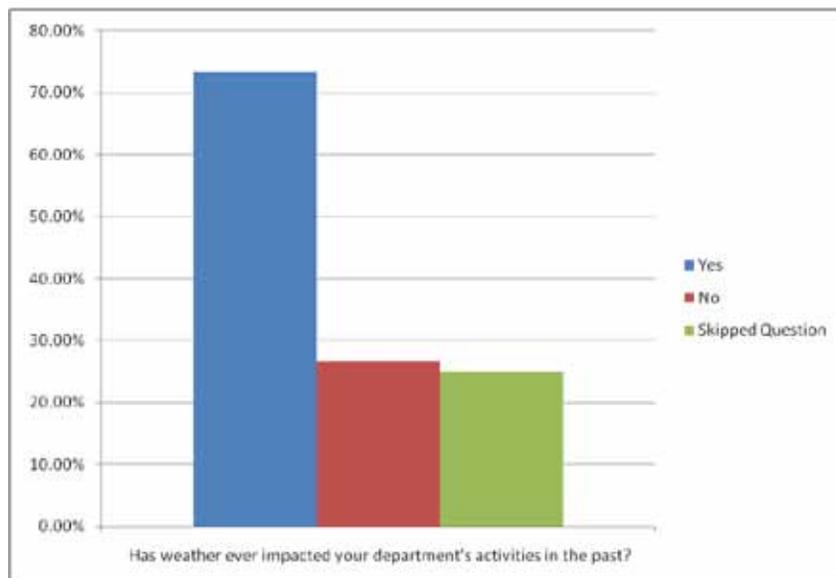
**Figure 16:** County assets in storm surge zones



**Figure 17:** Age of facilities

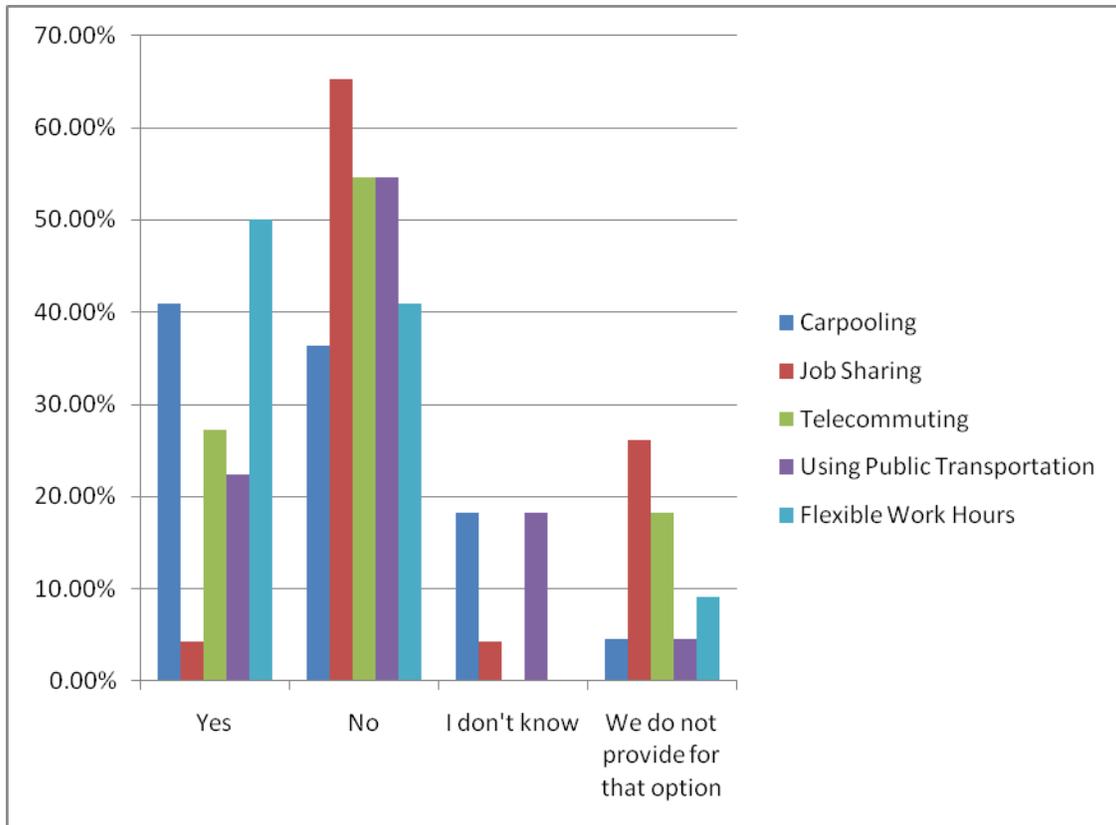


**Figure 18:** Weather dependence of county activities



**Figure 19:** Impacts of weather on activities

Finally, participants were asked if measures that could be taken to minimize and/or mitigate for certain climate change effects were utilized in their departments. These measures mainly serve to reduce greenhouse gas emissions and reduce energy usage.



**Figure 20:** Participation in minimization and/or mitigation activities

Subsequently, SWFRPC staff met with Lee County staff in thirty-nine departments and with four county commissioners to conduct interviews regarding climate change resilience in Lee County. Departments contacted included Animal Services, Budget Services, Community Development, Contracts, County Attorney, County Lands, County Manager, Economic Development, Emergency Operations, Equal Opportunity, Extension Services, Facilities Management, Fleet Management, GIS, Hearing Examiner, Human Resources, Human Services, Library, Natural Resources, Parks & Recreation, Public Resources/MSTBU, Public Safety, Public Works, Purchasing, Risk Management, Smart Growth, Solid Waste, Sports Authority, Tolls (LeeWay), Transit (LeeTran), Transportation, Utilities, Veterans Services, and Visitor & Convention Bureau. Constitutional officers were also interviewed: Clerk of the Court, Property Appraiser, Sheriff, Supervisor of Elections, and Tax Collector. The following is the outline used in the interviews:

1. Did you look at the draft Vulnerability Report before completing the survey?
2. If so, what did you think of the Report?
3. Did we leave anything important out of the Report?
4. What did you think of the survey?
5. Did we leave anything important out of the survey?
6. How do you distinguish between the weather and the climate?
7. We're talking to everyone at your level of the org chart and above, including the commissioners. Is there anyone else we should talk to or send the survey to?
8. What do you think the effects of climate change might be on your department?
9. What do you see as Lee County's greatest vulnerability to climate change? In other words, what do you think is most likely to be negatively affected by sea level rise and/or temperature increase?
10. How important do you think it is for Lee County to try to deal with climate change in an organized manner? (Scale of 1-10, with 1 being not important at all and 10 being more important than anything else)
11. AMMA stands for "avoidance", "minimization", "mitigation", and "adaptation", and refers to strategies for dealing with climate change effects. Climate change effects that could potentially affect Lee County include higher sea level (with higher high tides), warmer air and water temperatures, unusual rain patterns, more intense rain storms and more intense tropical storms and hurricanes. Let's discuss this for a moment.
  - a. The easiest way to avoid the negative consequences of climate change is to not place resources or infrastructure in a location or position to be impacted. This *avoidance* can take the form of not building in floodplains, setting aside coastal areas to remain natural, and placing critical facilities and shelters away from and above storm surge. Are there ways your department could avoid climate change effects?
  - b. The primary goal of *mitigation* is to reduce the magnitude of climate stresses on society and ecosystems. Investment in the region's substantial renewable energy resources (e.g., solar, wind, and biomass) could provide incentives for new technology development and economic diversification while reducing air pollutants and greenhouse gases. In what ways could your department's activities help offset climate change effects?
  - c. Employing "best practices" in land and resource use can *minimize* ecologically harmful side effects while continuing to provide significant, and often increased, economic benefits. What could your department do to minimize the negative effects of climate change on your operations?
  - d. *Adaptation* to climate change refers to staying in place and changing our infrastructure to deal with changes in the environment. How do you think your department should change to deal with environmental changes in sea level and/or temperature?

**Figure 21:** Talking points for senior staff interviews

## Lee County interviewee-identified vulnerabilities by category

<b>Buildings and County Infrastructure</b>
Impacts to roads from increased creek and stream flows
Increased cost of building materials not just air conditioning. A harsher climate will create the need for more frequent replacement of materials
Increased cost of maintaining facilities including roadways from hotter temperatures and impacts to asphalt
More frequent flooding events with associated structural damage
More frequent storm events with associated structural wind and storm surge damage
<b>Coastal Protections</b>
Impacts to beaches and the demand for beach renourishment
More frequent storm events with associated erosion
<b>Coastal Economies</b>
Declining property values impacting the County's ability to maintain infrastructure and provide adequate services
If it is warmer and the land becomes inundated, people may choose other locations to vacation – impact on tourism.
Increased cost of doing business
Increased impact on human resources – hotter temperatures will increase the cost of workers' compensation and may require compensation to be reevaluated for those employees working in harsher strenuous environments.
Lee County's sporting events may be impacted by more frequent storm events and hotter temperatures
More extreme temperatures will increase the cost burden to low income residents.
More storms translates into more impact and a drain on financial resources
Normal, everyday work may take more hours to perform
Perception of vulnerability can have real economic consequences. Sporting event organizers may choose to locate events according to the reputation or perception of an area. Hotter temperatures can influence this perception.
<b>Emergency and Hazard Planning</b>
Residents may experience radio communication problems during and following storm events
<b>Health and Human Services</b>
Increased health cost resulting from those living without air conditioning or unable to pay utility bills
Increased impact on the economically disadvantaged
More people may seek out financial assistance from the Department of Human Services to weatherize their homes
Possible modification of work hours due to hotter temperatures.
Utility assistance requests may rise if the weather becomes more extreme.

<b>Land Use Planning and Growth Management</b>
EMS may have a harder time serving those in low lying areas
Possible reduction of in migration to the area and a possible increase in out migration from the area.
Residents may experience increased response times for emergency services
<b>Urban, Suburban and Rural Landscape</b>
Increased impact on Stormwater management systems
More frequent storms will increase the burden on the County and County departments
<b>Water and Wastewater</b>
Could experience strains on our freshwater aquifers
Surface water management issues
<b>Waste Management</b>
Possible increased demand for carbon credits if a cap and trade program is adopted nationally. Lee County Solid Waste is eligible for carbon credits for their new turbine but not for the older two turbines.
<b>Economic Development</b>
Higher utility bills
More frequent adverse working conditions for outdoor workers
<b>Natural Systems and Resources</b>
Changes to the day to day hydroperiod, base flows water budget, wetland impacts, water bodies and the volume, timing and distribution of flows.
Concerns regarding Lake Okeechobee flows
Could experience impacts to landscaping and plants
Could impact sea life and the estuary
Destruction of ecological systems which could severely impact our tourism industry
<b>Education and Outreach</b>
Could impact nearly every area of how the County functions impacting the budget and demanding more interdepartmental and intergovernmental coordination
Potential for increased variability of weather – more rainfall during and longer periods of drought

**Table 2.** Lee County interviewee-identified vulnerabilities by category

Note: If no suggestion was made for a category, that category is not included on this table.

## Description of Specific Implementation Actions

<b>Buildings and County Infrastructure</b>
Automatically shutting down the power to buildings after hours.
Building to LEED certification standards.
Consideration of solar path and incorporating structural shading of doors and windows.
Continually explore increased energy-efficient materials and systems with a reasonable return on investment.
Daylighting for new facilities.
May have to build or modify structures where they can function in areas with higher surface waters.
Need to limit the placement of county facilities and infrastructure in flood prone and storm surge areas. This can be problematic since the facilities and infrastructure should be community-based.
New facilities should not only be energy efficiency but water efficient.
PACE program for hardening structures.
Technology infrastructure (aerials for the property appraiser) reduces the need for driving the fleet of automobiles to property locations for valuations.
Building and development codes should be reviewed in light of vulnerabilities/to address strategies.
<b>Coastal Protections</b>
Beach renourishment.
Land acquisition for carbon sequestration.
<b>Coastal Economies</b>
Widening of Alico Road to accommodate business interested in energy research.
<b>Emergency and Hazard Planning</b>
Careful consideration of critical facilities.
Observation of Coastal Control Line and not allowing building seaward of the coastal construction control line.
The County may consider placing some requirements on affordable housing sites to reserve land for post-disaster housing.
<b>Health and Human Services</b>
Locating healthcare facilities out of vulnerability zones.
Modify County dress codes.
<b>Land Use Planning and Growth Management</b>
Address requirements of HB 697
Adopt standards that take scenarios into consideration
Comprehensive Plan – update to reflect changing conditions.
Development of a Solar Strategy for inclusion in the comprehensive plan.
Need more policy analysis regarding land use regulations.

Need to actively reduce automobile dependency in our area.
Need to consider transit oriented development and fight urban sprawl.
Need to incentivize development and redevelopment within the urban area.
Promote increased density and a reduction in the amount of impervious surface.
Reduce density in coastal high hazard area.
Lee County needs to do more sustainability planning.
Lee County needs to identify policies that can be implemented without funding.
Lee County should work very closely with planning/community development to address climate change
<b>Urban, Suburban and Rural Landscape</b>
None identified
<b>Water and Wastewater</b>
Careful consideration in the placement of facilities to avoid hazard areas.
Increase the use of rain barrels.
Native plants and reduced irrigation for County facilities.
<b>Waste Management</b>
Recycling cleaning fluids and waste stream from the fleet maintenance department.
Reduce travel, increase use of webinars, teleconferencing, etc.
The solid waste recycling program is converting to a single stream recycling system.
<b>Economic Development</b>
Encouraging FGCU regarding their research and “Energy Diamond” project.
May have to modify locations for sporting events.
<b>Natural Systems and Resources</b>
Conservation 20/20
Installation of filter marshes to treat potential increased stormwater volume.
Keeping fertilizers, yard clippings and pet waste out of surface water bodies.
Restoration of flow ways and increasing surface water storage.
Lee County needs to evaluate and utilize our environmental BMPs, the Florida Yards program and land stewardship strategies.
Lee County needs to recognize that the economy of Lee County is directly linked to the environment.
<b>Renewable, Green Energy</b>
Algenol
Converting buses to hybrids.
Coordinate with the airport regarding photovoltaic panels.
Emphasis on biomass, reducing greenhouse gas emissions, providing economic stimulus dollars for renewables.
Encouraging the Green Lodging Certification.
Green purchasing policies for office supplies and other materials.

Purchasing hybrid vehicles and other more efficient fleet vehicles.
The new public safety building may have a PV system.
<b>Education and Outreach</b>
Education is critical.
Encourage behavior change in employee trips (carpooling, transit, bicycling, walking, teleworking, four day work weeks, reduction of VMTs, etc)
Encouraging personal accountability for actions.
Identify Lee County's energy goals.
Increase awareness that citizens can renew driver's licenses, hunting/fishing licenses, pay taxes and fees online and thus reduce automobile trips.
Key staff/human resources are critical to developing strategies to address these issues.
Lee County is working closely with FGCU on their research efforts and the creation of new school curriculum.
Need to cast a wider net (be more inclusive) of stakeholders. Lee County needs to have more people at the table providing input on resiliency strategies and how we adjust to climate change in Lee County.
Offsite data storage and protection.
Public Information is an important tool to help avoid and/or reduce impacts associated with climate change.
Recycling and hazardous waste collection days and encouraging green incentives.
Lee County needs to reach out to the community and make them aware of the importance of this issue.
<b>Other</b>
Possibly rank geographic areas based upon their individual vulnerabilities.
Reduce paperwork and switch to electronic forms – ties in with the County's digital infrastructure.

**Table 3.** Lee County interviewee identified resiliency strategies by category

Note: If no suggested was made for a category, that category is not included on this table.

## Specific Adaptations by Group

### Buildings and County Infrastructure (Facilities and Operations)

The goal of energy-efficient (green) buildings is to reduce their impact on the environment. By reducing energy impacts, the green building design can reduce the local climate effects of urban heat islands, desertification from inefficient water use, increase groundwater recharge, reduce the level of stormwater pollution and coastal eutrophication and minimize greenhouse gas production for the purposes of building operation, maintenance and utility provisions.

Green building practices apply to construction, renovation, operation, maintenance, and demolition. Green building techniques include thermally-efficient roofs, walls, and windows; building shape and orientation; thermal mass and daylighting strategies that reduce cooling loads; smaller heating, ventilation, and air conditioning systems and efficient electrical lighting strategies that capitalize on daylighting; water efficient supply and waste fixtures; and interior designs providing visual access to the outdoors and access to daylight. The concept also features interior finishes and installation methods having lower volatile organic compound emissions; landscaping strategies that require little or no irrigation, groundwater replenishment and on-site stormwater management; and siting to minimize stress on natural systems either by building on previously contaminated sites or avoiding ecologically sensitive areas. Benefits of green building include improved air and water quality, reduced solid wastes, conserved natural resources, decreased operating costs and enhanced profits, and reduced strain on local infrastructure.

### **What Lee County Government Can Do to Increase Climate Change Resilience for Buildings and County Infrastructure (Facilities and Operations)**

Local government strategies to create more energy efficient buildings (both existing and new) and operations can begin with a number of steps.

Note: This and all following tables related to climate change resiliency strategies are not ranked by any form of prioritization. Strategies discovered in the course of staff interviews to already be in use by Lee County to some extent are indicated with this symbol + . They are included to recognize these accomplishments and to encourage expansion of those policies and practices. Not all strategies being used by Lee County may be accounted for. Key words are shown in bold italics. Some strategies are applicable in more than one area of interest. These strategies are repeated where applicable.

<b>Energy Efficiency</b>
Add energy efficiency as a dominant criterion in <i><b>purchasing</b></i> policies, including requiring the purchase of ENERGY STAR appliances. Calculate the cost/benefit of equipment price to include the energy cost of operation. EPA provides guiding principles and standards for Environmentally Preferable Purchasing ( <a href="http://www.epa.gov/opptintr/epp">www.epa.gov/opptintr/epp</a> ). It also maintains a database of environmental products and services, along with guidelines, contract language, standards, and specifications for over 600 products and services ( <a href="http://yosemite1.epa.gov">yosemite1.epa.gov</a> ). The Green Seal Standard and Certification ( <a href="http://www.greenseal.org">www.greenseal.org</a> ) has been issuing product standards and certifications since 1991. +
Automatically shut down the <i><b>power</b></i> to buildings after hours. +
Build and retrofit to meet <i><b>LEED</b></i> ® (Leadership in Energy and Environmental Design) certification standards.
Conduct <i><b>energy audits</b></i> to understand current conditions and the potential cost savings from altering public buildings and implementing energy efficiency retrofits to existing ones. Audits should include both the structural and operational efficiencies (for example, lighting, cooling,

water use). An energy tracking and management system should be established to monitor progress over time and make course corrections as needed.
Consideration of solar path and incorporating <i>structural shading</i> of doors and windows.
Increase the use of <i>daylighting</i> for new facilities.
Encourage and support appropriate staff to become <i>LEED® Accredited Professionals</i>
Establish procedures to turn off and unplug <i>office equipment</i> when not in use, since idle office equipment continues to use energy. +
Improve water pumping efficiency including disperse <i>solar powered systems</i> .
Install energy-efficient <i>exit sign lighting</i> .
Install green or reflective <i>roofing</i> .
Install <i>room occupancy light sensors</i> , particularly for rooms with sporadic occupancy. +
Institute <i>lights-out-at-night</i> and lights-out-when-not-in-use policies. +
<i>Limit the placement of county facilities and infrastructure in flood prone and storm surge areas</i> . This can be problematic since the facilities and infrastructure should be proximate to the population.
<i>Reduce electricity transmission and distribution</i> through clustering of facilities within a site.
Require installation of <i>energy-efficient vending machines</i> .
Retain an <i>Energy Service Company (ESCO)</i> to analyze the potential cost savings from altering an existing building. An ESCO develops, installs, and finances projects designed to improve the energy efficiency and maintenance costs for facilities over a seven-to-20 year time period.
<i>Technology infrastructure</i> reduces the need for driving the fleet of automobiles to property locations for valuations, meter reading, etc.
Use <i>energy efficient lighting</i> (for example, replace conventional incandescent bulbs with more efficient compact fluorescent bulbs).
Use EPA's <i>combined heat and power (CHP) program</i> ( <a href="http://www.epa.gov/chp">www.epa.gov/chp</a> ) that produces both electricity and steam for heating and cooling from a single power plant located near consumers. CHP systems recover heat that is normally wasted at power plants and funnels the heat into surrounding buildings, thereby reducing energy costs and GHG emissions.
When mainline natural gas is available <i>switch from electric to natural gas</i> for heating, cooling, laundry, and cooking.

<b>Water Efficiency</b>
If irrigation is essential for “signature” exotic species such as royal palms, royal Poinciana, orange trees, mango trees, utilize <i>micro-irrigation and low flow pumps</i> .
New facilities should not only be energy efficiency but <i>water efficient</i> .
<b>Storm / Sea Level Rise Hardening</b>
May have to build or modify structures to be able to function in areas with <i>higher surface waters</i> .
<i>PACE</i> program for hardening structures.
Perform heating, cooling, and ventilation system <i>retrofits</i> (for example, boilers, fans, pumps, coolers, belts).

**Table 4.** Resiliency strategies to address county buildings and infrastructure

Adopt more stringent residential and commercial <i>energy code requirements</i>
Promote <i>green building</i> initiatives and retrofits.
Promote the use of <i>green roofs</i> ( <a href="http://www.epa.gov/nps/roofcover.pdf">www.epa.gov/nps/roofcover.pdf</a> ) through incentives or requiring developers to construct LEED® certified or ENERGY STAR homes.
Create a fund to <i>finance energy-efficient housing</i> projects that lower overall energy costs for residents.
<i>Do not approve</i> new utility facilities that utilize oil or coal as the fuel source for energy generation.
Encourage utilities to install <i>energy efficient co-generation</i> power production facilities.
Establish <i>incentives</i> including reduced fees, licenses, and/or property taxes to promote more energy efficient practices.
Offer <i>weatherization assistance</i> programs for lower-income residents.
Promote energy conservation and green building through <i>education campaigns</i> targeted at residents and businesses.
Promote <i>LEED® Design for Neighborhood Development</i> (LEED® ND).

Promote participation in a local <i>green business</i> program.
Promote through <i>incentives</i> the purchase of <b>ENERGY STAR</b> appliances.
Work with the Lee County school board to incorporate green building practices into <i>school renovations and construction</i> .
Work with the Lee County school board to locate schools with <i>good walking connections</i> to user neighborhoods.
Work with the Lee County school board, Lee County MPO and transportation planning staff to implement a “ <i>Safe Routes to School</i> ” program.
Work with utilities to implement district heating and cooling and time-of-use or peak demand <i>energy pricing</i> .

**Table 5.** Policy and program-related resiliency strategies

### **Resources for Buildings and County Infrastructure (Facilities and Operations) Resilience**

In Florida, the principal resource organizations on energy efficient, green building practices are the six Florida USGBC chapters and the Florida Green Building Coalition ([floridagreenbuildings.org](http://floridagreenbuildings.org)), a nonprofit organization dedicated to improving the built environment and that also hosts a state conference called Green Trends ([www.greentrend.org](http://www.greentrend.org)). The coalition offers a number of designations for green homes, green development, and green cities and counties ([floridagreenbuilding.org/standard/govs](http://floridagreenbuilding.org/standard/govs)). It has also teamed with the Florida Homebuilders Association to promote affordable green buildings ([www.fhba.com](http://www.fhba.com)). An additional resource is the Southeast Rebuild Collaborative ([www.southeastrebuild.org](http://www.southeastrebuild.org)), a joint effort of the state energy offices of Alabama, Florida, Georgia, Mississippi, and South Carolina to promote energy efficiency to individuals, school districts, state and local governments, colleges and universities, vendors, trade organizations, and other allies in the member states.

Three other national organizations that serve as resources on green building are the American Institute of Architects (AIA), the American Society of Landscape Architects (ASLA), and the American Planning Association (APA). The AIA offers a green building on-line toolkit, developed in partnership with the USCM ([www.aia.org/static/state\\_local\\_resources/adv\\_sustainability](http://www.aia.org/static/state_local_resources/adv_sustainability)).

The AIA adopted a 2030 Challenge position statement that calls for the immediate energy reduction of all new and renovated buildings to half the national average for that building type. Increased reductions of 10 percent are required every five years so that all buildings designed by the year 2030 will be carbon-neutral (they will use no fossil fuel energy). In June 2006, the U.S. Conference of Mayors unanimously adopted the 2030 Challenge.

The ASLA ([www.asla.org](http://www.asla.org)) recently released a new performance report on green roofs and offers a live green roof web cam, and the APA sponsors a Green Communities Program ([www.planning.org/yourcommunity/greencommunities.htm](http://www.planning.org/yourcommunity/greencommunities.htm)), which offers grants for green affordable housing. That program is presented in conjunction with the Enterprise Foundation ([www.enterprisecommunity.org/programs/green%5Fcommunities](http://www.enterprisecommunity.org/programs/green%5Fcommunities)).

Other Florida resource organizations include the Florida Solar Energy Center ([www.fsec.ucf.edu](http://www.fsec.ucf.edu)), created by the state of Florida to conduct research in advanced energy technologies, and Eco-\$mart, Inc. ([www.ecosmartinc.com](http://www.ecosmartinc.com)), a Florida House Institute for Sustainable Development initiative to bridge the gap between understanding and applying sustainable development principles. Additional national resource organizations include the Building Codes Assistance Project ([www.bcap-energy.org](http://www.bcap-energy.org)), which assists states and local jurisdictions in the advancement of energy-efficient building energy codes; Building Green ([www.buildinggreen.com](http://www.buildinggreen.com)); Capital E, which published *Greening America's Schools: Costs and Benefits*, a summary of green schools developed across the nation ([www.cap-e.com/ewebeditpro/items/O59F9819.pdf](http://www.cap-e.com/ewebeditpro/items/O59F9819.pdf)); the Congress for the New Urbanism ([www.cnu.org](http://www.cnu.org)) that worked with the USGBC to develop the LEED® Design for Neighborhood Development standards; the Green Mechanical Council ([www.greenmech.org](http://www.greenmech.org)); and the National Association of Energy Service Companies ([www.naesco.org](http://www.naesco.org)).

## Coastal Protections

The following discussion depends significantly on the contributions Titus (1998), Trescott and Walker (2009), and Volk (2008a).

Coastal erosion is responsible for hundreds of millions of dollars of property damage each year; the threat of erosion, that is, merely being located in an erosion-prone area, significantly lowers property values as well. Both beach nourishment (the addition of sand to the eroded shore) and shoreline stabilization (in the form of seawalls, riprap, revetments and other structures) can help waterfront property owners protect the sales value of individual properties. However, when analyzed at the scale of a community, the implications of the two approaches are quite different. Completed beach nourishment increases property values for both waterfront properties and for non-waterfront properties a few rows inland. Thus the total benefits to the community may be substantially greater than estimated for waterfront properties alone, as is typically the case. In contrast, shoreline stabilization appears to lower property values a few rows inland. Thus, while it is beneficial for each individual waterfront property owner to stabilize his own shoreline, non-waterfront property owners lose value as a result of the actions of their waterfront neighbors. Moreover, as more and more waterfront property owners rely on shoreline stabilization, waterfront property values eventually decline as well. The first few property owners to stabilize their shoreline achieve significant benefits, but as more and more of their neighbors follow suit, property values drop to about where they started (Kriesel and Friedman 2002).

Many options that maintain sediment transport are reactionary, in that they seek to reverse changes that have already occurred or changes that will continue to occur. Because sediment transport is based on a constant cycle of gains and losses, all of these options require maintenance. However, when combined with other actions, these options may work to prevent

loss of coastal habitats and enable marshes and mangroves to accrete at a rate consistent with sea level rise (Martinich 2008).

Options to maintain sediment transport include either trapping sediment that would otherwise migrate or reintroducing sediment into systems. Constructing groin structures traps sand and prevents it from traveling down shore. Adding sand to beaches with beach nourishment projects that extend the shoreline or create dunes, and replacing sand in water bodies following storms allows for sediment transport to continue and reverses losses due to erosion (Martinich 2008).

Possible responses to sea level rise include building walls to hold back the sea, allowing the sea to advance while adapting to it, and raising the land and/or structures (e.g., by replenishing beach sand and/or elevating houses and infrastructure). Each of these responses is costly, either in out-of-pocket expenses or in lost land and structures. For example, the cumulative cost of enough sand replenishment to protect Florida's coast from a 20-inch rise in sea level by 2100 is estimated at \$1.7 to \$8.8 billion (USEPA 1997).

The effects of sea level rise in Lee County will be to increase the level of risk and expense borne by property owners, particularly if property owners choose to remain in place utilizing the expensive strategy of armoring the shoreline and filling land to keep up with storm surge and the increasing average tide height. The likelihood that the County will respond in a way that reduces these effects is complicated by factors including County population increases, coastal property values, increased density in coastal development, the value of coastal tourism, demand for individual coastal access, and the level of insurance subsidization.

The three primary options for development responses to sea level rise and storm surge effects are *protection* (armoring, filling, diking), *managed retreat* which is better described as *planned relocation*, and structural *accommodation* methods (such as elevation of infrastructure). Each method possesses advantages and disadvantages (TCRPC 2005). To date, Lee County has only employed protection methods, with variable success to address sea level rise and shoreline issues.

One of the major problems in evaluating the different options to address flooding from storm surges, sea level rise and the combination of the two is that the names utilized to describe the activities have psychologically loaded contexts. The term "**protection**" that can represent expensive and complex engineering solutions has a heroic and active connotation of man vs. nature, triumph over adversity. In contrast, the terms "**managed retreat**" and "**accommodation**" have passive and negative connotations associated with defeat, particularly for those that seek active, physically tangible solutions to problems.

It was the determination of the study *Summary of Research on Strategies for Adaptation to Sea Level Rise in Florida* by Michael Volk of the University of Florida, that a variety of strategies will be necessary for adaptation, particularly along protected shorelines. These strategies may be categorized based on the existing and projected land use and on the natural coastal ecology. Volk's (2008) strategies are broken down based on high or low energy shorelines, and developed or undeveloped land use. The general recommendation from that study was for **managed retreat** from the shoreline.

Volk's conclusions are that ecologically and financially sustainable shoreline **protection** is probably not possible, particularly on high energy shorelines. **Protection** of any shoreline will only be feasible up to a certain amount of sea level rise, after which the financial costs will be too great to justify **protection**. As an alternative to shoreline **protection**, **managed retreat** policies could be implemented and shorelines could generally be allowed to **retreat** naturally. There may however be cases where shoreline **protection** is deemed appropriate, such as in the case of historic downtown Fort Myers.

### ***Protection***

**Protection** refers to shoreline stabilizing or hardening techniques, such as seawalls and beach nourishment, that attempt to maintain a static shoreline position. It also includes diking and filling to keep pace with sea level. **Protection** may be financially sustainable in the short term because it does not require **relocation** or discontinuation of property use. If the structural method is a relatively small proportion of the total infrastructure investment both in terms of effort and costs, including maintenance, then it is more easily selected. However, in the long term **protection** is likely to prove to be financially unsustainable. Recurrent property damage will likely increase due to the effects of sea level rise coupled with more severe storms and storm surges. Protective structure maintenance and construction costs will increase. The concentration of public resources on **protection** of shoreline infrastructure will require an unbalanced use of public funding sources repetitively on the same parcels. Armoring, filling and diking all damage the recreational and fisheries values of coastlines by causing shoreline ecosystem loss. **Protection** will likely be ecologically unsustainable because it tends to damage coastal ecosystems, alter shoreline processes such as sediment flows, and prohibit ecosystem translocation (Titus 1991 et al.).

Under some circumstances, where shorelines are well-developed, shoreline armoring and other **protection** measures may be necessary. The historic downtown district of Fort Myers, where Lee County has invested significant infrastructure is an example of an area where some passive **protection** strategies could be employed. Buildings can be raised either by lifting them with jacks and adding fill beneath, or by filling in ground-level floors and adding additional stories at the top. Raising a building by just one eight to ten foot story would compensate for the maximum amount of sea level rise predicted to occur by 2200. New structures could be designed to have the additional height in the initial design.

While adverse impacts should first be avoided and then minimized, sometimes some loss of ecological function and/or public access to the shoreline is unavoidable. Mitigation can be required to compensate for these lost uses and functional values. Depending on the type of loss, mitigation can take the form of restoring another impaired shoreline, preserving a shoreline of significant ecological value, or enhancing or creating another public access site. Similar to established wetland mitigation banks, shoreline mitigation banks could also be created to facilitate selection and prioritization of mitigation projects. Property owners could pay into a mitigation bank which is then used to fund regional shoreline restoration and beach renourishment efforts.

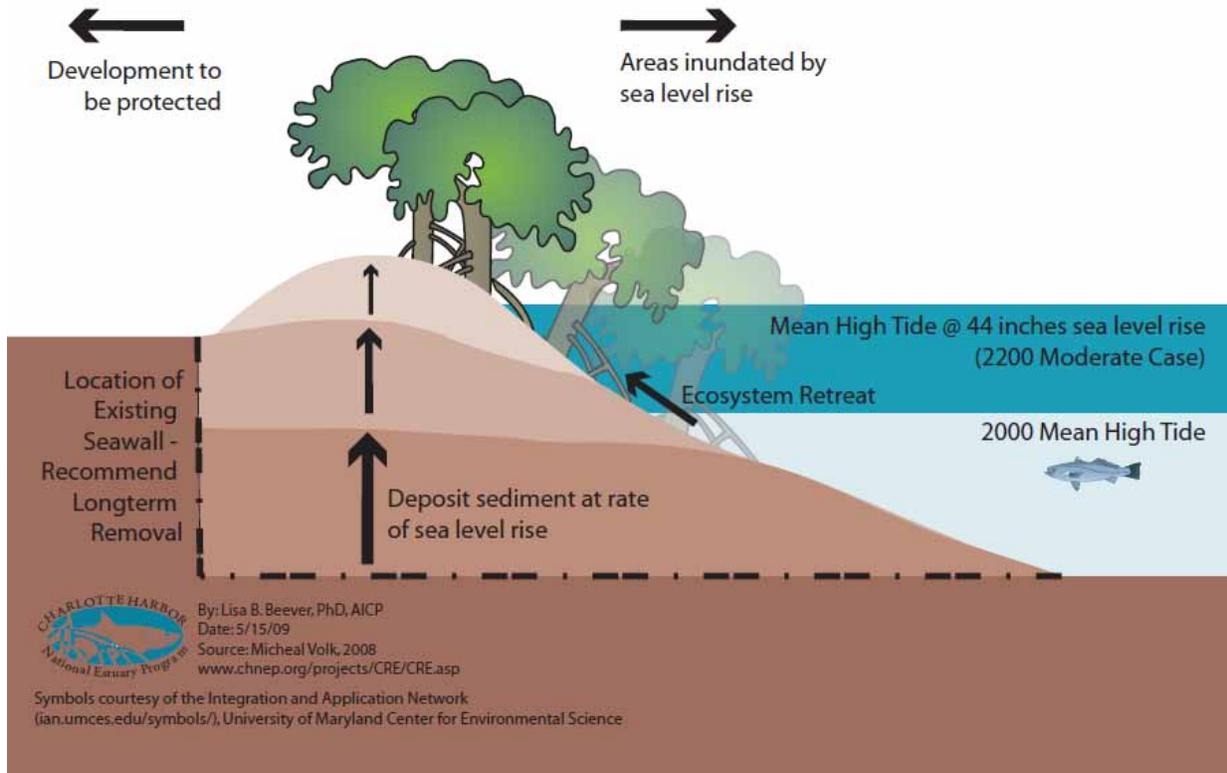
In highly developed areas where a hardened structure is already present and is the only feasible alternative, mitigation allows for positive environmental/societal benefits to be gained to offset any adverse environmental or public access impacts that occur at the site.

However, mitigated systems are rarely as good as the unaltered natural systems they are meant to replace. Good scientific data and project monitoring is needed to ensure that the mitigation will be comparable to the functions and uses lost. Mitigation may not be environmentally or socially relevant if the mitigation project is geographically removed from the project area (NOAA 2009).

Strategies for shoreline **protection** were examined for high and low energy developed shorelines as well as for critical conservation lands by Volk (2008). It was determined that ecologically and financially sustainable **protection** of high energy developed shorelines is not possible, due to the dynamic nature of shoreline processes.

Seawalls or other hard stabilizing structures along these shorelines will destroy shoreline ecosystems, require continued maintenance, and will cease to be feasible after some level of rise (15 feet for example). Beach nourishment used along shorelines will also have negative ecological effects, and will likely become more financially unsustainable as sea levels rise. Sustainable **protection** of low energy developed shorelines was determined to have a higher level of feasibility than **protection** of high energy shorelines due to decreased wave and erosive energy. It may be possible to maintain functional shoreline ecosystems while still maintaining a 'static' protected shoreline. For this to happen, ecosystems must still be allowed to **retreat** upland from rising seas. Ecosystem **retreat** inland from the existing shoreline is likely not possible if the existing shoreline position is to be maintained.

A second option is to establish ecosystems seaward of the existing shoreline, which can **retreat** up to the existing shoreline position. With this option, shoreline ecosystems may exist while maintaining an essentially static shoreline. The goals of a strategy such as this would be to maintain the same level of **protection** as would be gained through construction of a traditional protective structure such as a dike, to reestablish, maintain, and facilitate the adaptation of functional shoreline ecosystems, and to spread shoreline **protection** costs spread over a long period of time in keeping with rate of sea level rise. Several important issues created by this strategy, which could preclude its use, are sediment sources, takings of sovereign submerged lands, source of funding, and upland drainage. It should be noted that drainage of uplands will be an issue with any strategy protecting lands lower than the mean high tide.



**Figure 22:** A method of gradual filling of areas in front of shoreline protection.

Designed to keep pace with sea level rise. *Based upon Volk 2008.*

## *Managed retreat*

*Managed retreat* or **planned relocation** refers to moving development and infrastructure out of harm's way in a planned and controlled manner over time using techniques such as long-range infrastructure planning, property abandonment, structure **relocation**, and hazard avoidance.

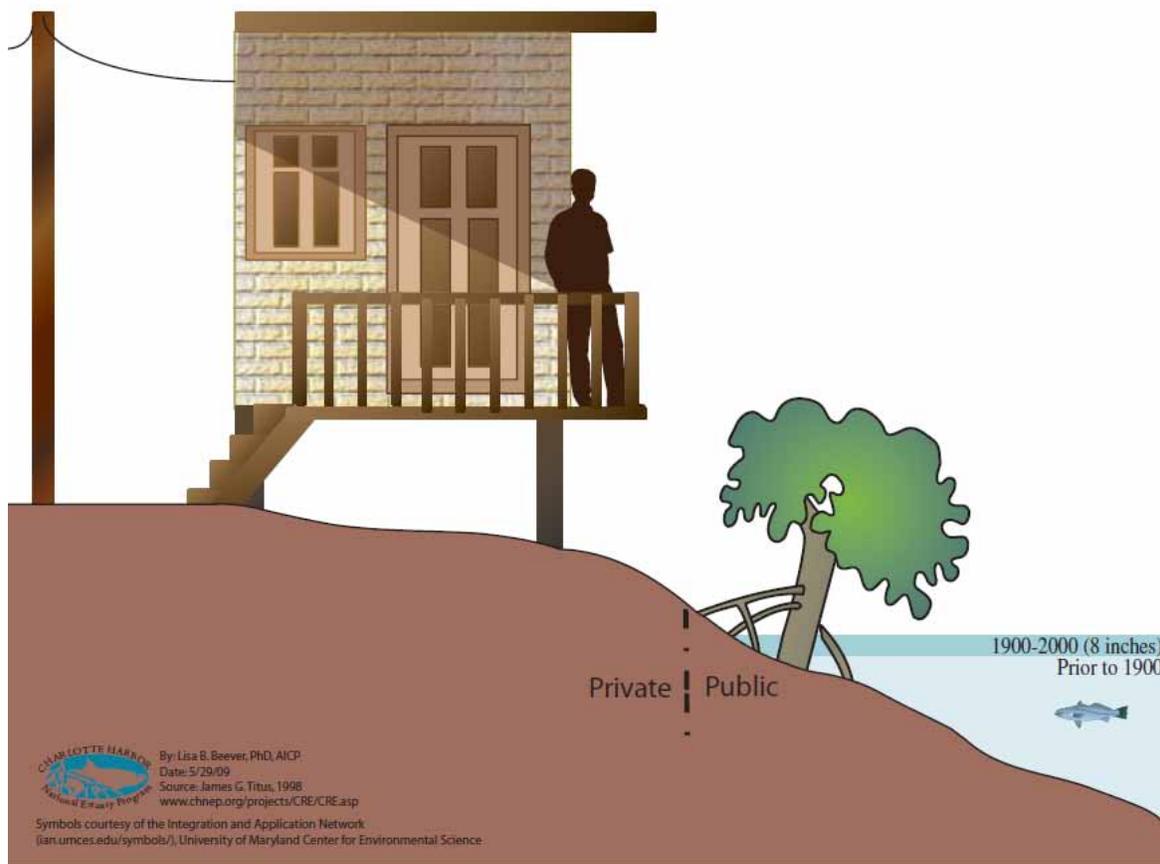
**Planned relocation** is ecologically sustainable because it allows natural ecosystem processes and shoreline **relocation** to occur while protecting the public financial and infrastructure investment. It is financially sustainable because it avoids the long-term costs associated with **protection**, particularly if it is based on long-range planning. There are however a number of issues related to **planned relocation** including dry land property loss, in-migration land use conflicts, the possibility of 'takings' arguments and litigation, the ability to overcome existing external financial incentives for coastal development, potential tourism and tax base impacts, and the potential short-term costs.

**Protection** of conservation lands is not generally recommended (Volk 2008; Titus 1991 et al., SWFRPC 2005). Rather, facilitation of ecosystem adaptation and migration should occur. However, there may be cases where the criticality of conservation lands is such that it justifies short term **protection**. Figures 23-26 illustrates conceptually how this could occur. Water flow and disturbance of the existing tidal ecosystems are issues created by this strategy.

The primary elements of a **planned relocation** strategy could be as follows.

First, Lee County would conduct comprehensive shoreline assessments to determine the unique characteristics of the specific shoreline, suitability analyses to determine which lands should be protected or where shoreline **retreat** should be allowed, and hazard projections to determine the area first in line to be inundated based on erosion, sea level rise, and storm surge estimates.

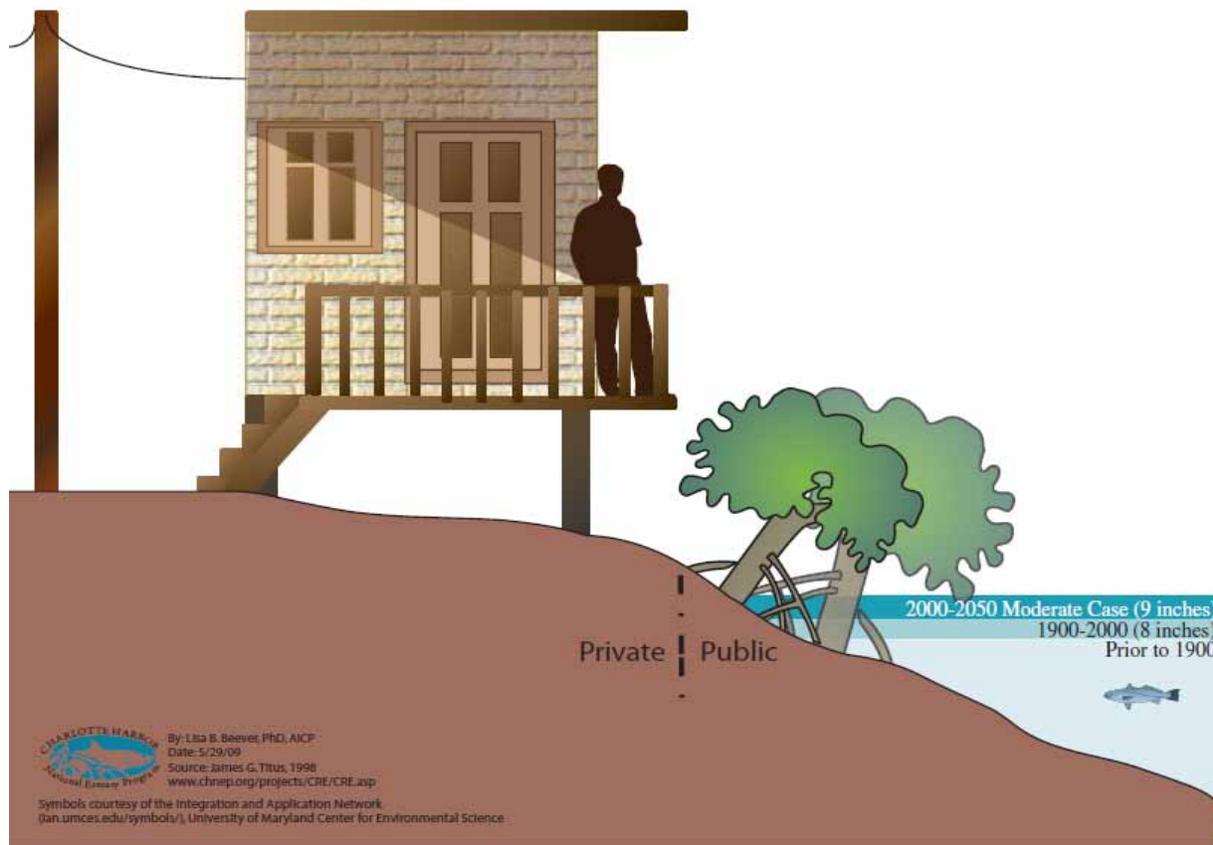
Second, rolling easements or similar policies that allow shoreline **retreat** and disallow coastal **protection** or hardening could be implemented. Rolling easements are a special type of easement purchased from property owners along the shoreline to prevent them from holding back the sea but which allow any other type of use and activity on the land. As the sea advances, the easement automatically moves or "rolls" landward. Because shoreline stabilization structures cannot be erected, sediment transport remains undisturbed and wetlands and other important tidal habitat can migrate naturally. Similarly, there will always be dry or intertidal land for the public to walk along, preserving lateral public access to the shore. This step does not need to be implemented all at the same time and easements could be acquired in order of priority related to level and timing of exposure to coastal flooding.



**Figure 23: Rolling easement step 1 Year 2010.**

Easement established at current shoreline. *CHNEP 2009 Based on Titus 1998.*

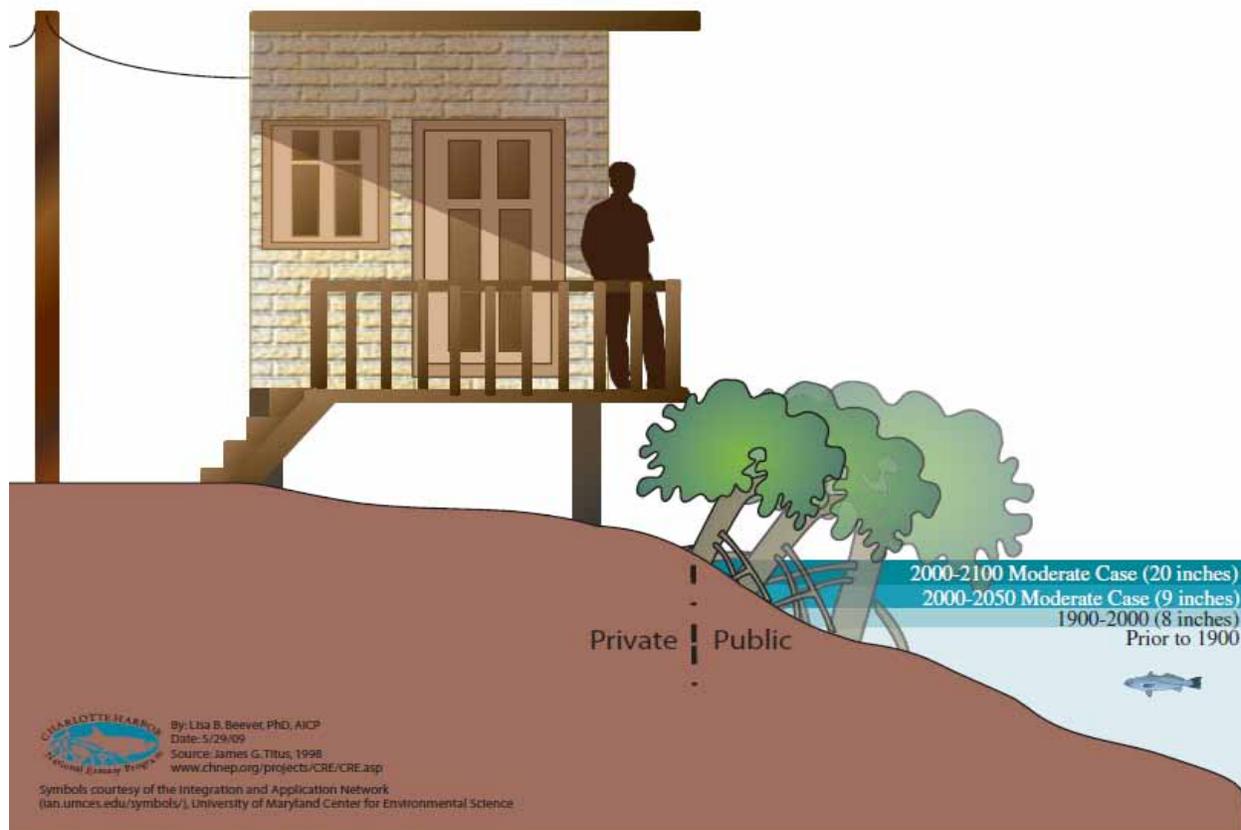
Unlike setbacks, which prohibit development near the shore and can often result in "takings" claims if a property is deemed undevelopable due to the setback line; rolling easements place no restrictions on development. They allow the landowner to build anywhere on their property with the understanding that they will not be able to prevent shoreline erosion by armoring the shore, or the public from walking along the shore—no matter how close the shoreline gets to their structure. If erosion threatens the structure, the owner will have to relocate the building or allow it to succumb to the encroaching sea.



**Figure 24: Rolling easement step 2 Year 2050.**

Moderate case 9 inches sea level rise. Mangroves and marsh move inland. Former mangroves become inundated. *CHNEP 2009 Based on Titus 2008.*

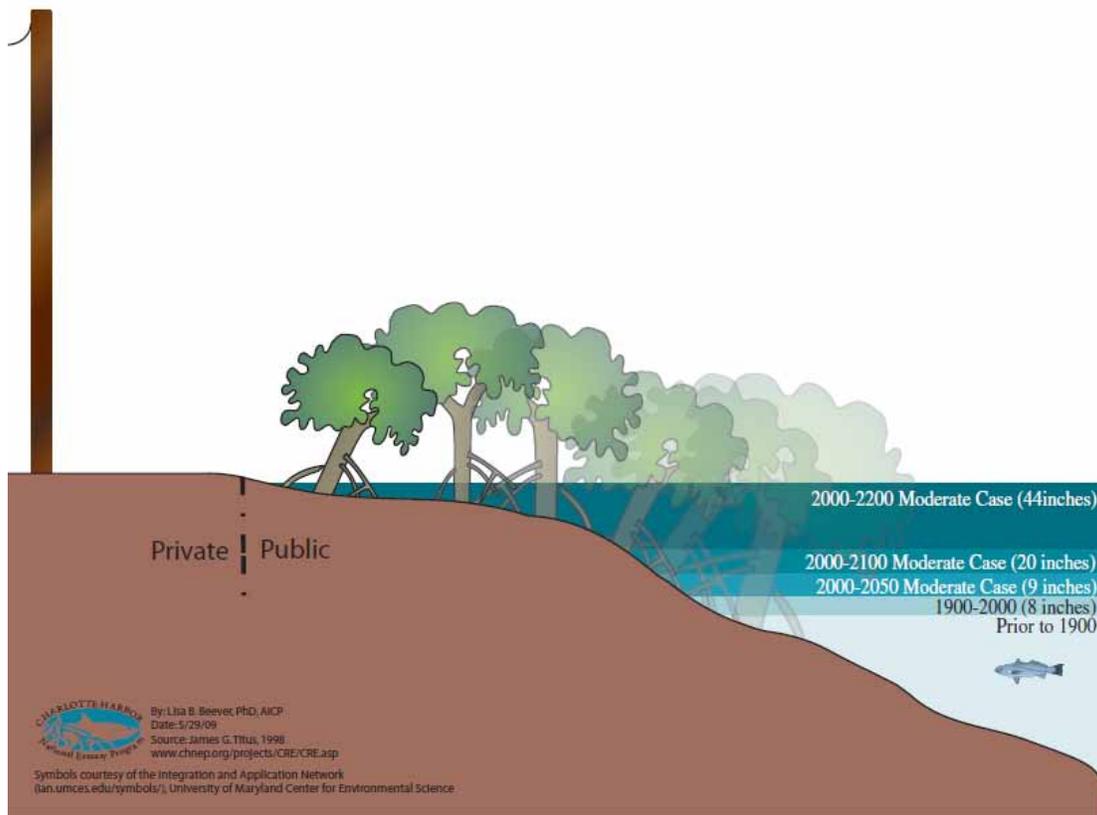
Under the Public Trust Doctrine, the public has the right to access tidal lands for fishing and recreation. Therefore, for most states, tidal land is public land. Even for "low-tide" states where private ownership is permitted up to the low-tide line, the public still has the right to access the intertidal zone. For the purposes of a rolling easement, eventually, as the shore continues to erode, the structure that was once on private property, will be sitting on public land. At this point, the private owner could decide to relocate the structure inland. Alternately, the property owner could allow the structure to remain until it becomes unsafe and pay rent to the state for use of public land.



**Figure 25: Rolling easement step 3 Year 2100.**

Moderate case 20 inches sea level rise. Mangroves and marsh move inland. Former mangroves become inundated. *CHNEP 2009 Based on Titus 2008.*

Because there are no restrictions to land use, rolling easements have minimal impacts on property values, usually reducing property values by one percent or less (Titus 1998). "Takings" claims are also limited because it could be decades or more before erosion impacts are felt. In the meantime, the landowner would have full use of their property. To circumvent any potential "takings" claim, the government could purchase the easement from the property owner. More detailed examples about the cost advantages and disadvantages of rolling easements can be found in Titus (1998).



**Figure 26: Rolling easement step 4 Year 2200.**

Moderate case 20 inches sea level rise. Mangroves and marsh move inland. Former mangroves become inundated. Residence moved to new location or abandoned and removed. *CHNEP 2009 Based on Titus 2008.*

In addition, because landowners are aware that their structure may one day need to be relocated, rolling easements can encourage the building of smaller, and more mobile structures that can be relocated easily.

Rolling easements can even be used where the shoreline is hardened to allow for continued lateral public access to the shore. As the beach disappears at the base of the hard stabilization structure, the rolling easement steps over the structure, enabling the public to walk along the landward side of the armored shore—an area that used to be private property. Without a rolling easement to enable public access, once the sea advances to the toe of the bulkhead or riprap, the public would be barred from walking along the shore since the dry upland falls into private ownership. The rising water levels would have drowned all access to tidal beach on public trust land.

Although rolling easements, like erosion control easements, can be useful shoreline management tools by themselves, and an effective way to implement managed **retreat**

policies they are typically more effective if used in coordination with other approaches including setbacks and other building along the shore.

Among the benefits of rolling easements is that they help minimize activities that could enhance erosion problems without prohibiting development altogether. Often property owners can receive tax benefits for placing a conservation easement on their property. Rolling easements can help maintain natural shoreline processes. There are minimal "takings" issues as compared to setbacks. Rolling easements do not require as much scientific data as some other shoreline management approaches such as setbacks. Rolling easements are typically less costly than setbacks as well.

Among the drawbacks of rolling easements is that they are not as effective for shorelines that are already significantly developed. Property owners may be hesitant to place easements on their property because the restrictions may decrease or be perceived to decrease the resale value of their property. Property boundaries typically do not align with drift cell boundaries or other environmentally relevant scales. Therefore, placing an easement along the shoreline to prohibit shoreline armoring or limit development in one area but not for another site in the same drift cell could exacerbate erosion rates down drift from the hardened/developed shoreline, negating any benefits a conservation easement could have. Enforcing rolling easements could be difficult.

Third, the County may designate a special overlay district in areas likely to be inundated based on hazard projections. Unique design guidelines should be implemented in these areas. Public financing in these areas should be minimized, particularly for new infrastructure. Within this area likely to be inundated, the County should create an along-shore buffer or easement for ecosystem retreat, management, and restoration. Property purchases, purchase of development rights, setbacks or deed restrictions, development disincentives, and sale incentives are some ways to create this easement. The County will need to plan for removal of inundated structures, infrastructure, and identify strategies for mitigation of hazards related to inundated structures. Creative reuse will be essential; for example, the reuse of building foundations as marine habitat could be appropriate.

Finally, the County will need to continue to integrate good waterfront design principles, and adapt existing useable infrastructure for new evolving waterfront. Communities that allow **retreat** must realize that the waterfront will be constantly evolving, and must allow for this change within land-use plans and waterfront projects.

### *Accommodation*

*Accommodation* or in-place **adaptation** refers to strategies that allow for the use of vulnerable lands to continue, but that do not attempt to prevent flooding or inundation with shoreline **protection**. Examples include **relocation** friendly construction, short-term land uses, and inundation friendly uses. **Accommodation** adaptations, if not part of a long-range plan for **planned relocation**, can have the same negative financial and ecological impacts as *protection*.

Strategies for **accommodation** are addressed in Volk (2008) through draft guidelines for construction and land use in areas likely to be inundated. **Accommodation** is recommended as part of an overall **managed retreat** strategy, and would occur in areas likely to be inundated where **retreat** is ultimately planned. It is important to adopt special guidelines for these areas first because suitable land uses within these areas will be better able to respond and adapt to coastal hazards, minimizing financial loss and hazards to coastal populations. These guidelines must be adopted for the use of areas likely to be inundated in order to minimize negative ecological effects and hazards to development, and proactive human action will likely be necessary to facilitate ecosystem adaptation to sea level rise. Two of the most important elements to this are discontinuing coastal hardening and providing lands for ecosystem **retreat**.

Second, suitable land use within these areas may help to facilitate ecosystem adaptation and maintain functional shoreline ecology. The key concepts behind the guidelines discussed by Volk (2008) are the support of land uses that are water dependent, temporary, adaptable, or evolve as sea levels rise, that are financially sustainable investments with consideration of sea level rise, that allow natural shoreline and ecosystem processes to continue, and that integrate good waterfront design principles.

In Lee County, the largely undeveloped areas adjacent to the coast are uncommon. Some areas where **planned relocation** is the best strategy contain significant areas of conservation land such as the Bunche Beach shoreline of San Carlos Bay, the north mainland shoreline of Estero Bay from Matanzas Pass to Mullock Creek, and on a more limited scale the east mainland shoreline of Estero Bay. Pine Island, on both Pine Island Sound and Matlacha Pass shorelines, particularly along the main body of the islands agricultural lands is also a good candidate for **planned relocation**. In these areas, ecosystem retreat would enable the migration of the extensive mangrove forests and salt marshes, which form an important protective barrier against storm surge and tropical storm-related winds.

Ecosystem retreat inland from the existing shoreline is likely not possible if the existing shoreline position is to be maintained. A second option is to establish ecosystems seaward of the existing shoreline, which can retreat up to the existing shoreline position. With this option, shoreline ecosystems may exist while maintaining an essentially static shoreline. The goals of a strategy such as this would be to maintain the same level of protection as would be gained through construction of a traditional protective structure such as a dike, to reestablish, maintain, and facilitate the adaptation of functional shoreline ecosystems, and to spread shoreline protection costs spread over a long period of time in keeping with rate of sea level rise. Several important issues created by this strategy, which could preclude its use, include sediment sources, takings of sovereign submerged lands, source of funding, and upland drainage. It should be noted that drainage of uplands will be an issue with any strategy protecting lands lower than the mean high tide. Protection from inundation of conservation lands is not generally recommended (Titus 1991 et al.). Rather, facilitation of ecosystem adaptation should occur. However, there may be cases where the criticality of historical or conservation lands is such that it justifies short-term protection. Water flow and disturbance of the existing tidal ecosystems are issues created by this strategy.

Strategies for **accommodation** are addressed in the TCRPC study through draft guidelines for construction and land use in areas likely to be inundated. Accommodation is recommended as part of an overall managed retreat strategy, and would occur in areas likely to be inundated where retreat is ultimately planned. It is important to adopt special guidelines for these areas first because suitable land uses within these areas will be better able to respond and adapt to coastal hazards, minimizing financial loss and hazards to coastal populations. Second, suitable land use within these areas may help to facilitate ecosystem adaptation and maintain functional shoreline ecology. The key concepts behind the guidelines discussed are the support of land uses that are water dependent, temporary, adaptable, or evolve as sea levels rise; that are financially sustainable investments give consideration of sea level rise; that allow natural shoreline and ecosystem processes to continue; and that integrate good waterfront design principles.

The conclusions of the TCRPC (2008) study are that ecologically and financially sustainable shoreline protection is probably not possible, particularly on high energy shorelines. Protection of any shoreline will only be feasible up to a certain amount of sea level rise, after which the financial costs will be too great to justify protection. As an alternative to shoreline protection, managed retreat policies should be implemented and shorelines should generally be allowed to retreat naturally. There may however be cases where shoreline protection is deemed appropriate, such as in the case of historic St. Augustine, Florida. Accommodation, if used, should be part of a greater strategy for retreat. Guidelines must be adopted for the use of areas likely to be inundated in order to minimize negative ecological effects and hazards to development, and proactive human action will likely be necessary to facilitate ecosystem adaptation to sea level rise. Two of the most important elements to this are discontinuing coastal hardening and providing lands for ecosystem retreat.

Although the southwest Florida region does not have an explicit sea level rise response policy, policies designed to address other issues with similar consequences define an implicit response for many parts of the region. Trends in land use, construction practices, economic growth, environmental sensibilities, and consumer preferences also contribute to the momentum that defines the region's likely response to sea level rise (Titus 1991 et al.).

## **Federal Policies and Programs**

The federal government has several major policies that directly and indirectly affect the likelihood that shores will be protected from erosion, inundation, and increased flooding as sea level rises. We will first examine some policies that encourage retreat, and that encourage shore protection.

### ***Federal Policies that Encourage Shore Protection***

The federal wetland program explicitly allows shoreline armoring, while having no explicit policies to *prevent* shoreline armoring. The federal government has long provided subsidies for jetties that stabilize harbor entrances, and beach nourishment along intensely developed shores. In areas like Miami Beach, seawalls did—and probably still would—protect development from eroding shores, so the subsidy for beach nourishment fundamentally influences the type of shore protection. Along more moderately developed shores in this region, the absence of shore

protection would probably result in seawalls designed for a modest storm; but a major storm would destroy the seawall, and permanently erode the shore 50 to 100 feet inland. In these areas, the availability of federal beach nourishment funds enables the shore to continue to be protected.

Numerous federal policies appear to encourage or enable relatively dense development in the coastal zone. Federal flood insurance decreases the risk to the owner of coastal construction. Improved building codes resulting from flood insurance regulations enable homes to continue standing in the waters of the Gulf of Mexico after storm-generated erosion, making retreat unnecessary, provided that the beach returns (either naturally or from a beach nourishment project). Federal subsidies for sewage treatment plants make it possible to more densely develop coastal areas where a proliferation of septic tanks would severely pollute coastal bays.

### ***Federal Policies that Encourage a Retreat from the Shore***

The federal government influences shore protection as a landowner, a regulator, and a subsidizer (Titus 2000). As a coastal land owner, the federal government has made several very large parcels of land in southwest Florida unavailable to development by acquisition for conservation purposes. Because undeveloped lands are much less likely to be protected than developed areas, federal ownership itself often makes shore protection unlikely, even where there is no specific policy on whether to protect the shore or retreat. Several conservation-oriented landowning agencies consciously allow wetlands and beaches to migrate inland. Everglades National Park and Big Cypress National Preserve all follow the National Park Service general policy of allowing natural processes to work their will. The most noteworthy example of the National Park Service's commitment to allowing shores to retreat was the recent relocation of Hatteras Light in North Carolina, which was moved over one thousand feet inland on a special-purpose railroad track at a cost of over \$10 million. National Wildlife Refuges generally allow wetlands to migrate inland within their boundaries, which would apply to the refuges at Ding Darling on Sanibel Island, Matlacha Pass, Pine Island, and Caloosahatchee National Wildlife Refuges all in Lee County.

Even agencies that regularly protect some shores may foster shore retreat to some extent. Military bases armor shores to protect buildings and naval port facilities; but military bases often have substantial undeveloped buffer areas where natural shores are preserved.

The federal government does not generally regulate the use of privately owned uplands; so it does not directly discourage development in the coastal zone. However, Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act require landowners to obtain permits to fill wetlands. Regulations interpreting the requirements of these statutes often discourage or prohibit fill and other beach nourishment activities along bay shores. Although bulkheads and stone revetments are generally allowed in this region, they are technically fill and require a permit if below mean high water. Although these structures can be built inland of mean high water, eventually they sit within the ebb and flow of the tides as sea levels rise and shores erode; therefore replacement or repair might require filling in the "waters of the United States" and hence require a permit.

The Coastal Barrier Resources Act (CoBRA) prohibits federal subsidies and flood insurance to specific designated portions of barrier islands, barrier spits, and other coastal areas (Titus 2000).

In this region, the designated coastal barriers are in Charlotte and Lee Counties, including parts of Don Padre Island, parts of Cayo Costa and North Captiva Islands (state parks) and in Collier County, parts of Keewaydin and Cape Romano Islands. The second designation of “other coastal areas” includes numerous undeveloped unbridged islands within the bays of the region.

In this region, the main impact of CoBRA has been that the lack of bridge access made development relatively unattractive, leading other areas to be developed first and keeping land prices on these portions of the coast relatively low. As a result, state and local land acquisition programs have acquired parcels on some of these islands. Cayo Costa State Park is a good example of how CoBRA has worked, where the presence of thousands of platted lots with vested development rights has discouraged development, giving time for a voluntary state land acquisition program to acquire about 97% of this state park from private land owners.

In other parts of the state, CoBRA areas with easier access have been developed, but the unavailability of federal subsidies makes beach nourishment unlikely. Lack of federal subsidies for sewage treatment has limited the density in still other areas. The unavailability of flood insurance and federally backed mortgages also discourages development.

Even though the other parts of the Federal Flood Insurance Program encourage shore protection, the program does have a component that also encourages retreat. Specifically, the repetitive loss program (a repetitive loss consists of two flood insurance claims on the subject property) offers a 50/50 federal/local match to buy the parcel for preservation. Otherwise a repetitive loss owner can match 50% of the cost to raise the structure to prevent further flooding which is a form of encouraging shore protection.

### **Florida State Policies and Programs**

Similar to the federal policies, no state policies specifically address the issue of sea level rise, but many policies are already in place to deal with consequences. These policies are included in the Coastal Construction Control Line Program, the Beach Erosion Control Program, the Coastal Building Zone, Strategic Beach Management Plans and Environmental Resource Permits.

#### ***Florida Policies that Encourage Shore Protection***

The Florida Beach and Shore Preservation Act was enacted by Florida’s legislature to preserve and protect Florida’s beach and dune system. Beaches and dunes are the first line of defense against storms, acting as a buffer between the sea and coastal development. One of the programs authorized by the Beach and Shore Preservation Act to be an essential element in the protection effort is the Coastal Construction Control Line (CCCL) Program (Beach and Shore Preservation Act, Florida Statutes Chapter 161).

The CCCL Program was designed to protect Florida’s beach and dune system from irresponsible construction that could weaken, damage, or destroy the health of the dune system. Structures that are built too close to the sea can inhibit the beach and dune system from its natural recovery processes and can cause localized erosion. Improperly constructed structures are a threat to other nearby coastal structures, should they be destroyed by storms. The CCCL Program gives the state the jurisdiction to apply stringent siting and design criteria to construction projects seaward

of the control line. The CCCL is not a setback line, but is rather a demarcation line of the state's authority.

The CCCL is marked at the landward limit of coastal areas that are subject to the effects of a 100-year storm surge. While wind and flooding may intrude further inland than the 100-year storm surge area, effects landward of the CCCL are considerably less than seaward of it. Seaward of the CCCL, the State prohibits the construction or siting of structures that would cause a significant adverse impact to the beach and dune system, result in the destabilization of the system or would destroy marine turtle habitat. To meet these requirements, structures are required to be located a sufficient distance from the beach and frontal dune and must also be sited in a way that does not remove or destroy natural vegetation. The CCCL also requires all structures to be constructed to withstand the wind and water effects of a 100-year storm surge event. This involves creating structures that meet the American Society of Civil Engineering 7-88 Section 6 wind design standard for 110 mph winds (115 mph for the Florida Keys). Water design standards include a foundation engineered to withstand a 100-year storm event, including the effects of surge, waves and scouring. There is no prohibition of rebuilding under the CCCL Program. Due to the effects of erosion, the CCCL Program discourages the construction of rigid coastal armoring (seawalls) and instead encourages property owners' use of other protection methods, such as foundation modification, structure relocation and dune restoration.

Another similar endeavor to regulate coastal construction is the Coastal Building Zone (CBZ). The CBZ was established as part of the Coastal Protection Act of 1985 to protect coastal areas and to protect life and property. The CBZ is similar to the Coastal Construction Control Line program in that it is a regulatory jurisdiction, rather than a setback line. The CBZ envelopes land from the seasonal high water line to 1500 feet landward of the CCCL. In those areas fronting on the ocean but not included within an established CCCL, the Coastal Building Zone includes the land area seaward of the most landward V-Zone line, as established by the National Flood Insurance Program's (NFIP) flood maps. The V-Zone is an area likely to experience a wave greater than three feet high with storm surge, or areas within the 100-year storm event used by the CCCL program. Local governments, rather than the state, enforce the Coastal Building Zone as a part of their building codes.

Within the CBZ, new construction is required to meet the Standard Building Code 1997 wind design standard of 110 mph (115 mph for the Florida Keys). As for water standards, structures are required to meet NFIP requirements or local flood ordinance requirements, whichever are stricter. Foundations must also be designed to withstand a 100-year storm surge. CBZ construction standards are less stringent than CCCL standards. This is due to the fact that NFIP flood maps have lower base flood elevations for 100-year storm events than do CCCL studies.

Another State effort to protect Florida's beaches, authorized by the Beach and Shore Preservation Act, is the Beach Erosion Control Program (BECP). The BECP is the primary program that implements the Florida Department of Environmental Protection's beach management recommendations. The BECP was created to coordinate the efforts of local, state, and federal governments in protecting, preserving and restoring Florida's coastal resources. One of the activities of this program is the offering of financial assistance to counties, local governments and other special districts for shore protection and preservation efforts. The BECP

will provide up to 50 percent of project costs. The mix between federal, state and local funds is different for each project.

Beach management activities eligible for funding from the BECP include beach restoration and nourishment activities, project design and engineering studies, environmental studies and monitoring, inlet management planning, inlet sand transfer, dune restoration and protection activities, and other beach erosion prevention related activities.

Another endeavor of the BECP is the development and maintenance of a Strategic Beach Management Plan (SBMP) for Florida. The SBMP is a multiyear repair and maintenance strategy to carry out the proper state responsibilities of a comprehensive, long-range, statewide program of beach erosion control; beach preservation, restoration, and nourishment; and storm and hurricane protection. The SBMP is divided into specific beach management plans for Florida's coastal regions.

Like the Federal Wetland Program, a State of Florida Environmental Resource Permit (ERP) is authorized by Part IV of Chapter 373, Florida Statutes, to regulate activities involving the alteration of surface water flows. This includes new activities in uplands that generate stormwater runoff from upland construction, as well as dredging and filling in wetlands and other surface waters. ERP applications are processed by either the Department of Environmental Protection or one of the state's water management districts. The South and Southwest Florida Water Management Districts cover parts of this region.

### ***State Policies that Encourage a Retreat from the Shore***

Florida also has one of the largest land and water (including wetlands) acquisition programs in the country, called "Florida Forever" (FF). The funding from this program is used for restoration, conservation, recreation, water resource development, historical preservation, and capital improvements on acquired conservation lands. Land acquisition through this program is almost exclusively voluntary, as the state wishes to avoid using its power of eminent domain. The funding for this program comes from \$3 billion in bond issues over a 10-year period, which is being paid back from an excise tax. Florida Forever funds are distributed annually to various governmental agencies for land and water acquisition: Department of Environmental Protection (38%), Water Management Districts (35%), Florida Communities Trust (24%), Department of Agriculture/Forestry (1.5%), and the Fish and Wildlife Conservation Commission (1.5%). Since the program began in 1999, Florida Forever funds have been used to protect over 270,000 acres of natural floodplains, nearly 500,000 acres of significant water bodies, over 24,000 acres of fragile coastline, and over 520,000 acres of functional wetlands (FNAI 2008).

Similar to and developed at about the time as the first federal CoBRA designations, the Florida Legislature passed the Coastal Infrastructure Policy law in Chapter 380.27(1 & 2), F.S. that states the following:

- (1) No state funds shall be used for the purpose of constructing bridges or causeways to coastal barrier islands, as defined in s. 161.54(2), which are not accessible by bridges or causeways on October 1, 1985.

- (2) After a local government has an approved coastal management element pursuant to s. 163.3178, no state funds which are un-obligated at the time the element is approved shall be expended for the purpose of planning, designing, excavating for, preparing foundations for, or constructing projects which increase the capacity of infrastructure unless such expenditure is consistent with the approved coastal management element.

The State Comprehensive Plan, under Section 8 Coastal and Marine Resources, contains the following policies that encourage retreat:

1. Accelerate public acquisition of coastal and beachfront land where necessary to protect coastal and marine resources or to meet projected public demand.
3. Avoid the expenditure of state funds that subsidize development in high-hazard coastal areas.
4. Protect coastal resources, marine resources, and dune systems from the adverse effects of development.
9. Prohibit development and other activities which disturb coastal dune systems, and ensure and promote the restoration of coastal dune systems that are damaged.

As part of Local Government Comprehensive Planning, Chapter 163 F.S. titled Intergovernmental Programs, Part II Growth Policy; County and Municipal Planning; Land Development Regulation and specifically the Coastal Management law in Chapter 163.3178(1) F.S. could encourage both shore protection and retreat depending on how local governments implement this law relative to natural disaster planning as follows:

- (1) The Legislature recognizes there is significant interest in the resources of the coastal zone of the state. Further, the Legislature recognizes that, in the event of a natural disaster, the state may provide financial assistance to local governments for the reconstruction of roads, sewer systems, and other public facilities. Therefore, it is the intent of the Legislature that local government comprehensive plans restrict development activities where such activities would damage or destroy coastal resources, and that such plans protect human life and limit public expenditures in areas that are subject to destruction by natural disaster.

The Coastal High Hazard Area, as defined in the Coastal Management Law Chapter 163.3178(2)(h), is equivalent to the Category 1 hurricane storm surge zone. To provide direction on implementing the Coastal Management Law, the Florida Department of Community Affairs adopted rules in Chapter 9J5.012 (3) (b) Florida Administrative Code. The following sections apply to encouraging retreat or shore protection:

- (3) Requirements for Coastal Management Goals, Objectives, and Policies.
  - (b) The element shall contain one or more specific objectives for each goal statement which address the requirements of paragraph 163.3177(6) (g) and Section 163.3178, F.S., and which:

1. Protect, conserve, or enhance remaining coastal wetlands, living marine resources, coastal barriers, and wildlife habitat;
  4. Protect beaches or dunes, establish construction standards which minimize the impacts of man-made structures on beach or dune systems, and restore altered beaches or dunes;
  5. Limit public expenditures that subsidize development permitted in coastal high-hazard areas subsequent to the element's adoption except for restoration or enhancement of natural resources;
  6. Direct population concentrations away from known or predicted coastal high-hazard areas;
- (c) The element shall contain one or more policies for each objective and shall identify regulatory or management techniques for:
1. Limiting the specific impacts and cumulative impacts of development or redevelopment upon wetlands, water quality, water quantity, wildlife habitat, living marine resources, and beach and dune systems;
  2. Restoration or enhancement of disturbed or degraded natural resources including beaches and dunes, estuaries, wetlands, and drainage systems; and programs to mitigate future disruptions or degradations;
  3. General hazard mitigation including regulation of building practices, floodplains, beach and dune alteration, stormwater management, sanitary sewer and septic tanks, and land use to reduce the exposure of human life and public and private property to natural hazards;
  4. Hurricane evacuation including methods to relieve deficiencies identified in the hurricane evacuation analysis, and procedures for integration into the regional or local evacuation plan;
  5. Post-disaster redevelopment including policies to: distinguish between immediate repair and cleanup actions needed to protect public health and safety and long-term repair and redevelopment activities; address the removal, relocation, or structural modification of damaged infrastructure as determined appropriate by the local government but consistent with federal funding provisions and unsafe structures; limiting redevelopment in areas of repeated damage;
  7. Designating coastal high-hazard areas and limiting development in these areas;
  8. The relocation, mitigation or replacement, as deemed appropriate by the local government, of infrastructure presently within the coastal high-hazard area when state funding is anticipated to be needed.
  10. Providing, continuing, and replacing adequate physical public access to beaches and shorelines; enforcing public access to beaches renourished at public expense; enforcing the public access requirements of the Coastal Zone Protection Act of 1985; and providing transportation or parking facilities for beach and shoreline access.

## Local Policies and Programs

In Florida each local government is required to complete a comprehensive land use plan, which may have policies that encourage either retreat or shore protection. Normally, these policies would be in the Coastal Management Element which was discussed above in terms of state requirements.

Approaches for maintaining shorelines in the face of sea level rise include protection and retreat. Each of these approaches, or some combination of them, may be appropriate depending on the characteristics of a particular location (e.g., shore protection costs, property values, the environmental importance of habitat, the feasibility of protecting shores without harming the habitat). Note that the strategies presented include both shoreline hardening/armoring and removing armoring to create living shorelines. These different and seemingly conflicting options are each appropriate in different situations. Protection options can include hardening the shoreline through measures such as bulkheads, seawalls, revetments, breakwaters, sills, and creating or reinforcing headlands. Shoreline protection can also be achieved through "softening" measures, which develop living shorelines through beach nourishment, planting dune grasses, marsh creation, and planting submerged aquatic vegetation (SAV). Planned retreat (or wetland migration) is an alternative to shoreline protection in the face of natural forces such as coastal erosion or sea level rise (Martinich 2008).

With two simplifying assumptions, it is possible to estimate the value of real estate at risk from sea level rise. First, Stanton and Ackerman (2007) assumed that the value of real estate will grow uniformly in all parts of the state, in proportion to gross state product (GSP), throughout this century. Second, they assume that the fraction of the state's residential property at risk is proportional to the extent of sea level rise. Then, starting from the calculation of \$130 billion of residential real estate, as of 2000, that would be vulnerable to 27 inches of sea level rise, it is possible to project the effects of both scenarios (business-as-usual and rapid stabilization) through 2100. The cost of inaction — that is, the annual increase in the value of residential real estate at risk of inundation — rises from \$11 billion in 2025 to \$56 billion in 2100, or almost 1 percent of GSP. And sea levels will continue to rise beyond 2100.

No one expects coastal property owners to wait passively for these damages to occur; those who can afford to do so will undoubtedly seek to protect their properties. But all the available methods for protection against sea level rise are problematical and expensive. It is difficult to imagine any of them being used on a large enough scale to shelter all of Florida from the rising seas of the 21st century, under the worst case (Stanton and Ackerman 2007).

Elevating homes and other structures is one way to reduce the risk of flooding, if not hurricane-induced wind damage. A FEMA estimate of the cost of elevating a frame-construction house on a slab-on-grade foundation by two feet is \$58 per square foot, after adjustment for inflation, with an added cost of \$0.93 per square foot for each additional foot of elevation (FEMA 1998). A house with a 1,000 square foot footprint would thus cost \$58,000 to elevate by two feet. It is not clear whether building elevation is applicable to multistory structures; at the least, it is sure to be more expensive and difficult (Stanton and Ackerman 2007).

Another strategy for protecting real estate from climate change is to build seawalls to hold back rising waters. There are a number of ecological costs associated with building walls to hold back the sea, including accelerated beach erosion and disruption of nesting and breeding grounds for important species, such as sea turtles, and preventing the migration of displaced wetland species (NOAA 2000). In order to prevent flooding to developed areas, some parts of the coast would require the installation of new seawalls. Estimates for building or retrofitting seawalls range widely from \$300 to \$4,000 per linear foot (Yohe et al. 1999; U.S. Army Corps of Engineers 2000; Kirshen et al. 2004; Dean 2007b; Stanton and Ackerman 2007).

Specific costs for coastal armoring for southwest Florida are listed below in Appendix A. Costs do not include labor for installation. For future analyses these could be updated for current costs.

The United States Geological Survey (USGS) has created an index to rate the vulnerability of U.S. shoreline to sea level rise, taking into consideration tides and erosion, as well as elevation (USGS 2000). According to their assessment, out of 4,000 miles of total Florida shoreline, 1,250 miles are in the “high” vulnerability category and 460 miles are in the “very high” category. If just these 1,700 miles of shoreline were protected with seawalls, and construction costs averaged \$1,000 per linear foot (or a bit over \$5 million per mile), the total cost would be just under \$9 billion. The 4,000 total miles of shoreline assumed by USGS, however, do not take into account Florida’s many channels and inlets, which make the actual coastline much longer. (Conversely, other estimates of the length of Florida’s coastline range down to 1,350 or fewer miles; the varying estimates reflect the different resolutions at which the measurements are made.). The actual coastline length, when these features are accounted for, is 22,000 miles (Stanton and Ackerman 2007). If seawalls were needed for 42 % of Florida’s actual coastline (the share of very high and high vulnerability coastline under the USGS definition), or 9,200 miles, the cost would be \$49 billion. In other words, constructing seawalls sufficient for statewide protection would be an engineering mega project, several times the size of the long-term Everglades restoration effort (Stanton and Ackerman 2007).

Yet another approach involves beach nourishment, bringing in sand as needed to replenish and raise coastal beaches (which as noted above can have major environmental impacts). A large-scale analysis of the costs of protecting the U.S. coastline from sea level rise, conducted by USEPA in 1989, relied heavily on restoring and building up beaches (Titus et al. 1991). The study projected that most of the sand would need to be dredged up from more than five miles offshore. It estimated the cost of sand to protect Florida against 39 inches of sea level rise (a level reached in 2087 in the worst case) would be between \$6 billion and \$30 billion in 2006 dollars, depending on assumptions about the quantity and cost of sand. As with statewide seawall construction, beach nourishment on this scale would be a mammoth engineering project, with uncertain environmental impacts of its own. In short, while adaptation, including measures to protect the most valuable real estate, will undoubtedly reduce sea level rise damages, there is no single, believable technology or strategy for protecting the vulnerable areas throughout the state (Stanton and Ackerman 2007).

## What Lee County Government Can Do to Increase Climate Change Resilience against Coastal Erosion and Sea Level Rise

The existing scientific literature has identified actions that can better adapt human economies to sea level rise and associated geomorphic changes (Ebi et al. 2007; Fiedler et al. 2001; Lee County Visitor and Convention Bureau 2008; Peterson et al. 2007; Titus 1998; USCCSP 2008; USNOAA 2008; USEPA CRE 2008). (Note: This and all following tables related to climate change resiliency strategies are not ranked by any form of prioritization. Strategies found by staff interview to already be in use by Lee County to any extent are indicated with this symbol + . They are included to encourage expansion of those policies and practices. Not all strategies being used by Lee County may be accounted for. Key words are shown in bold italics. Some strategies are applicable in more than one area of interest. These strategies are repeated where applicable.)

These include:

Address climate change impacts in plans for <i>working waterfronts</i> .
<b><i>Strengthen building codes</i></b> in coastal areas to provide additional protection for properties from wind and storm surges.
Adopt <b><i>soft defense strategies</i></b> , such as establishing aquatic vegetation beds, using natural or artificial breakwaters, and beach nourishment, where appropriate (for example, shorelines that are more undeveloped and where a seawall would inhibit wetland migration and damage natural defense systems).
<b><i>Allow coastal wetlands to migrate inland</i></b> in areas explicitly indicated.
Allow shoreline <b><i>hardening</i></b> where appropriate. +
Allow <b><i>beach nourishment</i></b> where appropriate. +
Investigate <b><i>carbon offsets</i></b> to mitigate climate change generally.
Change building codes to promote <b><i>energy efficient building</i></b> .
Change to energy efficient buses and taxis, including those using <b><i>alternative fuels</i></b> . +
Change the <b><i>placement and design of infrastructure</i></b> (for example, for water supply, wastewater treatment, power plants and other utilities, and transportation).
Connect landscapes with <b><i>corridors</i></b> . +
<b><i>Conserve land in coastal areas</i></b> by removing or limiting development potential through acquisition, conservation easements, and the purchase and transfer of development rights.
Consider <b><i>congestion zone tolls</i></b> in downtowns.
Consider sea level rise in <b><i>infrastructure planning</i></b> . +
Consider sea level rise in <b><i>site design</i></b> .
<b><i>Constrain locations</i></b> for certain high risk infrastructure.
Construct <b><i>groins</i></b> in appropriate areas.

Create a regional <i>sediment management plan</i> .
<i>Create dunes</i> to protect shorelines.
<i>Create marsh</i> .
Create more <i>energy- and cost-effective communities</i> through community design and green building.
Create <i>natural buffers</i> against sea level rise.
Create <i>water markets</i> .
Design new <i>coastal drainage systems</i> .
Develop and adopt <i>building design criteria</i> to deal with the consequences of possible sea level rise.
Ensure appropriate <i>foundations</i> for buildings.
Establish <i>early warning sites and baseline data</i> . +
Establish or broaden <i>use containment areas</i> to allocate and cap water withdrawal.
Establish <i>rolling easements</i> to maintain sediment transport.
<i>Expand planning horizons</i> .
<i>Improve land use and management</i> . +
<i>Explicitly indicate</i> in the Lee County Comprehensive Plans which areas will retain natural shorelines.
Fortify <i>dikes</i> .
Identify, protect and adapt protections of <i>ecologically important areas/critical habitat</i> . +
Implement <i>stormwater management</i> processes that more closely mimic nature by retaining rainfall close to its source so that it can be filtered, stored, and allowed to evaporate.
Improve <i>flood pain management/regulation</i> . +
Incorporate <i>Low Impact Development</i> (LID) principles.
Incorporate <i>LEED</i> standards into building codes.
Incorporate wetland protection into <i>infrastructure planning</i> data.
Increase <i>shoreline setbacks</i> and exchange/purchase/acquisition.
Increase use of <i>alternative and renewable energy</i> .
<i>Land exchange</i> programs.
Encourage use of <i>living shorelines</i> in residential, commercial and institutional properties.
<i>Manage realignment</i> of infrastructure.
Prepare for <i>more frequent storm events</i> with associated erosion.
Encourage <i>natural breakwaters</i> where appropriate.

Partner with utility companies to <b>educate the public</b> on energy efficiency and expand and increase incentives to homeowners (free/low cost loans for photovoltaic systems, net metering, and solar panels).
Plant <b>submerged aquatic vegetation</b> and other vegetation.
Prevent or limit <b>groundwater extraction</b> from shallow aquifers to protect coast from subsidence and saltwater intrusion.
Prohibit development or engineering "solutions" to block <b>migration of wetlands</b> .
Prohibit <b>development subsidies</b> (federal flood insurance and infrastructure development grants) to estuarine and coastal shores at high risk.
Promote <b>green building alternatives</b> through education, green-lending, taxing incentives, and building and design standards.
Promote <b>green roof technology</b> through building codes.
Promote <b>wetland accretion</b> by introducing sediment and prohibiting hard shore protection.
<b>Protect barrier islands</b> that shelter beaches.
Protect <b>water quality</b> for fisheries and reefs. +
Protect and restore <b>natural defenses</b> such as salt marshes, sand dunes, and natural vegetation. +
Provide <b>alternative transportation</b> . +
Purchase <b>upland development rights</b> or property rights.
Redefine <b>flood hazard zones</b> .
<b>Reduce carbon emissions</b> .
Regulate <b>fertilizer application and use</b> . +
<b>Regulate pumping</b> near shorelines, especially for flood control.
Remove hard protection or other barriers to shoreline retreat and replace shoreline armoring with <b>living shoreline protections</b> .
Replicate habitat types in multiple locations to <b>spread risks</b> .
<b>Restrict/prohibit development</b> in erosion/flood/damage prone areas.
<b>Relocate</b> structures away from vulnerable/affected shoreline.
Retreat from and/or abandon <b>shore headland control</b> .
<b>Retrofit roads and bridges</b> , which may involve rebuilding roads and bridges at higher elevations and developing engineering techniques that allow them to float or withstand flooding.
Revising <b>port master plans</b> to reflect the impact of sea-level rise.
Use adaptive <b>stormwater management</b> .
Use <b>integrated coastal zone management</b> .
Use natural and artificial breakwaters to <b>reduce wave energy</b> .

**Wetland conservation/restoration** accounting for climate change and human engineering such as canals, floodgates, levees, etc.

**Table 6.** Resiliency strategies to address coastal erosion and sea level rise

### **A hypothetical comparison of relative costs of various sea-level rise adaptations**

The relative costs of different approaches to sea level rise can vary significantly.

In an example of rolling easements, Volk (2008) reports that as of 2005, Worcester County in Maryland secured \$7.25 million from the Maryland Rural Legacy Program and contributed \$400,000 in local funds to purchase rolling conservation easements for 6,000 acres of land (representing eight miles of shoreline) within the Worcester County Bays Rural Legacy Area. The county continues to work with land owners within the Coastal Bays Rural Legacy Area to encourage others to place conservation easements on their property as well.

This Rolling Easement total cost is \$7.65 million for 6,000 acres of land (representing eight miles of shoreline) that in 2005 dollars is \$1,275/acre or \$1,045,752/mile of shoreline. This would be \$1,143,781 per mile of shoreline in 2008 dollars.

In estimating the shorelines of Lee County, SWFRPC GIS measured the total length of all major tidal manmade canals including all shorelines in the county as 1,590 or 8,395,200 linear feet. So a rolling easement for the entire Lee County shoreline in 2008 land values could be as high as \$1,818,611,790.00. Given devaluation of property land values of 11.74% from 2008 to 2009 and 14.73% from 2009-2010 in the ensuing recession of 2009-2010 the relative cost of a rolling easement can be expected to decrease in accordance with the level of devaluation of coastal properties. Using this estimation the cost of a rolling easement for the entire Lee County shoreline in 2010 land values could be as low as \$1,368,674,539.24

The costs of a total shoreline treatment of the county boundary (set at the mean tide line and including the man-made canals) with a complete 4 foot vertical concrete bulkhead along all public and private properties would be \$35,679,600,000 for the bulk head alone. Based on SFWMD elevation data, a 4 foot back fill of the currently developed areas of the county would add 312,518.36acre/feet (504,199,213cubic yards) of fill. At \$18 a cubic yard, this would cost \$907,558,583 in materials. Estimated construction costs or the bulkhead installation with normal salaries would be approximately \$3,974,563,519.49. This would be a total of \$40,561,722,102.49 in 2008 dollars for complete currently developed County protection with backfill to an approximately 4 foot elevation above the current mean tide line.

Utilizing the method of gradual sand filling to keep pace with sea level rise the current estimate for careful sand placement would be in the neighborhood of 1.5 million for each mile of shoreline. At the manmade waterfront there would need to be a concomitant raising of bulkheads if the standard navigable depth of canals were to be maintained. Examining only the outer shoreline the cost for the method of keeping pace with sea level rise would be

\$2,835,000,000.00.

**Table 7.** A hypothetical comparison of relative costs  
Various sea-level rise adaptations for Lee County. Costs are in billions of dollars

<b>Alternative</b>	<b>Rolling Easements</b>	<b>Bulkhead with fill to 4 feet (2/3 Galveston Solution)</b>	<b>Gradual Sand Filling to keep pace (Volk 2008)</b>	<b>Elevating Infrastructure (Venice Solution)</b>	<b>Armored Dike 160 major pumps (New Orleans Solution)</b>
<b>Cost Estimate</b> (Billions of Dollars)	\$1.82 -\$1.37	\$40.561	\$2.835	\$36.536	\$40.997

Elevating the existing infrastructure in place would include increasing the height of buildings that are historical or are too valuable to rebuild, and replacing buildings that have exceeded their useful life with new construction that would be elevated to the new standards. As a unified area of structures achieves elevation, then the roadway network and utilities would need to be brought up to the new height. Based upon house elevation flood hazard mitigation performed in Sarasota County for a house in the Myakka River flood plain the total cost was \$170,000 (FEMA 2003). House elevation costs listed for post Hurricane Katrina recovery are in the neighborhood of \$150,000. With a total of 214,922 buildings in storm surge zones and potential sea level rise inundation, the total cost of elevation of only the structures would be approximately \$36,536,740,000.00.

Construction of perimeter earthen dikes that are generally waterproof with a seepage management system would be \$406,841,643.56 to \$453,218,983.96 in fill material alone if all manmade tidal canals are left open to tide. If the dike is armored the increased cost would be from \$11,226,173,353.96 to \$37,344,451,879.01. In this method the area behind the dike would not be elevated but major pumps would be needed to address discharge of storm waters, dike seepage, and drainage. Pumps of sufficient scale to maintain a relatively dry city would range in cost from \$7 to \$20 million (SFWMD 2006, Wood 2006) depending on design, power sources and portability. Presuming a minimum of 1 major pump for every 5 square miles the costs of an armored dike system with pumps would range from \$12,753,014,997.52 to \$40,997,670,862.97 for an exterior coastline with embayments and the canals open to navigation access. Of course this does not account for the costs accrued when the dike fails.

## **What Lee County Government Can Do to Increase Climate Change Resilience for Coastal Economies**

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

the County's financial future. This section will describe Lee County's major economic sectors, from the estuaries to the inland areas, emphasizing those sectors' vulnerabilities to climate change. Economic sectors evaluated separately include agriculture, forestry, tourism, land development, the ocean economy, and mining. The top nonfarm industries include construction, health care, retail sales, professional services, manufacturing, administrative services, finance/insurance, and manufacturing.

Residents and visitors alike benefit economically from the natural resources of the Charlotte Harbor region. 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. Climate change impacts can significantly change the health and vitality these economic activities.

## **Tourism**

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 alone 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.

Tourists and residents are drawn to southwest Florida because of many natural amenities, with an emphasis on beaches. Climate change will likely have a variety of impacts on beaches and on the tourism industry. Increasing erosion of beaches, harmful algal blooms, variations in extremes of temperature and other climate change effects may create needs to protect this vital tourism industry. Tourists also enjoy other outdoor activities including kayaking/canoeing, hiking in natural areas, and the like. As temperatures become more extreme, these activities may become less desirable.

As sea levels have increased, so has the frequency of beach renourishment. In addition the life expectancy of these projects has been reduced. Red tide can cause serious respiratory and skin

problems. Blue-green algae blooms are also toxic. These imbalances come into the system with high stormwater flows and nutrients. Extreme weather events such as the 2004 and 2005 hurricane seasons created high nutrient-laden water flows. In southwest Florida, the tourism industry has suffered in the wake of several types of algal blooms. Red tide, blue-green algae, and brown drift algae have at various times negatively impacted tourism seasons to the extent that the Lee County Tourist Development Council has invested more than \$200,000 in research on red tide and red drift algae. In addition, many tourist businesses have joined forces to lobby to develop better water and nutrient management ([www.leewaterfacts.org](http://www.leewaterfacts.org)).

Tourism plays a major economic role in southwest Florida that extends beyond the actual tourist visit. Many residents initially came to the area for work in the tourism industry, 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).

In Lee County 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. 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.

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

## **What Lee County Government Can Do to Increase Climate Change Resilience for Land Development and Building**

The same qualities that render Lee County desirable for tourists make it desirable to move to here permanently. In fact, many residents saw the area first as tourists. In addition to the

vulnerabilities found in tourism, water availability, increased intensity of storms, increased and vulnerability of low lying development will affect the future health of the construction industry.

Much of the land platted for residential development was created on the coast from dredged low-lying areas. Many of these areas are vulnerable to the impacts of sea level rise. Additional land that had been slated for development within the most vulnerable zones associated with Estero Bay and Charlotte Harbor was acquired and managed for environmental purposes, improving the overall resiliency of area.

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. Alongside the pre-existing residential centers such as Fort Myers, North Fort Myers, Fort Myers Beach, Bonita Springs, and Sanibel/Captiva, new residential entities were created out of speculative development including Cape Coral, Estero, Lehigh Acres, and the Treeline corridor from SR 82 to Corkscrew.

Land and home values increased rapidly through the end of the last century and peaked in 2007. Construction employed tens of thousands of people in 2007 (Table 11.20 UFBEBR 2008). Subsequently, home values across the region have generally decreased 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 for Lee County was \$40,113. Economic sectors generating the most non-farm total earnings for Lee County residents in 2006 were construction and retail trade (Table 5.00 Florida County Perspective 2008).

Health care and social assistance employed over 22,000 residents in 2002 (Table 6.00, FCP 2008). As of 2007, there were at least 17 free standing nursing care facilities (Table 7.00, FCP 2008).

According to the Southwest Florida Regional Planning Council, in May 2010, 91 residential permits were issued in Lee County. This is 9 more permits than were issued in May 2009. The number of units covered by these permits nearly doubled from 89 in May 2009 to 176 in May 2010 (Economic Views July 2010). As of April 2010, the unemployment rate in Lee County was 12.7% (Economic Views July 2010).

The value of manufacturing shipments from the county totaled \$986,100 in 2002, the most recent year with available data. Wholesale trade sales in the county amounted to more than \$2 billion in 2002, the most recent year figures were available, with retail sales for the same period totaling over \$6 billion (Table 8.00 Florida County Perspective 2008).

In 2007, there were 54 banks, including commercial and state-chartered banks, and credit unions (Table 8.00 Florida County Perspective 2008).

In 2007-2008, Lee County collected almost \$27,000,000 in tourist development taxes, accounting for nearly 5% of the state total. In 2006-2007, there were 658,490 motor vehicle tags sold in Lee County, and over 49,000 recreational boats registered (Table 12.00).

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

As of January of 2009, there are state, county and municipally-owned bridges in the county, along with centerline miles of all types of roadways. Drivers traveled daily vehicle miles. There are commercial and general aviation airports in the county that had well over a take-offs and landings in 2007(UFBEBR 2008 Table 13.9).

## **Ocean Economy and Coastal Economy**

This area's "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, redfish (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 % 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.

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 of the 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 321 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. 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).

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 likely have devastating effects on the estuarine wetland ecosystems and coral reefs upon which many fish species depend. 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. Sea level rise in the upper range for 2100 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). Mangrove wetlands are critical to the life stages of some species and are an important aspect of the food web. 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 are 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 region 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 clam. Clams require proper salinity, oxygen and nutrients to grow at a reasonable rate, as well as good water quality to be safe to eat.

## **What Lee County Government Can Do to Increase Climate Change Resilience in Emergency and Hazard Planning**

Although climate change may not specifically be identified in emergency preparedness plans, it is an issue that's being addressed simply because of its nature. The all-hazards emergency management community plans for all types of emergencies, whether manmade or natural. Changing climate and weather patterns automatically lend themselves to increased planning and new mitigation actions. Although scientists and planners have advice for how the changing climate can be included in emergency preparedness, the field is continuing to evolve as more information becomes available and agencies begin developing best practices.

Planning for climate change can mean looking at current natural hazards and anticipating which of them will become more extreme in the future. One of the barriers to the new planning considerations is that the future being planned for isn't likely to be next year, but many years from now. Emergency management also has traditionally been response-based, which can hinder how agencies include climate change in their planning.

Throughout the history of settlement in Florida, extreme weather events—particularly in the form of hurricanes—have played a major role in shaping culture, commerce, and community development. As a result, Florida's state government has developed one of the more robust emergency preparedness and response infrastructures in the nation. This was particularly evident in the depth of aid provided by Florida to Mississippi during the 2006 hurricane season in the aftermath of Hurricane Katrina.

Current science supports increased intensity and duration for storms that form in the Atlantic and the Gulf of Mexico. When coupled with rising sea levels, future hurricane events may yield greater storm surge effects to put coastal communities at greater risk for damage than is the case today. In addition, there could be more intense rain events, droughts, wildfires, and heat emergencies.

Extreme weather in Lee County could:

- Overtax the emergency response systems and funding for flood response,
- Result in major storms and power outages,
- Affect buildings or transportation routes, and
- Cause drought-related fires.

Hurricanes, as Florida's typical extreme weather event, may no longer be the only major threat to Floridians. An analysis of predictable climate change impacts would include projections for other intense rain events, increased droughts, wildfires, heat, and public health emergencies. Additionally, given the many fronts that climate change is expected to present to Lee County's emergency infrastructure, there is the possibility that several of these impacts might occur simultaneously. Delayed emergency response could become more common.

Florida's current emergency preparedness and response functions are a coordinated effort between federal, state, and local governmental agencies, as well as nongovernmental organizations (NGOs). The objective of Florida's future emergency preparedness and response functions has been to build on the excellence gained through past experience to ensure sufficient capacity and efficacy in protecting public health and welfare in more severe storm events with increased incidence of storm surge and the associated coastal damage. As the impact of sea level rise (SLR) and higher storm surges becomes more evident, development patterns must be constrained to increase the resiliency of coastal communities and to protect those communities.

Lee County must be prepared to address the synergistic effects of multiple climate stressors on its emergency response infrastructure and, prior to such occurrences, must devise an approach to deal with this by building on existing skills in emergency preparedness and environmental

response. Policy makers in particular need information and data on changes in risks from climate change and need to know where to get such information.

Coastal communities and ecosystems are at particular risk from increased storm surge and increased hurricane intensity. The majority of Lee County's population lives in the coastal zone or low elevation areas. Likewise, the vast majority of the County's existing building stock is situated near the coast. While many coastal ecosystems have adapted to periodic extreme weather, system resiliency in some cases may be undermined because of the loss of habitat, pressures from invasive exotic species, or other incidences that prevent post-hurricane recovery. Aside from risk to the human population from hurricane events, increases in temperatures may cause certain water- and vector-borne diseases normally associated with more southern climates to migrate to Florida. Increased flooding and infrastructure damages resulting from increased heat and flooding could aggravate these risks.

Many of the impacts that climate change is projected to bring are already familiar to Lee County. Consequently, programs to address impacts such as increased intensity of hurricanes and major storm events, storm surge and erosion, saltwater intrusion, and the availability of potable drinking water supplies have been implemented. Additionally, Lee County's excellent emergency response infrastructure has proven itself under many scenarios, and the planning mechanisms that are part of that infrastructure are in place to deal with a large variety of catastrophic events. However, it is uncertain to what extent these programs and infrastructure will be affected by future impacts associated with climate change, or to what extent additional financial resources will be needed to meet these future conditions.

Florida's Energy and Climate Change Action Plan has identified an **Adaptation (ADP) Planning Framework for Florida. The Goals and Strategies include:**

**Goal 1:** Ensure sufficient response capability among regional, state, and local first responders to potential increases in extreme weather events.

**Goal 2:** Increase the resiliency of coastal communities to storm surge.

**Goal 3:** Assess the role of ecosystems such as coastal wetlands and beaches and dunes in reducing risks from extreme events.

**Goal 4:** Plan for other extreme events (e.g., flooding, wildfire, and heat waves).

**Goal 5:** Develop a process for early detection, evaluation, and handling of extreme events resulting from climate change. Effectively distribute such information to key emergency preparedness and response personnel.

**Goal 6:** Invest in emergency response and mitigation strategies for extreme environmental events likely to be exacerbated by climate change.

**Strategies:**

Encourage the search for practical and effective solutions to ensure that existing and future built
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environment in Florida will remain habitable, providing <i>viable shelter</i> for the full range of human activity and ensuring continuity of critical and essential functions in the aftermath of impact by climate change–exacerbated hazards. +
Establish educational and professional <i>licensing requirements</i> to ensure that key professional sectors become practitioners of adaptation in support of planning, building design, and construction activities.
Foster an environment of <i>communicating and sharing knowledge</i> about adaptation to climate change and the adaptation/protection of the built environment among the scientific community, lawmakers, various professional sectors (practitioners), and the general public.
Make <i>the practice of adapting</i> the built environment to the impact of climate change an integral component of comprehensive planning, building codes, life-safety codes, emergency management, land development and zoning regulations, water management, flood control, coastal management, and community development.
Make the practice of adapting the built environment to the impact of climate change a <i>preferred objective</i> of building design, siting, and construction research funded by public monies in Florida.
Promote an environment for <i>connecting scientific research with practical applications</i> that will contribute to the adaptation of the built environment to the impact of climate change.
Promote an environment to <i>connect science with decision making</i> regarding climate change and the need to adapt the built environment to its impacts.
<i>Reduce the potential for damage</i> to the built environment from the impact of natural hazards, especially from those hazards caused or exacerbated by climate change, make this a high priority for all levels of government and the private sector in Florida.
Require the state, county, and municipal governments throughout Florida to develop and maintain a <i>local climate change adaptation plan</i> , to provide a framework for assessing vulnerability, identifying risks, defining and quantifying the value of the built environment that is at risk (see attachment on Quantifying Value at Risk), and identifying and implementing effective adaptation measures at each jurisdictional level (i.e., state, county, municipality, and individual facility).
State, regional, and local governments and modal partners in Florida should work cooperatively to <i>identify and evaluate transportation infrastructure at risk</i> and to coordinate adaptation efforts for infrastructure immediately landward of coastal high hazard areas or to provide emergency evacuation routes for coastal populations.

**Table 8.** Resiliency strategies to address emergency and hazard planning

## What Lee County Government Can Do to Increase Climate Change Resilience in Health and Human Services

Lee County must be prepared for an increased incidence of heat-related illness in large sectors of the public, particularly given the large population of senior citizens. As temperatures rise and the climate becomes more tropical, water- and vector-borne diseases now associated with more equatorial climes might become commonplace in Lee County. This situation will be aggravated by increased flooding events and their associated impacts on certain portions of the public infrastructure such as sewage systems, hospitals, and nursing homes.

Consider the impact of sea-level rise or flooding and storm surges and more frequent and intense tropical storms in <i>local emergency evacuation plans</i> . +
Conduct a needs assessment and cost-benefit analysis of implementing an <i>emergency heat warning system</i> .
Conduct community wide assessments to identify the homes occupied by <i>disabled persons and seniors</i> ; assess the safety, energy and water use efficiency of these homes, and modify or retrofit homes, if needed. Modifications could include installing: access/mobility enhancing features and other physical safety improvements (e.g., smoke alarms and walkway lighting); weatherproofing; energy efficient appliances; shade cover including planting trees.
Conduct <i>health assessments of proposed mitigation and adaptation strategies</i> , including impacts on vulnerable populations and communities and assessment of cumulative health impacts; conduct health assessments of land use and transportation proposals that could impact health, greenhouse gas emissions, and community resilience for climate change.
Consider climate change as part of planning efforts directed at attaining the health based ambient <i>air quality standards</i> .
Develop climate change <i>communication tools, techniques, and messages</i> that promote active public and individual discourse, engagement, and positive actions.
Develop integrated and comprehensive approaches to <i>respond to economic and physical dislocations and shifts</i> that provide support and structures to either mitigate the impacts of these shifts or stabilize neighborhoods and communities as quickly as possible after dislocations.
Develop <i>real-time surveillance and reporting</i> of deaths, and collect supplemental information from coroners and explore partnering with the health care providers' system for syndromic surveillance opportunities.
Develop <i>regional definitions for heat alerts/warnings</i> which are based on public health thresholds for heat morbidity.

Disseminate <i>information specific to vulnerable populations</i> (e.g., outdoor workers and residents in urban heat islands or people with chronic illness regarding heat, immigrants with literacy/language needs).
Disseminate <i>information to address specific risks</i> associated with climate change (e.g. to prevent heat illness in communities and in workplaces, vector borne, or food-borne disease, etc.).
Educational materials should be available in <i>multiple languages</i> to reach wider audiences. +
<i>Elevate structures</i> above the minimum threshold for the 100-year storm.
<i>Empower and engage communities</i> for action to mitigate and adapt to climate change.
<i>Engage vulnerable communities</i> and at-risk populations.
<i>Ensure public health participation</i> in and preparation for discussions about proposed mitigation and adaptation strategies and in land use and transportation planning processes.
<i>Ensure that health care providers are educated</i> about climate change and health impacts thereof, including diagnosis and treatment of climate-related illness and recognition of emerging trends.
<i>Expand “safe routes to school” and “green tools for schools”</i> to promote increased physical activity, enhance school performance, and improve health and safety of children in and around school.
Expand training and education of health and social services systems/providers to identify and treat <i>mental health problems</i> and integrate mental health into systems and services deployed post disaster and in the wake of economic and other dislocating or disruptive climate related changes.
Formally engage the full community in planning and preparing for an <i>effective disaster response</i> , as well as climate change mitigation and adaptation. It is especially critical that efforts are made to engage the most vulnerable segments of the community in this planning. This could help to fortify community mental health in advance of a disaster or the changes required for mitigation or adaptation.
Identify <i>“heat island” areas</i> of the community and increase ground cover and shade by creating or expanding urban forests, community gardens, parks, and native vegetation-covered, open spaces.
Identify and provide research to develop and continually refine <i>comprehensive strategies to minimize the impacts</i> of climate change on human health.
Identify specific groups at risk for <i>heat-related illness</i> , including the elderly and outdoor workers (farm workers, construction).
Improve <i>coordination of health-risk communication</i> strategies and integrate climate change in

other efforts (e.g. PH preparedness).
Increase access to <b>air conditioning</b> , particularly in areas where it is currently not common and in population groups that lack access. Consider expanding existing programs that help low income people pay for residential heating to include residential cooling as well. (Note that air conditioning use may increase greenhouse gas emissions and health problems related to fossil fuel combustion.)
<b>Increase public awareness</b> and understanding of climate change impacts on human health, the need to prepare for these changes, and the likelihood that adaptation and preparedness efforts will be overwhelmed without also taking urgent and strong actions to prevent dangerous climate change.
Increasing community <b>bike/walkability and expanding public transit</b> – measures that will also improve health through increased physical activity and possibly reduced injury rates. +
Increasing <b>preparedness and response to outbreaks of diseases</b> that may become more prevalent with warmer temperatures.
Initiatives like the California Green Chemistry Initiative that support <b>reduced use of toxic materials</b> and use of alternatives that maintain product performance but reduce environmental and health effects will be central to any strategy to build community resilience.
<b>Integrate climate change mitigation and adaptation</b> ; encourage adaptation strategies that maximize health co-benefits, minimize unintended consequences, and simultaneously mitigate climate change.
Maintaining strict regulation of <b>air pollutants</b> will be an important support to community resilience. Some pollutant levels will be altered by changing temperatures and locations. Furthermore, some of the regulated air pollutants may act as green house gases and therefore require more stringent regulation. New controls for green house gases that are not presently regulated as pollutants will be required.
<b>Outreach to businesses and private sector.</b>
<b>Outreach to clinicians and health sector.</b>
Prepare to reduce and respond to <b>heat stress</b> , which increases the incidence of heart attacks and other emergency room visits.
<b>Primary prevention</b> : preventing the occurrence of illness and injury through reduction of exposure to risk factors. True primary prevention in climate change is through reduction of greenhouse gas emissions to reduce the severity of climate change impacts (for example the amount of global warming) over time; some experts have called this “primordial” prevention (McMichael, 2000). +
Promote <b>healthy and resilient populations</b> , communities, and human environments, including

reduction of existing health and environmental inequities, to increase preparedness for unavoidable climate change and ability to reduce greenhouse gas emissions. +
Promote increased <b>access to health care</b> , to ensure adequate access for individuals who suffer health consequences related to climate change.
Promote sustainable <b>local food systems</b> : a sustainable food system provides healthy, accessible, and affordable food while maintaining healthy ecosystems with minimal negative impact on the environment. <a href="http://www.apha.org/advocacy/policy/policysearch/default.htm?id=1361">http://www.apha.org/advocacy/policy/policysearch/default.htm?id=1361</a> Local food systems help reduce the length of the supply chain between producer and consumer, as well as the amount of inputs needed to produce food, including fertilizers, transportation, and storage, all of which should help reduce costs. From an emissions perspective, food miles make up a very significant proportion of all vehicular transport which also contribute to congestion, demand for new roadways, and fuel consumption.
Provide and maintain <b>resources</b> required to implement comprehensive strategies to minimize the impacts of climate change on human health and well-being.
<b>Reduce health inequities</b> and ensure health promotion and protection for vulnerable populations and communities.
<b>Reduce climate-change related exposures</b> – for example by shading buildings to reduce heat exposure – are another example of primary prevention.
Reducing exposures to <b>combustion products</b> (e.g. through actions such as CARB regulations on diesel trucks, increased car fuel efficiency, etc.)
Review and, as appropriate, revise <b>occupational health and safety standards</b> to identify occupations at risk due to climate change or climate mitigation and adaptation strategies: for example, agricultural and construction workers exposed to heat, solar installation workers at high risk of falls (similar to roofers), forest fire fighters, solar panel manufacturing workers, etc.
Review and expand existing <b>vector control programs</b> as necessary. +
<b>Secondary prevention</b> : early detection and slowing the onset or progression of illness. For example, identification of people that might be particularly sensitive to heat and provision of advice and cooling and hydration stations. +
<b>Strengthen surveillance</b> for temperature-related mortality and adverse health effects of air pollution exposure and wildfires, as well as infectious diseases related to water, vector, and food borne pathogens.
<b>Tertiary prevention</b> is the treatment and management of illness and disability that could not be prevented, such as provision of appropriate health care to those who suffer heat illness in order to prevent severe heat stroke, or management of heat stroke to prevent neurological damage.
<b>Urgently expand dissemination</b> of climate change health impact information including impacts,

**Table 9.** Resiliency strategies to address health and human services

## **What Lee County Government Can Do to Increase Climate Change Resilience Land Use Planning and Growth Management and the Urban, Suburban and Rural Landscape**

Land use and climate change in Florida are deterministically linked issues. Past and current projections of development within Lee County are not consistent with either the goals of sustainable development or maximizing the opportunity for climate mitigation and adaptation through land management.

Adaptation options that protect coastal land and development focus on land use planning and management, land exchange and acquisition programs, and changes to infrastructure. Some adaptation options aim to protect the land itself, while others are aimed at protecting existing development (e.g., homes and businesses) and infrastructure (e.g., sewage systems, roads). Land use management involves using integrated approaches to coastal zone management as well as land use planning. Land exchange and acquisition programs allow for coastal land to be freed up for preservation uses. Changes to infrastructure can include limiting where hazardous and polluting structures can be built (including landfills and chemical facilities) as well as changing engineering structures that affect water bodies and will be impacted by climate change (Martinich 2008).

Land use planning and management, as well as changes in infrastructure, would be appropriate adaptation options for programs that are looking to implement anticipatory changes. These options require working with various key stakeholders and have a longer timeline for implementation. Land exchange and acquisition programs would be viable options for estuaries that have a management goal of acquiring more land in order to protect currently threatened areas (Martinich 2008).

One way for decision makers to more completely understand the impacts of land use changes is to analyze choices using Cost of Community Services studies.

### **Cost of Community Services**

Cost of Community Services (COCS) studies use a case study approach to determine the fiscal contribution of existing local land uses. It is a subset of the much larger field of fiscal analysis. COCS studies have emerged as an inexpensive and reliable tool to measure direct fiscal relationships (American Farmland Trust 2007). Their particular niche is to evaluate working and open lands on equal ground with residential, commercial and industrial land uses.

COCS studies are a snapshot in time of costs versus revenues for each type of land use. They do not predict future costs or revenues or the impact of future growth. They do provide a baseline of current information to help local officials and citizens make informed land use and policy decisions. In a COCS study, researchers organize financial records to assign the cost of municipal services to working and open lands, as well as to residential, commercial and industrial development. Researchers meet with local sponsors to define the scope of the project and identify land use categories to study. For example, working lands may include farm, forest and/or ranch lands. Residential development includes all housing, including rentals, but if there is a migrant agricultural work force, temporary housing for these workers would be considered part of agricultural land use. Often in rural communities, commercial and industrial land uses are combined. COCS study findings are displayed as a set of ratios that compare annual revenues to annual expenditures for a community's unique mix of land uses (American Farmland Trust 2007).

COCS studies involve three basic steps:

1. Collect data on local revenues and expenditures.
2. Group revenues and expenditures and allocate them to the community's major land use categories.
3. Analyze the data and calculate revenue-to-expenditure ratios for each land use category.

The process is straightforward, but ensuring reliable figures requires local oversight. The most complicated task is interpreting existing records to reflect COCS land use categories. Allocating revenues and expenses requires a significant amount of research, including extensive interviews with financial officers and public administrators.

Communities often evaluate the impact of growth on local budgets by conducting or commissioning fiscal impact analyses. Fiscal impact studies project public costs and revenues from different land development patterns. They generally show that residential development is a net fiscal loss for communities and recommend commercial and industrial development as a strategy to balance local budgets. Rural towns and counties that would benefit from fiscal impact analysis may not have the expertise or resources to conduct a study. Also, fiscal impact analyses rarely consider the contribution of working and other open lands, which's very important to rural economies.

American Farmland Trust (AFT) developed COCS studies in the mid-1980s to provide communities with a straightforward and inexpensive way to measure the contribution of agricultural lands to the local tax base. Since then, COCS studies have been conducted in at least 128 communities in the United States.

Southwest Florida has paid a high price for unplanned growth. Scattered development frequently causes traffic congestion, air and water pollution, loss of open space and increased demand for costly public services. This is why it is important for citizens and local leaders to understand the

relationships between residential and commercial growth, agricultural land use, conservation and their community's bottom line.

COCS studies help address three claims that are commonly made in rural or suburban communities facing growth pressures:

“1. Open lands—including productive farms and forests—are an interim land use that should be developed to their 'highest and best use'.”

“2. Agricultural land gets an unfair tax break when it is assessed at its current use value for farming or ranching instead of at its potential use value for residential or commercial development.”

“3. Residential development will lower property taxes by increasing the tax base.”

While it is true that an acre of land with a new house generates more total revenue than an acre of hay or corn, this tells us little about a community's bottom line. In areas where agriculture and/or forestry are major industries, it is especially important to consider the real property tax contribution of privately owned working lands. Working and other open lands may generate less revenue than residential, commercial or industrial properties, but they require little public infrastructure and few services.

COCS studies conducted over the last 20 years show working lands generate more public revenues than they receive back in public services. Their impact on community coffers is similar to that of other commercial and industrial land uses. On average, because residential land uses do not cover their costs, they must be subsidized by other community land uses. Converting agricultural land to residential land use should not be seen as a way to balance local budgets.

The findings of COCS studies are consistent with those of conventional fiscal impact analyses, which document the high cost of residential development and recommend commercial and industrial development to help balance local budgets. What is unique about COCS studies is that they show that agricultural land is similar to other commercial and industrial uses. In every community studied, farmland has generated a fiscal surplus to help offset the shortfall created by residential demand for public services. This is true even when the land is assessed at its current, agricultural use. As more communities invest in agriculture this tendency may change. For example, if a community establishes a purchase of agricultural conservation easement program, working and open lands may generate a net negative.

Communities need reliable information to help them see the full picture of their land uses. COCS studies are an inexpensive way to evaluate the net contribution of working and open lands. They can help local leaders discard the notion that natural resources must be converted to other uses to ensure fiscal stability. They also dispel the myths that residential development leads to lower taxes that differential assessment programs give landowners an “unfair” tax break, and that farmland is an interim land use just waiting around for development (American Farmland Trust 2007).

In COCS studies in Florida the ratios of public revenues gained to public costs are 1: 1.39 for residential including farm houses; 1: 0.36 for commercial and industrial; and 1: 0.42 for agricultural and natural lands (Dorfman 2004).

## **Carbon Markets and Land Use**

Florida, and Lee County, is uniquely endowed to become a leader in greenhouse gas mitigation through the effective management of agriculture, forestry, and natural ecosystems, but realizing this potential requires that policy makers consider the consequences of competing land uses. Appropriate land management and sustainable development can be partly driven by the economic incentive provided by carbon markets. Land use approaches to mitigation must consider the implications for sustainability through comprehensive planning over a timescale of at least a century. To the extent that enhanced carbon sequestration is consistent with maintenance of ecosystem services, creation of carbon offsets through land use represents the first step toward reconciling the planet's living carbon economy with its monetary economy. Properly implemented, sustainable land management strategies for climate mitigation can be socially, environmentally, and economically viable, and can create jobs and opportunities for enhancing the wellbeing of Floridians for generations to come (Mulkey 2007).

Lee County can become a leader in mitigation of GHGs through effective management of agriculture, forestry, and natural ecosystems. Mitigation in these sectors can significantly offset the projected increase in fossil fuel-derived GHGs over this century. Such management will not be possible without comprehensive data on the carbon budgets and emissions of these systems. The state could develop the resources necessary to collect these data.

Florida soils have the highest soil organic carbon content of all the states, and, with proper management, can sequester significant quantities of additional carbon. Agricultural lands can be managed to reduce methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) through conservation tillage and management of livestock wastes. Biofuel crops and biogas production can significantly reduce the use of fossil fuels (Mulkey 2008).

Afforestation (the planting of trees or seeds in order to transform open land into forest or woodland) and management of industrial forests for both fuel wood and carbon sequestration provide the largest single land-use opportunity in Florida for climate mitigation over this century. To prepare for participation in carbon markets, the state could immediately begin to assess its forestlands and develop best-practices for management. Because much of Florida's forests are under private ownership, the legislature could consider mandates and incentives for the management of carbon on these lands.

There is no comprehensive assessment of the carbon dynamics of Florida wetlands, and, because of their significant carbon stores and CH<sub>4</sub> emissions, it is important that these data be developed. Loss of carbon from the vast stores in the Everglades can be reduced through proper management of hydroperiod and control of wildfires. Current wetland mitigation and wetland banking practices can be reviewed in the context of climate mitigation.

Development of carbon markets is an unparalleled opportunity for monetizing ecosystem services and thereby progressively incorporating the natural economy into the human economy. Through targeted land use, Lee County can participate in carbon markets with the potential for development of a major new source of revenue.

For carbon markets to function effectively there must be transparent and comprehensive accounting of carbon sequestration, reversal, and leakage associated with biological systems over spatial and temporal scales consistent with the goals of GHG mitigation. Existing state agencies can establish appropriate accounting and best-practices procedures, and provide a mechanism for certification of verifiers. Appropriate environmental safeguards are essential to ensure that the methods of mitigation are consistent with the long-term health of Florida’s ecosystems. The Critical Lands and Waters Identification Program, (CLIP), developed by the Florida Natural Areas Inventory (FNAI) and others, is a comprehensive inventory that provides essential data for this purpose.

In urban areas, a critical element of reducing GHG emissions involves the protection of green space and vegetation because they absorb urban heat caused by heat islands, sequester carbon, reduce flooding, and clean stormwater runoff. Trees also provide shade from the sun.

The fact that Florida’s increase in vehicle miles of travel more than doubled the rate of population growth underscores the land use planning-climate change connection and the fact that most Floridians depend on a car to get to where they want to go. The predominant pattern of growth in the state (low density, disconnected development pushing into rural areas and away from urban areas) not only encourages more driving, but also requires it. That has led to longer commutes for daily activities, more time stuck in traffic (meaning higher carbon emissions), less green space to sequester carbon, and higher energy consumption. Those outcomes, coupled with limited opportunities for biking, walking, and transit due to the low density form of development, have only magnified Florida’s GHG emissions (and explain why 40 percent of those emissions are attributable to transportation). The strategies outlined below illustrate steps that local governments and communities can take to start reshaping land use patterns, thereby reducing the number of miles Floridians drive each day and the state’s GHG emissions.

Address requirements of <b>HB 697</b> . +
Adopt an <b>urban growth boundary</b> or other measures to contain growth within a designated urban area. +
Adopt standards that take <b>scenarios</b> into consideration.
<b>Allocating land</b> for long-term potential population migrations.
Careful consideration of <b>critical facilities</b> . +
Consider climate change impacts in all nine of Florida’s required <b>comprehensive plan elements</b> , particularly those addressing Coastal Management and Capital Improvement.

Create a <b>Main Street program</b> to encourage reinvestment in existing downtowns.
Create an Employee Assisted Housing Program to encourage employees to <b>live closer to work</b> .
Designate <b>priority growth areas</b> for targeting infrastructure investments and other types of funding.
Development of a <b>Solar Strategy</b> for inclusion in the comprehensive plan.
Enacting <b>land use policies</b> (for example, overlay zones), to minimize development in coastal hazard areas (locating it away from coastal hazards and retreating or relocating public facilities and infrastructure) and low lying interior areas.
Establish an <b>assessment of GHG emissions</b> as a part of the development review and environmental impact assessment processes.
Establish targets for <b>reducing vehicle miles of travel</b> in comprehensive plans and in metropolitan planning organization plans.
Establish <b>zoning</b> (for example, Agricultural Zoning and Conservation Design) and incentive programs (e.g., a purchase or transfer of development rights program) to protect farmland and natural systems. +
Identifying adaptation projects in a community's <b>hazard mitigation plan</b> .
Incorporating sea-level rise scenarios in modeling of the <b>30-year erosion line</b> used for the Coastal Construction Control Line and revising land suitability criteria to prevent development of vulnerable land.
<b>Policy analysis</b> regarding land use regulations. +
Actively <b>reduce automobile dependency</b> in our area.
Consider <b>transit oriented development</b> and fight urban sprawl. +
<b>Incentivize</b> development and redevelopment within the urban area.
Promote increased density and a reduction in the amount of <b>impervious surface</b> .
Reduce density in <b>coastal high hazard area</b> .
Site facilities next to one another to reduce travel time and <b>maximize building use</b> .
Target expenditures through the Capital Improvement Plan to existing neighborhoods and town centers to <b>limit sprawl</b> on the edge of town.
Use local zoning and land development regulations to require and/or provide <b>incentives</b> for compact mixed-use, walkable, and transit-oriented development, brownfield and greyfield redevelopment, and infill development. Incentives might include density bonuses or impact fee reductions or waivers.

Use <b>scenario planning</b> to understand the impacts of alternative growth patterns on how far people have to drive (vehicle miles of travel).
Utilize <b>Brownfields and Greyfields</b> for government buildings.
<b>Sustainability planning.</b> +
Identify policies that can be <b>implemented without funding.</b>
Work very closely with <b>planning/community development</b> to address climate change.

**Table 10.** Resiliency strategies to address land use planning

For more information on energy-efficient land use planning practices that create more compact walkable, less car-dependent communities and preserve farmland and natural systems, go to the American Farmland Trust ([www.farmland.org](http://www.farmland.org)), American Planning Association ([www.planning.org](http://www.planning.org)), the Congress for the New Urbanism ([www.cnu.org](http://www.cnu.org)), the Conservation Fund ([www.conservationfund.org](http://www.conservationfund.org)), the Lincoln Institute of Land Policy ([www.lincolninsti.edu](http://www.lincolninsti.edu)), the Local Government Commission ([www.lgc.org](http://www.lgc.org)), the Nature Conservancy ([www.nature.org](http://www.nature.org)), the Trust for Public Lands ([www.tpl.org](http://www.tpl.org)), Smart Growth America ([www.smartgrowthamerica.org](http://www.smartgrowthamerica.org)), the Smart Growth Network ([www.smartgrowth.org](http://www.smartgrowth.org)) and its *Getting to Smart Growth: 100 Policies for Implementation* ([www.smartgrowth.org/pdf/gettosg.pdf](http://www.smartgrowth.org/pdf/gettosg.pdf)), and the U.S. Green Building Council ([www.usgbc.org](http://www.usgbc.org)). In Florida, resource organizations include the Department of Community Affairs ([www.dca.state.fl.us](http://www.dca.state.fl.us)), the Department of Environmental Protection ([www.dep.state.fl.us](http://www.dep.state.fl.us)), 1000 Friends of Florida ([www.1000fof.org](http://www.1000fof.org)), and Florida’s regional planning councils (listed at [www.nefrpc.org/links.htm](http://www.nefrpc.org/links.htm)).

Acquire/protect <b>critical habitat</b> areas. +
Adopt building design criteria that consider <b>more severe hurricanes.</b>
Adopt building design criteria that consider <b>sea level rise.</b>
Change building codes to <b>promote energy efficient building.</b>
Consider climate change in <b>infrastructure planning.</b> +
Consider climate effects in choice of <b>building materials.</b>
Consider sea level rise in <b>site design.</b>
<b>Constrain locations</b> for certain high risk infrastructure. +
Control building with <b>zoning and permitting.</b> +
Create more energy- & cost-effective communities through <b>community design and green building.</b>
Don't allow development or engineering solutions to block migration of wetlands
Ensure that master plans explicitly indicate which areas will <b>retain natural shorelines.</b>

Establish a <i>green payment program</i> (described in the Agricultural Land Conservation chapter) to compensate farmers for providing cropland that can store carbons, using practices such as no-till farming, and planting grasses and trees.
Establish a <i>Transfer of Development Rights Program</i> to move density from open space areas to be protected to areas suitable for development.
Establish <i>rolling easements</i> .
Improve <i>land use management</i> .
<i>Infill</i> incentives.
Insist on " <i>greening</i> " <i>measures</i> .
Maintain and restore <i>parks</i> . +
Plant shade <i>trees</i> around local government buildings and in and around parking lots and garages.
Preserve <i>open space</i> and create greenways. +
Promote <i>green roofs</i> through building codes.
Provide <i>alternative transportation</i> . +
Reduce/eliminate development in <i>sensitive areas/coast</i> .
Start an Urban Forest or <i>Plant-A-Tree</i> program.
Strict <i>enforcement</i> of existing codes. +
<i>Urban growth boundaries</i> . +
Use <i>integrated coastal zone management</i> in land planning. +
<i>Subsidize retrofitting</i> buildings for energy efficiency.
<i>Purchase upland development rights</i> /property rights.
Increase use of <i>alternative and renewable energy</i> .
<i>Identify conflicting policies</i> between programs. +
Reduce local <i>GHG emissions</i> .
Integrate <i>carrying capacity principles</i> into comprehensive planning.
<i>Elevate land surfaces</i> .
<i>Establish living shorelines</i> .
<i>Increase shoreline setbacks</i> .
Adopt <i>building design criteria</i> that consider all adaptation requirements.
Redefine <i>flood hazard zones</i> .
Use <i>LID</i> standards in building.
Use <i>flexible planning</i> .
Ensure appropriate <i>foundations</i> for buildings.
Plan for regional <i>relocation &amp; displacement</i> .
<i>Remove unnecessary/inundated infrastructure</i> .

**Table 11.** Resiliency strategies to address to address urban, suburban, and rural land use

Two useful documents related to the multiple values of trees to urban areas are:

- *Summary Report of Calculated Public Tree Values and Benefits for Historic Springfield District and Mandarin Road: The City of Jacksonville, Florida* prepared in 2001 by the city's Urban Forester. The report documents the public values of trees using the U.S. Forest Service's STRATUM (Street Resource Analysis Tool for Urban Forest Managers) Benefit Model. The results quantify the following benefits of trees in two test neighborhoods: energy savings avoided and sequestered carbon dioxide, air quality, stormwater reduction, and aesthetic, property value, social, and economic benefits. The conclusion: a per tree cost of \$12.52 and a total benefit of \$56.52 means a net per tree benefit of \$44.00.
- *Urban Ecosystem Analysis: City of Jacksonville, Florida*, a study by American Forests in conjunction with the state of Florida and the City of Jacksonville. The study highlights the ecosystem services that Jacksonville's urban tree canopy (their natural capital) provides. According to the report, the city's urban tree canopy saves money on managing air and water quality, helps meet environmental regulations, and fulfills city environmental protection goals. The Urban Ecosystems Analysis enables county decision-makers to calculate the value of their green infrastructure and apply that information to their planning and investment decisions.

Florida resource organizations on urban landscape programs include the Florida Urban Forest Council [[www.fufc.org](http://www.fufc.org)], which works with communities and state, local, and professional organizations to promote urban and community forestry initiatives, and the Florida Division of Forestry [[www.fl-dof.com](http://www.fl-dof.com)] and its Florida Tree USA Program [[www.fl-dof.com/forest\\_management/cfa\\_urban\\_tree\\_city.html](http://www.fl-dof.com/forest_management/cfa_urban_tree_city.html)], which offers grants to local governments. Additional Florida resources include the University of Florida IFAS [<http://edis.ifas.ufl.edu/mg249>]; Audubon of Florida [[www.audubonofflorida.org](http://www.audubonofflorida.org)]; the Florida Chapter of the Nature Conservancy [[www.nature.org](http://www.nature.org)]; and the Florida Chapter of the Trust for Public Lands [[www.tpl.org](http://www.tpl.org)]. At the national level, resource organizations include American Forests [[www.americanforests.org](http://www.americanforests.org)]; American Society of Landscape Architects [[www.asla.org](http://www.asla.org)], Community Trees [[www.communitytrees.org](http://www.communitytrees.org)]; Keep America Beautiful [[www.kab.org](http://www.kab.org)]; the Local Government Environmental Assistance Network [[www.lgean.org](http://www.lgean.org)]; the Alliance for Community Trees [[actrees.org/site](http://actrees.org/site)]; the National Arbor Day Foundation [[www.nationaltreetrust.org](http://www.nationaltreetrust.org)], and, in Florida, [[www.nationaltreetrust.org/states/?state=FL](http://www.nationaltreetrust.org/states/?state=FL)]; the National Association of Conservation Districts [[www.nacdnet.org](http://www.nacdnet.org)]; and the Urban and Community Forestry Program [[www.fs.fed.us/ucf](http://www.fs.fed.us/ucf)], a program of the U.S. Department of Agriculture Forest Service.

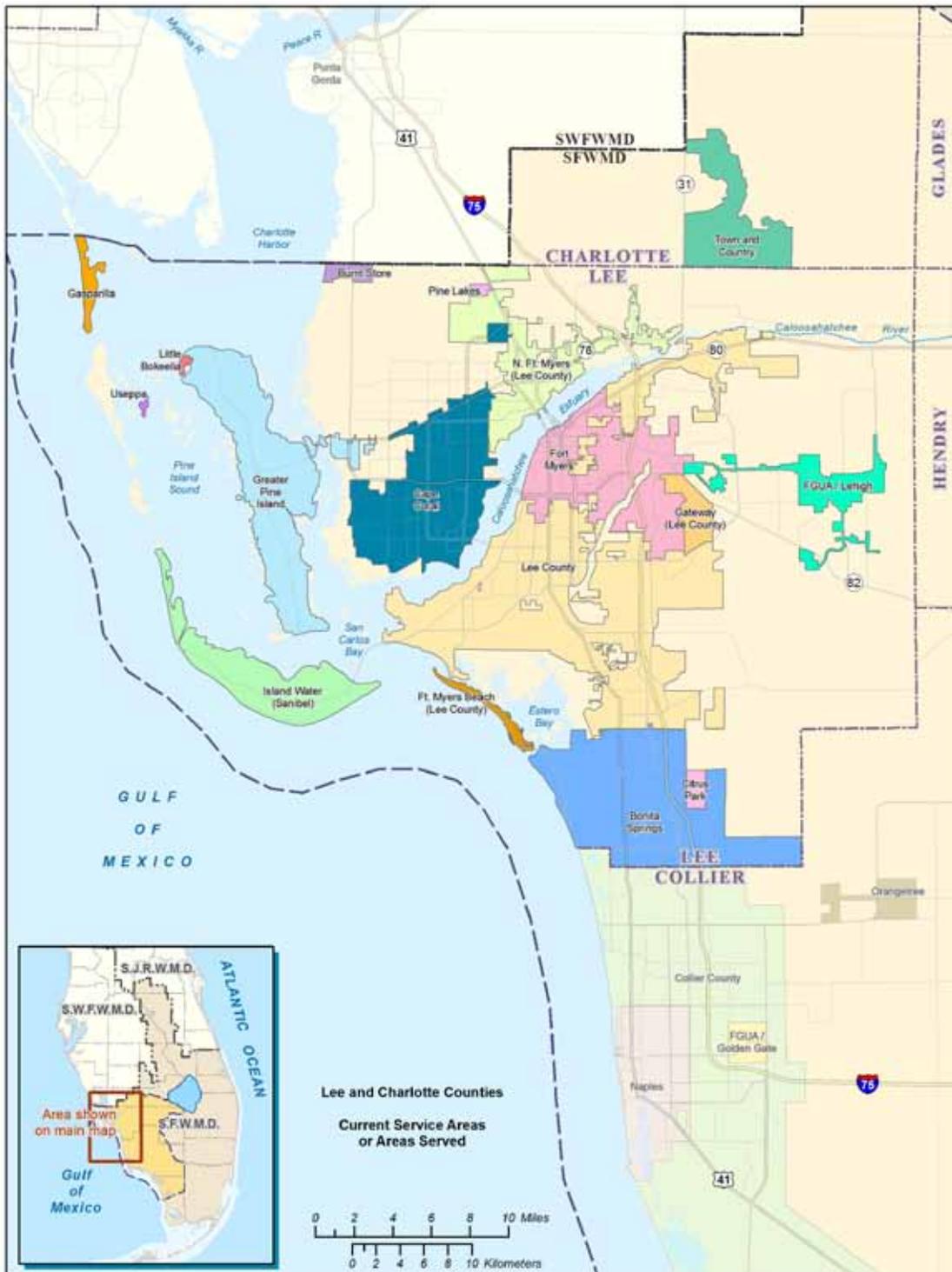
## **What Lee County Government Can Do to Increase Climate Change Resilience Water and Wastewater**

An often overlooked consumer of energy is the municipal potable water service. The vast majority of Lee County's fresh water comes from ground water. In the county, there are a

number of potable water providers including Lee County Utilities, Florida Governmental Utility Authority (FGUA), Pine Island Water Association, The Island Water Association, Inc. and Bonita Springs Utilities. Both The Island Water Association and Bonita Springs Utilities primarily service municipalities. However, they also serve some customers in unincorporated Lee County. The following map shows service areas for water utilities located within Lee County and the portion of Charlotte County in the South Florida Water Management District.

Utility	2005	2010	2015	2020	2025	2030
Bonita Springs	44,371	50,866	58,313	66,849	76,635	87,845
Burnt Store	1,485	1,798	2,177	2,636	3,192	3,862
Cape Coral	113,221	136,694	165,034	199,249	240,558	290,717
Citrus RV	1,685	1,706	1,728	1,749	1,771	1,795
Fort Myers	58,505	62,964	67,764	72,929	78,488	84,528
Greater Pine Island	12,259	13,877	15,708	17,781	20,127	22,795
Island Water Association	8,254	8,509	8,772	9,042	9,322	9,605
Lehigh Acres (FGUA)	21,430	29,059	39,404	53,431	72,452	98,298
Lee County Utilities	216,343	233,637	252,314	272,484	294,267	317,567
Pine Lake	3,322	3,322	0	0	0	0
Self-Supplied (DSS)	68,566	64,517	60,707	57,122	53,749	40,088
<b>Lee County Total</b>	<b>549,441</b>	<b>606,950</b>	<b>671,920</b>	<b>753,274</b>	<b>850,561</b>	<b>957,100</b>
<b>LWC Planning Area Total</b>	<b>910,375</b>	<b>994,777</b>	<b>1,090,633</b>	<b>1,209,052</b>	<b>1,349,288</b>	<b>1,506,233</b>

**Table 12.** Public water supply and domestic self-supply projections of population



**Figure 23:** Current service areas for water services

Strategies related to water and wastewater focuses on energy costs and efficiencies.  
Local governments can take actions to:

<b>Acquire land</b> for flood/water supply. +
Acquire land for <b>recharge</b> . +
<b>Agricultural water reuse</b> .
<b>Reduce local GHG emissions</b> .
Build <b>climate-friendly landscaping</b> into codes and educate homeowners.
Capture <b>digester gases</b> from wastewater reclamation plants and use them to produce electricity.
<b>Change ordinances</b> that require vegetation such as turf grass.
<b>Channel water</b> from impervious to pervious areas.
<b>Charge more for certain uses</b> .
<b>Charge more for treated water</b> similar to Sarasota.
Use and encourage use of <b>cisterns/rain barrels</b> .
<b>Comprehensive planning</b>
<b>Conservation</b>
<b>Conservation education</b>
Consider climate change in <b>water supply planning</b> .
Control <b>fertilizer</b> use. +
Control <b>invasive exotic</b> species.
<b>Control sprawl</b> .
Create <b>redundancy</b> in water supply.
<b>Desalinization</b>
Maintain <b>drinking water standards</b> . +
Engage in <b>drought preparedness planning</b> .

Encourage <i>composting and mulching</i> to reduce irrigation. +
Identify <i>alternative water sources</i> .
<i>Identify conflicting policies</i> between programs.
Improve plant efficiency through the installation of more <i>energy efficient motors and variable frequency drives on water pumps</i> .
Improve water distribution systems and <i>leak detection</i> and management.
Improved system of <i>retaining rainwater</i> .
Increase <i>stormwater management capacity</i> .
<i>Increase tree cover</i> to reduce evaporation from ground.
Install <i>rainfall sensors</i> to reduce automatic irrigation.
<i>Limit development</i> .
<i>Minimize impervious surfaces</i> to increase recharge.
<i>Minimize use of potable water for irrigation</i> . +
<i>Protect groundwater</i> sources. +
<i>Reduce runoff</i> into streams.
<i>Reinforce</i> existing infrastructure.
Re-price water on a <i>sliding scale</i> .
Require County use of <i>climate-friendly landscaping</i> .
<i>Reservoir(s)</i>
<i>Restore natural accretion</i> processes.
Use <i>native plants</i> in landscaping. +
Use of <i>grey water for irrigation</i> .
Use of <i>reclaimed water for irrigation</i> . +
Use <i>secondary water</i> from treatment plants for irrigation.

Replace irrigation with *water reuse* on public lands.

**Table 13.** Resiliency strategies to address water and wastewater

A number of water planning resource organizations are listed in the Water Resource chapter. Other sources of information about water and wastewater management include the EPA through its Energy Star Program [[http://energystar.gov/index.cfm?c=government.bus\\_government\\_local](http://energystar.gov/index.cfm?c=government.bus_government_local)] and its Office of Wastewater Management [[www.epa.gov/owm](http://www.epa.gov/owm)]; the Florida Department of Environmental Protection's Office of Wastewater Management [[www.dep.state.fl.us/mainpage/programs/wastewater.htm](http://www.dep.state.fl.us/mainpage/programs/wastewater.htm)]; the Florida Water Environment Association [[www.fwea.org](http://www.fwea.org)]; and the Water Environment Federation [[www.wef.org/Home](http://www.wef.org/Home)].

### **What Lee County Government Can Do to Increase Climate Change Resilience in Waste Management**

The collection, transportation and ultimate disposal of municipal household waste can be very energy intensive. Land use and transportation facilities are a very important factor in the cost of garbage collection. More dense urban environments may allow collection fleets to travel fewer miles to reach the collection capacity of the vehicle. Less dense land use patterns require collection vehicles to travel larger distances to fill vehicles to capacity. Landfill and/or incineration facility location can also influence the energy consumed and thus the cost of transporting municipal waste. These types of facilities are often unwanted land uses subject to local residents' opposition and thus are often located in areas removed from concentrated human populations.

Considering the greenhouse gas emissions required to collect and transport solid waste, it is important to offer strategies to reduce municipal waste and adapt to changing climactic conditions. Consumers should be aware that the many relatively small components of the national solid waste stream add up to millions of tons. One of the easiest and most effective strategies to reduce greenhouse gases produced from rubbish collection and transport is the promotion of a reduction in the amount of waste stream that must be collected. This can be accomplished in a number of ways and must be examined from the perspective of the full life cycle of products, materials and lawn vegetation/plants that ultimately produce waste. First, consumers should actively seek to minimize product packaging. This includes the packaging of the packaging (i.e. plastic and paper bags consumers use to "contain" materials purchased). Second, consumers should consider the life expectancy of a product prior to purchase. The longer the product lasts, the longer it stays out of the waste stream. Third, consumers should evaluate if products could be reused for other activities. Fourth, consumers should consider separating wastes by type. Food/agricultural wastes, landscape trimmings and yard wastes can easily be composted at the point of consumption (for residential consumers). Composting at the point of consumption can greatly reduce the amount of material that is collected and transported to either a landfill or waste to energy plant. The reduction in material generated can increase the number of garbage producers serviced per truck and thus reduce greenhouse gas emissions generated by the collection fleet.

Consideration should also be given to one time projects such as home construction, remodeling, replacement of building systems and materials, some fabrication and the wastes associated with those activities. Steps should be taken to reduce the waste stream generated from construction activities. The US Green Building Council's Leadership in Energy and Environmental Design (LEED®) certification framework encourages the reuse of building materials, use of recycled materials and the reduction and diversion of waste materials from the solid waste stream that is to be collected by waste haulers.

One time projects such as reroofs can contribute significantly to the waste stream. According to the Asphalt Roofing Manufacturers Association, over 12.5 billion square feet of asphalt shingle products are manufactured annually. That is enough to roof more than 5 million homes. Four out of five homes are roofed with asphalt shingles. [http://www.asphaltroofing.org/resources\\_faq.html](http://www.asphaltroofing.org/resources_faq.html). If we assume all 12.5 billion square feet of asphalt shingles are produced for reroofing work and the project includes a complete tear off of the existing finished roofing materials and underlayment and that each 100 square feet of asphalt roofing material weighs 240 pounds, then the estimated national waste stream generated by reroofing work would be 30,000,000,000 pounds (12.5 billion/100 square feet\*240 pounds per 100 square feet). This is an enormous annual burden on our solid waste disposal facilities.

Another consideration beyond the greenhouse gases emitted from the collection, transportation and processing of waste is the embodied-energy of materials. This concept acknowledges that it takes energy to harvest/extract raw materials for production, process transport and install and/or consume materials. If products consume less raw materials (less packaging or longer duration of use) or are reused then there is less energy input in the creation of additional products. Lee County's current solid waste collection system is separated into three parts 1) non-recyclable household waste 2) recyclable household waste and 3) yard (vegetative) waste. These are collected from source producers (such as individual households) and transported to the waste-to-energy plant located at 10500 Buckingham Road. At the facility, non-recyclable materials and yard waste are incinerated to generate electricity. The single stream recyclable materials are separated into their individual components. Components such as milk jugs, laundry bottles, steel cans, aluminum cans, cardboard and paper are separated and compressed into bundles. These bundles are sold on the open market to help offset the cost of waste collection.

In the 2009 fiscal year, the County's waste-to-energy plant generated approximately 355,000 megawatts of electricity. Of this, 60,000 megawatts were consumed by the facility and 295,000 megawatts were feed into the grid and sold to electric utility rate payers. The combustion of household waste reduces the volume of material that needs to be land filled by 90 percent. The combustion of waste also reduces the production of gases with high global warming potentials, such as methane. These gases are produced from the anaerobic decomposition of organic materials such as food waste. The combustion of these wastes at the waste to energy facility eliminates this process and the high global warming potential gases that are produced in the process.

Waste management tools to conserve energy and reduce GHG emissions focus mainly on reducing, recycling, and reusing waste. Reduction (often called waste prevention or source

reduction) programs address consuming and throwing away less – that is, they prevent the generation of waste. Strategies include purchasing durable, long-lasting goods; seeking products and packaging that are as free of toxins as possible; and redesigning and purchasing products that use less raw material in production, have a longer life, or can be reused.

Reuse programs promote selling, repairing, or donating products to charity and community groups. Reusing products can be better than recycling because the item does not need to be reprocessed before it can be used again. “Up-cycling” is a growing trend in which materials that have been used for their primary purpose are made into something else and are repurposed. Examples include items like wallets and purses made from durable plastic wrappers that are cleaned and sewn together, or clothing and home décor items made from cloth grain and flour sacks. EPA estimates that, nationwide, curbside recycling programs, along with drop-off and buy-back centers, resulted in a diversion of about 32 percent of the nation’s solid waste in 2005

. Composting, another form of recycling, involves the controlled biological decomposition of organic matter, such as food and yard wastes, into humus that can be used in vegetable and flower gardens, landscaping, and many other applications. Lee County currently collects all yard waste from residences and converts it to mulch, which is then provided free of charge to County residents at several locations. Use of mulch in residential landscaping, in turn, helps hold moisture in soil, reducing the need for irrigation.

Buy supplies made with <i>recycled content</i> . +
Consider <i>leasing programs</i> to ensure reuse and recycling.
<i>Donate used equipment</i> , along with magazines and publications, to schools or other organizations.
<i>Educate businesses and residents</i> on waste reduction, reuse, and recycling strategies and their benefits.
Enact <i>purchasing guidelines</i> that emphasize materials and products with recycled content. +
Establish a <i>Pay-As-You-Throw</i> (PAYT) Program (an EPA initiative that asks households to pay a variable rate depending on the amount of waste they throw away. [ <a href="http://www.epa.gov/osw/conserves/onthe-go/">www.epa.gov/osw/conserves/onthe-go/</a> ]).
Establish a <i>Recycle on the Go</i> program (an EPA initiative [ <a href="http://www.epa.gov/epaoswer/non-hw/payt/">www.epa.gov/epaoswer/non-hw/payt/</a> ]). The program involves placing recycling containers where large numbers of people gather, such as parks, stadiums, transportation hubs, special event venues, and shopping centers.
Establish an <i>internal program to recycle</i> paper, plastic, metal, and other products, including printer ink cartridges. +
Expand <i>community recycling</i> programs. For example, establish a large trash pick-up day and

extend recycling to include organic and yard debris collection and composting. +
For waste that must be land-filled, <i>capture the resulting methane</i> and utilize it as a clean, renewable source of energy. +
Implement and educate the public on <i>penalties for non-compliance</i> with recycling programs.
Purchase and use <i>refillable pens</i> .
Require that county fleet facilities implement or improve <i>recycling programs for tires, batteries, brakes, solvents, and oils</i> . +
Require that debris collected through trimming trees and cutting grass on public property (parks, medians, around government buildings) be <i>composted and reused as mulch</i> .
Require use of <i>durable coffee mugs, plates, and utensils</i> in by the County in offices and at meetings.
Set <i>recycling goals</i> and monitor results.
Set up a <i>paint collection program</i> and donate the paint to a local charity for distribution to needy families.
Use <i>two-sided printing and copying</i> . +

**Table 14.** Resiliency strategies to address waste management

In Florida, the Department of Environmental Protection, through its Division of Waste Management [[www.dep.state.fl.us](http://www.dep.state.fl.us)], offers information and technical assistance on recycling programs. Division programs include the Recovered Materials Dealers Certification Program, the Construction and Demolition Debris Facilities Reporting Program, and the Green Lodging Program that requires lodging facility improvement in the areas of communication, water conservation, energy efficiency, waste reduction, and clean air practices. Financial programs to encourage recycling include the Innovative Recycling and Waste Reduction Grants Program, a loan program for businesses that engage in recycling; and a Recycling and Reuse Business Assistance Center [[www.dep.state.fl.us](http://www.dep.state.fl.us)]. The EPA also offers information about programs to reduce, reuse, and recycle wastes [[www.dep.state.fl.us/mainpage/programs/waste.htm](http://www.dep.state.fl.us/mainpage/programs/waste.htm)] and sponsors a number of waste management programs – the Landfill Methane Outreach Program [[www.epa.gov/lmop](http://www.epa.gov/lmop)], WasteWise [[www.epa.gov/epaoswer/non-hw/reduce/wstewise/climate](http://www.epa.gov/epaoswer/non-hw/reduce/wstewise/climate)], and the Responsible Appliance Disposal Program [[www.epa.gov/ozone/snap/emissions/radp.html](http://www.epa.gov/ozone/snap/emissions/radp.html)].

Addition resources on waste reduction, reuse, and recycling include Florida’s America Recycles [[www.dep.state.fl.us](http://www.dep.state.fl.us)], the International City/County Management Association [[www.icma.org](http://www.icma.org)], the Local Government Commission [[www.lgc.org](http://www.lgc.org)], the National Recycling Coalition [[www.nrc-recycle.org](http://www.nrc-recycle.org)], Recycle Florida Today [[www.recyclefloridatoday.org](http://www.recyclefloridatoday.org)], the Southern Waste

Information Exchange [[www.wastexchange.org](http://www.wastexchange.org)], and the University of Florida TREEO Center [[www.treeo.ufl.edu/sw](http://www.treeo.ufl.edu/sw)].

## **What Lee County Government Can Do to Increase Climate Change Resilience in Economic Development**

Local and regional economic development organizations can offer industry recruitment incentives and entrepreneurial assistance programs to attract businesses involved in the emerging clean energy technology sector:

- Help businesses take advantage of the tax refund incentive that Enterprise Florida (the state's primary economic development organization: [www.eflorida.com](http://www.eflorida.com)) offers to attract new and expanding businesses in selected targeted industries. Alternative energy is among the targeted industries in the Emerging Technologies cluster. Described below under **Renewable, Green Energy**, the Florida Energy Office also offers state incentives for the use of renewable energy.
- Encourage developers to utilize the Florida Community Loan Fund ([www.greencommunitiesonline.org/about/programs/florida.asp](http://www.greencommunitiesonline.org/about/programs/florida.asp)), a joint initiative of the Florida Green Building Council ([floridagreenbuilding.org](http://floridagreenbuilding.org)) and Enterprise Partners, Inc., through its Green Communities Initiative ([www.greencommunitiesonline.org](http://www.greencommunitiesonline.org)). The two have joined forces to invest more than \$2.7 million to help build or renovate at least 200 affordable green homes in Florida that promote health, conserve energy and natural resources, and provide easy access to jobs, schools, and services. Incentives include more than \$2.5 million in discounted green loans to developers of affordable residential or supportive housing; \$200,000 in grants to help cover costs associated with building green; technical assistance at no cost through the Florida Solar Energy Center ([www.fsec.ucf.edu](http://www.fsec.ucf.edu)); and competitively priced equity through the Low-Income Housing Tax Credit.
- Work with the farming community, landowners, and conservation organizations to establish a green payment program that compensates farmers for environmental services provided by their land, thereby providing another source of income. Those services can include carbon sequestration, whereby energy companies begin to purchase carbon credits in the open market, paying farmers to help mitigate climate change by planting grasses or trees or using no-till planting techniques that leave the soil largely undisturbed and trap carbon in the ground instead of releasing it into the atmosphere. Forest land is also an important part of the carbon trading market. The Florida Forestry Association ([www.floridaforest.org](http://www.floridaforest.org)), which helps landowners market carbon sequestration to buyers seeking to reduce their greenhouse gas emissions, estimates that Florida's forests sequester 5.9 million tons of carbon annually.

Additional resource organizations for attracting green technology business include Ceres [[www.ceres.org](http://www.ceres.org)], a national network of investors, environmental organizations, and other public interest groups working with companies and investors to address sustainability challenges such

as global climate change, and Capital E [[www.cap-e.com](http://www.cap-e.com)], which provides consulting, technology assessment and deployment, and advisory services to firms and investors in the clean energy industry. The American Farmland Trust [[ecosystemmarketplace.com](http://ecosystemmarketplace.com)] provides information on green payments and agriculture's role in reaching climate change goals, including offsetting carbons, growing biofuels, and generating alternative energy such as wind and solar power.

## What Lee County Government Can Do to Increase Climate Change Resilience for Natural Systems and Resources

Adopt protections of <i>critical biogeochemical zones</i> .
Measures to <i>reduce local GHG emissions</i> .
Allow <i>coastal wetlands</i> to migrate inland.
Build <i>fish hatcheries</i> .
Collect data on and map <i>existing conditions</i> . +
Conservation <i>land acquisition</i> . +
<i>Controls/restrictions</i> on growth.
Create <i>dunes</i> . +
Design estuaries with <i>dynamic boundaries and buffers</i> .
Develop <i>GIS-based decision-making/visualization tools</i> .
Developing programs that <i>facilitate species migration</i> (for example, planting foods and providing shelter for birds whose habitat is covered with water).
Establish and use <i>land exchange</i> programs.
Establish <i>early warning sites</i> and gather baseline data.
<i>Establish funds</i> for land purchase. +
Establish <i>living shorelines</i> .
Establish <i>migration routes</i> for wildlife. +
Establish <i>seed banks</i> .

Establish <i>strong laws</i> to protect habitat.
<i>Explicitly indicate</i> in Comprehensive Plan which areas will retain natural shorelines.
<i>Fertilizer regulation.</i> +
<i>Habitat protection/retention</i> +
Implement fishery and coastal resource <i>management policies that incorporate the likely impacts</i> of global warming on marine food chains, marine life, and marine ecosystems, including coral reefs.
Improve <i>reef/marine management.</i>
Improve <i>site planning controls.</i> +
Incorporate wetland protection into <i>infrastructure planning.</i>
Incorporate wetland protection into <i>transportation planning.</i>
<i>Restore mangroves.</i>
<i>Minimize habitat alteration.</i>
Monitor fish catches and <i>adjust limits.</i>
Plant submerged <i>aquatic vegetation.</i>
Prohibit <u>new</u> <i>bulkheads.</i>
Promote <i>catch and release</i> fishing. +
Regulate import of <i>exotics.</i> +
Remove invasive species and <i>restore native</i> species. +
Restore <i>natural inlets</i> and accretion.
<i>Seagrass</i> protection and restoration. +
Stop unchecked <i>commercial fishing.</i>
Use of CLIP, FNAI, etc. to <i>prioritize land purchases.</i> +
Use more climate-resilient landscaping. +

**Table 15.** Resiliency strategies and actions to address natural systems and resources

## What Lee County Government Can Do to Increase Climate Change Resilience using Renewable, Green Energy

Renewable, green energy sources come from natural sources such as the wind, sun, tides, and geothermal heat that are constantly being replenished and will not run out. Examples include electricity generated from solar power, wind power, hydrogen, hydropower, and biomass (the organic matter that makes up plants). Biomass and biofuels can also be used to power transportation. Renewable energy sources are in contrast to energy from fossil fuels, such as coal, oil, and natural gas, which draw on nonrenewable sources that will diminish over time and cannot be re-created. According to the National Renewal Energy Laboratory, most renewable energy comes directly or indirectly from the sun in the form of solar energy that can serve a variety of uses, including heating, cooling, and lighting homes and other buildings, hot water heating, and commercial and industrial uses.

Conduct <i>education programs</i> on the benefits of alternative fuel vehicles.
Create <i>financial incentives</i> for greater use of renewable energy in new construction and in existing buildings.
<i>Generate electricity</i> from landfill or wastewater methane or refuse. +
Install <i>solar thermal and solar photovoltaic</i> systems (systems that use semiconductor materials to convert sunlight to electricity) in government facilities.
Launch <i>green power</i> programs for citizens and businesses.
Require the purchase of <i>energy from renewable, green sources</i> ; purchase renewable energy certificates (a shorter term action). Green energy certificates (also known as green tags or tradable renewable certificates) represent the environmental attributes of power generated from renewable electric plants.
Require use of <i>alternative fuels in county fleets</i> . +

**Table 16.** Resiliency strategies and actions to address renewable, green energy

In Florida, a principal resource for information about renewable fuel sources is the Florida Energy Office ([www.dep.state.fl.us/energy](http://www.dep.state.fl.us/energy)), the state’s primary center for energy policy. In addition to developing and implementing Florida’s energy policy, the Energy Office coordinates all federal energy programs delegated to the state. Under the state’s Energy Future program, the office is also focusing on advancing clean energy sources, energy conservation, and efficiency through the promotion of hydrogen power, solar energy, bio-based fuels, and clean vehicles. As a part of this focus, the Energy Office maintains a Directory of Biofuels (biodiesel and ethanol) Retailers in Florida and offers a number of financial incentives to businesses, organizations, and residents seeking to use renewable energy technologies

([www.dep.state.fl.us/energy/incentives.htm](http://www.dep.state.fl.us/energy/incentives.htm)). Those incentives include a Solar Energy Systems Rebate Program, a Renewable Energy Technologies Grant Program, a Renewable Energy Technologies Tax Incentives Program, and the Florida Farm to Fuel Grant Program.

The Department of Agriculture and Consumer Services, through its Florida Farm to Fuel Program ([www.floridafarmtofuel.com](http://www.floridafarmtofuel.com)), is assisting Florida farmers and ranchers with the production of biofuel crops to help reduce the nation's dependency on foreign oil. The department is partnering with the Florida Department of Financial Services to explore how Florida's economy could be affected by climate change and the state's opportunities to expand renewable energy sources ([www.floridaclimatechange.com](http://www.floridaclimatechange.com)). The Department of Agriculture and Consumer Services also sponsors an annual Farm to Fuel Summit ([www.floridafarmtofuel.com/summit\\_2007.htm](http://www.floridafarmtofuel.com/summit_2007.htm)).

At the national level, the EPA and the U.S. Department of Energy provide information on renewable, green power. EPA programs include the Green Power Partnership ([www.epa.gov/greenpower](http://www.epa.gov/greenpower)), which encourages organizations to buy green power in order to decrease the environmental impacts associated with conventional electricity use and the Landfill Methane Outreach Program ([www.epa.gov/lmop](http://www.epa.gov/lmop)). EPA also offers fact sheets on biofuels ([www.epa.gov/SmartwayLogistics/growandgo/info.htm](http://www.epa.gov/SmartwayLogistics/growandgo/info.htm)) and Renewable Energy Pollution Prevention ([www.epa.gov/solar](http://www.epa.gov/solar)), a web site addressing the pollution prevention benefits of using renewable energy and ways to obtain electricity from green power marketers and utilities. The Department of Energy's Green Power Network ([www.eere.energy.gov/greenpower](http://www.eere.energy.gov/greenpower)), operated and maintained by the National Renewable Energy Laboratory ([www.nrel.gov/learning](http://www.nrel.gov/learning)), provides news and information on green power markets and related activities. The Clean Cities Program ([www.eere.energy.gov/cleancities](http://www.eere.energy.gov/cleancities)), another Department of Energy initiative, works with a network of volunteer coalitions that develop public/private partnerships to promote alternative fuels and vehicles, fuel blends, fuel economy, hybrid vehicles, and idle reduction. Organizations providing green power in each state are listed at [www.eere.energy.gov/greenpower/buying/buying\\_power.shtml](http://www.eere.energy.gov/greenpower/buying/buying_power.shtml).

Additional renewable, green energy resource organizations in Florida include the Florida Center for Renewable Chemicals and Fuels [<http://frcr.ifas.ufl.edu>], the Florida Energy Commission [[www.floridaenergycommission.gov](http://www.floridaenergycommission.gov)], the Florida Hydrogen Initiative [[www.h2florida.org](http://www.h2florida.org)], the Florida State Chapter of the Energy Services Coalition [[www.escperform.org/chapters/FL/resources.htm](http://www.escperform.org/chapters/FL/resources.htm)], the Florida Solar Energy Center [[www.fsec.ucf.edu](http://www.fsec.ucf.edu)], and the University of Florida Institute of Food and Agricultural Sciences Living Green programs [[http://livinggreen.ifas.ufl.edu/energy/renewable\\_energy.html](http://livinggreen.ifas.ufl.edu/energy/renewable_energy.html)]. Additional resource organizations are the Alternative Fuels Data Center [[www.afdc.doe.gov](http://www.afdc.doe.gov)], the American Solar Energy Society [[www.ases.org](http://www.ases.org)], Apollo [[www.apolloalliance.org](http://www.apolloalliance.org)], Electric Drive Transportation Association [[www.electricdrive.org](http://www.electricdrive.org)], Fuel Economy [[www.fueleconomy.gov](http://www.fueleconomy.gov)], Renewable Choice Energy [[www.renewablechoice.com](http://www.renewablechoice.com)], the Renewal Energy Policy Project [[www.repp.org](http://www.repp.org)], and the U.S. Federation of Public Interest Research Groups [[www.uspirg.org/issues/new-energy-future](http://www.uspirg.org/issues/new-energy-future)].)

## **What Lee County Government Can Do to Increase Climate Change Resilience in Transportation**

As the contributor of 40 percent of Florida's GHG emissions, the state's transportation sector needs to address mobility and local government fleet emissions as reduction strategies.

Transportation-related strategies that should be used in combination to reduce GHG emissions include reducing vehicle miles of travel (VMT) and trip frequency, increasing vehicle efficiency, and using biofuels (providing a net reduction in GHG can be achieved). Due to land development patterns in Lee County, per capita VMT is higher than many other urbanized areas. While improved vehicle efficiency, increased use of hybrid and electric vehicles, and technological advances are expected to help reduce the rate of growth of VMT, modifying land use development patterns to reduce sprawl and facilitate proximate complementary land uses, combined with increased availability of local and long-distance mass transit services, will be needed to achieve a reduction in VMT while maintaining economic sustainability.

### ***Mobility***

Mobility issues in Florida are directly linked to land use planning – where development is located and the proximity of daily needs (shopping, job centers, and schools) relative to where people live. The more removed and separated those uses are, the further and more often people have to drive each day, thus making the use of alternative forms of transportation less likely. This means that to reduce GHG emissions, communities can make a big difference by changing local zoning and planning regulations and establishing incentive programs to enable and promote the creation of more walkable, mixed-use, and compact developments that support transit, walking and cycling, and that reduce the need to drive to take care of daily needs. Those strategies should be coupled with others calling for interconnected streets that provide additional and more direct routes.

Building regionally integrated transit systems will be an important part of sustaining economic vitality in Florida's metropolitan regions, enhancing the economy of the entire state. Clustering development around transit stations or stops improves the efficiency of a transit system, allowing for higher-quality service, which, with supportive planning and development policies, increases property values.

Compact development is walkable and cyclable. It encompasses residential and commercial development and can be adapted to urban, suburban, and even rural settings. Single-family houses, townhomes, and apartments all have a place in compact development. Compact development means neighborhoods or employment centers with most of all of the following:

- concentrations of population and/or employment;
- medium to high densities appropriate to context;
- a mix of uses;
- interconnected streets;
- creative approaches to parking, including “park once” strategies;
- pedestrian-, bicycle-, and transit-friendly design; and

- access and proximity to transit.

Transit tied to land use also provides environmental benefits. Developing around transit service will help protect urban areas from underdevelopment, and rural and environmentally sensitive areas from overdevelopment. By reducing driving, developing around transit can also have significant climate change benefits. Compact development patterns with transit service can reduce carbon emissions from 20 to 40 percent in comparison to auto-only development patterns.

Climate change will directly affect transportation primarily through increases in severe types of weather and climate extremes. Climate warming over the next 50 to 100 years will be manifested by increases in very hot days and heat waves, increases in average temperatures, rising sea levels coupled with storm surges and land subsidence, more frequent intense precipitation events, and increases in the intensity of strong hurricanes. The impacts will vary by mode of transportation and region, but they will be widespread and costly in both human and economic terms and will require significant changes in the planning, design, construction, operation, and maintenance of transportation systems (Transportation Research Board 2008).

Transportation professionals should acknowledge the challenges posed by climate change and incorporate current scientific knowledge into the planning, design, construction, operation, and maintenance of transportation systems. Every mode of transportation and every part of Lee County will be affected as climate change poses new and often unfamiliar challenges to infrastructure providers (Transportation Research Board 2008).

“Special Report 290: Potential Impacts of Climate Change on U.S. Transportation”—the report of a study conducted by a committee of experts under the auspices of the Transportation Research Board and the Division on Earth and Life Studies of the National Research Council—makes the case that focusing on the problem now should help avoid costly future investments and disruptions to operations (Transportation Research Board 2008).

One response to the threat of inundated transportation infrastructure is simply to elevate it to keep pace with the sea level rise. While elevation may be less expensive than letting rising waters wash out entire highways, it is expensive. One estimate put the average cost of elevating roads at \$2 million per mile (Dean 2007b). Approximately 862 miles of roadway in Lee County are at or below 3 feet of elevation, including 44 miles of primary highways and 36 miles of named state routes. The cost of rebuilding and elevating just these roads can sum to over \$495,590,000. This estimated total of road miles does not take into account the miles of city streets in Lee County’s vulnerable areas that would need to be elevated, nor does it consider the many additional miles and lanes of roads that will likely be built as Lee County’s population increases over the next 50 to 100 years.

Elevating roads, however, may cause other problems. Streets are typically built lower than surrounding residential and commercial property so that water from the land can drain into the street. Elevating the roads can prevent this drainage and put flooding back onto the adjacent lands. In such cases, it becomes necessary to raise surrounding land along with the street, so that relative engineered heights are preserved (Titus 2002).

The past several decades of historical regional climate patterns commonly used by transportation planners to guide their operations and investments will no longer be a reliable guide for future plans. In particular, future climate will include new classes (in terms of magnitude and frequency) of weather and climate extremes, such as record rainfall and record heat waves, not experienced in modern times (Transportation Research Board 2008). Decisions transportation professionals make today, particularly those related to the design and retrofitting of existing transportation infrastructure or the location and design of new infrastructure, will affect how well the system adapts to climate change far into the future (Transportation Research Board 2008).

***Inventory Critical Infrastructure***

Potentially, the greatest impact of climate change on Lee County’s transportation system will be flooding of coastal roads, bridge approaches and causeways because of a rise in sea level coupled with storm surge and exacerbated in some locations by land subsidence. The vulnerability of transportation infrastructure to climate change, however, will extend well beyond coastal areas. Railways, transit systems, and airport runways may also be flooded by interior precipitation-driven floods. Therefore, federal, state, and local governments, in collaboration with owners and operators of infrastructure such as airports, and private railroad and pipeline companies, should inventory critical transportation infrastructure to identify whether, when, and where projected climate changes in particular regions might be consequential (Transportation Research Board 2008).

***Incorporate Climate Change into Investment Decisions***

Public authorities and officials at various governmental levels, and executives of private companies are making short- and long-term investment decisions every day that have implications for how the transportation system will respond to climate change in the near- and long-terms. Transportation decision makers have an opportunity now to prepare for projected climate changes. State and local governments and private infrastructure providers should incorporate climate change into their long-term capital improvement plans, facility designs, maintenance practices, operations, and emergency response plans. Table 18 lays out a six step approach for determining appropriate investment priorities (Transportation Research Board 2008).

<b>Decision Framework for Transportation Professionals to Use in Addressing the Impacts of Climate Change on Transportation Infrastructure</b>
1. Assess how climate changes are likely to affect various part of the County and modes of transportation.
2. Inventory the transportation infrastructure essential to maintaining network performance in light of climate change projections to determine whether, when, and where their impacts could be consequential.
3. Analyze adaptation options to assess the trade-offs between making the infrastructure more robust and the costs involved. Consider monitoring as an option.
4. Determine investment priorities, taking into consideration criticality of the

infrastructure components as well as opportunities for multiple benefits (e.g., congestion relief, removal of evacuation of route bottlenecks).
5. Develop and implement a program of adaptation strategies for the near and long-terms.
6. Periodically assess the effectiveness of adaptation strategies and repeat Steps 1 through 5.

**Table 17.** Decision framework for transportation professionals  
For use in addressing the impacts of climate change on transportation infrastructure.  
*Transportation Research Board 2008*

***Adopt Strategic, Risk-Based Approaches to Decision Making***

The significant costs of redesigning and retrofitting transportation infrastructure to adapt to the potential impacts of climate change suggest the need for more strategic, risk-based approaches to investment decisions. Transportation planners and engineers should incorporate more probabilistic investment analyses and design approaches that apply techniques for trading off the costs of making the infrastructure more robust against the economic costs of failure, and should communicate these trade-offs to policy makers who make investment decisions and authorize funding. One model is the California Seismic Retrofit Program, which uses a risk-based approach to analyze vulnerability to earthquakes and criticality of highway bridges to determine priorities for retrofitting and replacement (Transportation Research Board 2008).

***Improve Communication***

Transportation decision makers note that one of the most difficult aspects of addressing climate change is obtaining the relevant information in the form they need to plan and design. Transportation professionals often lack sufficiently detailed information about expected climate changes, and their timing, to take appropriate action. The National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of Transportation (USDOT), the U.S. Geological Survey (USGS), and other relevant agencies are now working together to institute a process for better communication among transportation professionals, climate scientists, and those in other relevant scientific disciplines, and should establish a clearinghouse for transportation-relevant climate change information. In addition, better decision support tools are needed to assist transportation decision makers. Ongoing and planned research at federal and state agencies, and universities that provides climate data and decision support tools should include the needs of transportation decision makers (Transportation Research Board 2008).

***Integrate Evacuation Planning and Emergency Response into Transportation Operations***

Projected increases in weather and climate extremes underscore the importance of emergency response plans in vulnerable locations and require that transportation providers work more closely with weather forecasters and emergency planners, and assume a greater role in evacuation planning and emergency response. Climate extremes, such as more intense storms and more intense precipitation, will require near-term operational responses from transportation providers and greater attention to emergency response in transportation operations and budgets. Transportation agencies and service providers should build on the experience in locations where

transportation is well integrated into emergency response and evacuation plans (Transportation Research Board 2008).

### ***Develop and Implement Monitoring Technologies***

Monitoring transportation infrastructure conditions, particularly the impacts of weather and climate extremes, offers an alternative to preventive retrofitting or reconstruction of some facilities in advance of climate change. Greater use of sensors and other “smart” technologies would enable infrastructure providers to receive advance warning of potential failure due to water levels and currents, wave action, winds, and temperatures exceeding what the infrastructure was designed to withstand. Federal and academic research programs should encourage the development and implementation of these technologies (Transportation Research Board 2008).

### ***Share Best Practices***

As the climate changes, many U.S. locations will experience new climate-induced weather patterns. The geographic extent of Florida and its diversity of weather and climate conditions can provide a laboratory for best practices and information sharing as the climate changes. Drawing on existing technology transfer mechanisms, relevant transportation professional and research organizations should develop a mechanism to encourage sharing of best practices to address the potential impacts of climate change (Transportation Research Board 2008).

### ***Reevaluate Design Standards***

Environmental factors are integral to transportation infrastructure design. Climate change projections indicate that today’s 100-year precipitation event is likely to occur every 50 years or perhaps even every 20 years by the end of this century. Reevaluating, developing, and regularly updating design standards for transportation infrastructure to address the impacts of climate change will require a broad-based research and testing program and a substantial implementation effort. The Transportation Research Board recommended in 2008 that USDOT take a leadership role along with professional organizations in the forefront of civil engineering practice across all modes to initiate immediately a federally funded, multiagency research program. The program should focus on the reevaluation of existing design standards and the development of new standards as progress is made in understanding future climate conditions and the options available for addressing them. A research plan and cost proposal should be developed for submission to Congress for authorization and funding. Until new standards are developed, infrastructure rehabilitation projects in highly vulnerable locations should be rebuilt to higher standards (Transportation Research Board 2008). Lee County could consider adding this recommendation to their legislative agenda.

### ***Include Climate Change in Transportation and Land Use Planning***

One of the most effective strategies for reducing the risks of climate change is to avoid placing people and infrastructure in vulnerable locations. Transportation planners are not currently required to consider climate change and its effects on infrastructure investments. Land use decisions are made primarily by local governments, that have displayed too limited a perspective to account for the broadly shared risks of climate change. Integration between transportation and land use planning is uncommon. Lee County should require that climate change be included as a factor in the development of public-sector, long-range transportation plans; eliminate any

perception that such plans be limited to 20 to 30 years; and require collaboration in plan development with agencies responsible for land use, environmental protection, and natural resource management to foster more integrated transportation–land use decision making (Transportation Research Board 2008).

***Develop New Organizational Arrangements***

The impacts of climate change do not follow modal, corporate, or jurisdictional boundaries, yet decision-making in the transportation sector is based on these boundaries. Current institutional arrangements for transportation planning and operations were not organized to address climate change and may not be adequate for the purpose. Some models of cross-jurisdictional cooperation exist. Among them are regional authorities for specific facilities; regional and multistate emergency response agreements; and state-mandated regional authorities, such as those responsible for air quality improvement. Similar arrangements could emerge to address the effects of sea level rise on coastal real estate and infrastructure, the effects of drought on shipping along inland waterways, and the effects of hurricanes in the Gulf Coast region. However, state or federal incentives may be required to ensure the development of such organizational arrangements at the regional or multistate level. Actions to prepare for climate change can be taken almost immediately. Some steps can be undertaken by local governments and private infrastructure providers. Others depend on federal and state action. In all cases, leadership and continuing commitment are essential (Transportation Research Board 2008).

Adopt and implement land use policies which <i>facilitate mixed-use infill</i> development.
Adopt Comprehensive Plan and Long Range Transportation Plan policies to limit investment in public infrastructure which will be subject to extraordinary <i>future maintenance costs</i> .
Adopt policies to direct public investments in transportation infrastructure to projects which result in <i>energy savings</i> .
<b><i>Allow additional density near transit</i></b> as an incentive to use transit and encourage transit-oriented development.
Create high-occupancy vehicle lanes or other <i>demand management practices</i> such as lane reversals and road pricing (a charge applied for the use of a certain type of road or vehicle or for the use of a road at specific time of day, using for example, a toll, fuel tax, license fee, or congestion fee).
Develop and promote <i>bus rapid transit</i> .
<b><i>Educate employers and their employees</i></b> on the benefits of programs that encourage taking alternative forms of transportation to work and reducing the number of drive-along commuting trips.
Encourage and provide <i>incentives for companies to motivate employees</i> to switch to public transportation, carpooling, biking, and telecommuting and find other ways to save energy and

reduce GHG emissions on the way to and from work.
Encourage and provide <i>incentives to employees who car- or van-pool</i> , use public transportation, or non-motorized transportation (walking or biking) to get to work. Incentives can include free bus passes and reserved parking at county buildings for employees who carpool.
Encourage the use of <i>teleconferencing</i> .
Facilitate telecommuting and use of flex time to <i>reduce the number of peak hour trips</i> . +
Identify target areas for development which contribute to <i>jobs-housing balance</i> .
Implement a community-wide <i>trip reduction program</i> , including car-sharing.
Implement <i>corridor planning</i> approaches integrated with land use plans that encourage mixed land uses and alternate modes of transportation to reduce VMT.
Implement <i>infrastructure programs</i> to make bicycling (bike lanes, conveniently placed bike racks, and bike racks on county buses) and walking more convenient (for example, wider sidewalks and traffic calming). +
Implement use of <i>life cycle cost analyses</i> in transportation planning and decision-making processes.
<i>Improve traffic light synchronization</i> and, although not related to mobility, install energy-efficient traffic lights (for example, advanced light-emitting diode [LED] technology that can reduce power consumption by 90 percent and last ten times longer than incandescent lighting). +
Promote development of “ <i>Park Once</i> ” <i>strategies</i> for activity centers, malls, downtowns and neighborhoods.
Use <i>municipal parking pricing</i> to deter travel by car, particularly single-occupancy vehicles.

**Table 18.** Resiliency strategies to address transportation

***Fleet Emissions***

Actions local governments can take to reduce fleet emissions relate to both conservation and use of alternative fuels. Local governments have access to a wide variety of strategies to reduce fleet emissions, including retiring older, more inefficient and infrequently used vehicles (trucks and buses as well as cars) and purchasing smaller and more fuel-efficient vehicles. Lee County has already made strides in this area, discouraging idle running of vehicles and using automatic cutoffs, and consideration of extended idling time as vehicle abuse. Adaptation of fleet vehicles to use alternative fuels is also being investigated.

<b><i>Educate residents and businesses</i></b> on the benefits of using fuel efficient vehicles.
<b><i>Eliminate SUVs from local government use</i></b> in all non-emergency applications; when SUVs are required, consider purchasing gas-electric vehicles.
Improve vehicle performance through <b><i>enhanced maintenance</i></b> . +
Install <b><i>alternative fueling stations</i></b> for government-owned vehicles.
<b><i>Open local government alternative fueling stations to the public</i></b> .
Promote the use of alternative fuel <b><i>school buses and taxis</i></b> .
Provide <b><i>electric plug-in stations</i></b> at truck stops and marinas and ports.
Provide more bicycles and more fuel-efficient vehicles, such as scooters and full motorcycles, for <b><i>law enforcement personnel</i></b> . +
<b><i>Restrict idling</i></b> at local government buildings. +
<b><i>Restrict idling</i></b> at public facilities. +
Retire older, less efficient, or infrequently used vehicles. When purchasing new vehicles, select ones that are smaller and more fuel-efficient (hybrid or alternative fuel). <b><i>Minimum fuel efficiency standards</i></b> should be part of vehicle purchasing programs.
Use <b><i>car-sharing programs</i></b> where possible instead of a large county fleet, thereby reducing the light-vehicle fleet.

**Table 19.** Resiliency strategies to address the county vehicle fleet

Two principal sources of information on transportation strategies to reduce GHG emissions are the U.S. Department of Energy and the EPA. The website entry to Department of Energy information is [[www.doe.gov/energyefficiency/transportation.htm](http://www.doe.gov/energyefficiency/transportation.htm)]. The department offers a

number of programs, including its FreedomCAR, Fuel Initiative, Clean Cities Program, and Alternative Fuels Data Center. EPA’s transportation-related programs to improve air quality and reduce GHG emissions are listed at [[www.epa.gov/cleanenergy/stateandlocal/support.htm](http://www.epa.gov/cleanenergy/stateandlocal/support.htm)]. Those programs encourage the use of renewable fuels, efficient freight transport, diesel retrofit technologies, idling reduction, and alternatives to single occupancy travel. EPA’s transportation initiatives include the *Best Workplaces for Commuters* program [[www.bestworkplaces.org](http://www.bestworkplaces.org)], which is a voluntary business-government program that provides national recognition and resource tools to employers offering commuter benefits such as free or low cost bus passes, strong telework programs, carpool matching, and vanpool subsidies. (In October 2007, the University of South Florida’s Center for Urban Transportation Research [CUTR] assumed program management responsibilities for the Best Workplaces for CommutersSM program.) Other EPA programs are the National Clean Diesel Campaign, focused on reducing emissions from diesel fleets, and the SmartWay Transport Partnership that is working to improve the environmental performance of freight operations. EPA also publishes a **Green Vehicle Guide** that provides fuel economy and emissions information for new cars and light trucks. Additional resources are the Center for Clean Air Policy’s Emissions Guidebook [[www.ccap.org/guidebook](http://www.ccap.org/guidebook)] and the U.S Department of Transportation’s Urban Partnership program [<http://ops.fhwa.dot.gov/speeches/ntoc2007>], which is aimed at reducing congestion on the nation’s transportation systems. Metropolitan planning organizations participating in the program commit to pursuing the “Four Ts” – tolling, which involves broad applications of congestion pricing; transit; telecommuting; and technology.

The leading resource organizations with expertise on improving mobility and reducing vehicle miles of travel are listed in the Land Use Planning and Development and Transportation chapters. Additional information on strategies to reduce fleet emissions is available from DEP’s Energy Office [[www.dep.state.fl.us/energy](http://www.dep.state.fl.us/energy)] and many of the organizations listed above under Renewable, Green Energy.

## What Lee County Government Can Do to Increase Climate Change Resilience with Education and Outreach

A sustained, well organized education and outreach effort should serve as the basis for a successful mitigation and adaptation program. Starting with the chief executive, it is important for the County to demonstrate to employees that addressing climate change is an important part of the county’s mission.

Education and outreach activities include the following:

Better <i>distribution</i> of information.
Climate <i>policy integration</i> where federal, state, and local governments work collaboratively.

Conduct a <b>public education campaign</b> about the benefits of reducing GHG emissions to the long-term livability of the community and the state, highlighting steps that residents can take as part of their daily routines.
Create out-of-area coalitions for <b>mutual aid</b> . +
<b>Educate businesses</b> on the environmental (work and community) and operating cost benefits of reducing energy output. Encourage them to take steps to reduce energy use, and provide technical assistance, “how-to” materials, and incentives (for example, utility incentive programs and joint purchasing of green products and services).
Educate homeowners associations regarding <b>climate-friendly landscaping</b> .
Establish <b>climate archives</b> for baseline and tracking data.
Establish <b>early warning sites</b> and gather baseline data.
Establish programs that encourage employees to <b>identify opportunities</b> for emissions reduction and conservation. Promote voluntary programs and provide incentives.
Fund and perform <b>long-term research</b> .
Funding for <b>education programs at all levels</b> .
Hold <b>public information workshops</b> .
<b>Identify barriers</b> to adaptation.
Identify <b>conflicting policies</b> between programs. +
<b>Increase public awareness</b> .
Obtain <b>state/federal grants/loans</b> . +
<b>Partner with community groups</b> to sponsor or cosponsor professional events and activities that raise awareness of global warming and promote opportunities for climate protection.
<b>Partner with utility companies</b> to educate the public on energy efficiency.
<b>Promote green building alternatives</b> through education, taxing incentives, green lending.
Redirect revenues to these issues/ <b>make funding a government priority</b> .
Sponsor or participate in <b>public forums and debates</b> that focus on climate protection (for example, addressing transportation and land use planning, taxation reform, and energy system planning).
Use government and community and civic newsletters, websites, brochures, and other media to <b>inform and motivate the public</b> .
Use pure <b>science/proven information</b> . +
Work with schools to integrate energy efficiency into the <b>curriculum</b> .

**Table 20.** Resiliency strategies to address education and outreach

Resource organizations on education and outreach programs as part of a climate change strategy include the International Council for Local Environmental Initiatives [[www.iclei.org](http://www.iclei.org)] and the U.S. Conference of Mayors [[www.usmayors.org/climateprotection](http://www.usmayors.org/climateprotection)].

The American Association for the Advancement of Science [[www.aaas.org](http://www.aaas.org)] provides materials for schools, including its publication *Communicating and Learning About Climate Change: An Abbreviated Guide for Teaching Climate Change*, from Project 2061 at AAAS, and EPA has a free tool called Climate CHECK that teaches school-age children about climate change and how to assess emissions from their school [[epa.gov/climatechange/wycd/school.html](http://epa.gov/climatechange/wycd/school.html)].

## What Lee County Government Can Do to Increase Climate Change Resilience in Historic Preservation

Historic areas of Lee County include downtown City of Fort Myers, parts of the Town of Fort Myers Beach and Koreshan State Park. The park is on the National historic register. It includes historic structures on the banks of the Estero River, and Mound Key, which is of archaeological significance. Three historic buildings there have been restored. Many of the structures are not at ground level, but are elevated slightly. Historically, builders did this to avoid wildlife, prepare for flooding, take advantage of cross breezes higher off the ground and avoid wood rot. When the buildings were first constructed, handicap accessibility was not considered. Now, remodeling and retrofits have to include compliance with the Americans with Disabilities Act (ADA). Hurricane preparedness was also considered in those restoration efforts, but further restoration has been challenged by limited funds resulting from the downturn in the economy. Mound Key also suffers from erosion and needs stabilization, and not all parcels on the Key have yet been acquired by the state, another pressing need. The state funds the park through collection of fees and redistribution of funds according to an attendance formula.

Pursue adaptive reuse/revitalization/encouragement of <i>reinvestment in historic structures</i>
Provide education and outreach to the public on the <i>importance of preserving historically significant resources</i> .
<i>Elevate</i> historic structures.
Consider using historic buildings for <i>affordable housing</i> .
<i>Discourage sprawl</i> with historic preservation.
<i>Identify climate change resiliency strategies</i> within the comprehensive plan for culturally significant resources (including as properties, structures and communities).
Prioritize government <i>funding for existing historic districts</i> and structures
Structural <i>hurricane hardening</i> for potential increased wind exposure.
Emphasize the uniqueness of places and the creative class as an <i>economic driver</i> .

Emphasize the role of historic preservation in supporting <i>economic development</i> , documented in <i>Economics and Historic Preservation: A Guide and Review of the Literature</i> by Randall Mason, Associate Professor of Architecture at the University of Pennsylvania.
<i>Vegetative planting</i> to prevent or reduce increased erosion of historic parcels and communities
<i>Weatherization</i> of historic buildings. Weatherization means making buildings more energy efficient.

**Table 21.** Resiliency strategies for historic preservation and historic districts

Strategies for increasing the resiliency of historic elements can also be found at the federal level. For the National Historic Trust, for example, the key was to not just undertake building preservation but to look at land-use practices in a broader context. [http://www.architectmagazine.com/preservation/futures-of-the.aspx]

## How Climate Change Resiliency Can be incorporated into the Lee County Comprehensive Plan

The current Lee County Comprehensive Plan (AKA the Lee Plan) does not have explicit language concerning planning for climate change or preparing the County for resilience to future climate changes including sea level rise.

In the Lee Plan, Policy 4.3.3, Site and Building Design, states that, “Local climate and history will dictate the architectural and landscape design and natural methods of cooling and heating will be encouraged. Evaluate Green Building techniques as an alternative way to provide open space.” This could be interpreted as a very subtle encouragement for building design to adapt with changing climate. Policy 13.1.2 and Policy 14.1.3 both provide for using mean sea level as a benchmark when determining the *maximum* height of buildings at the peak of the roof.

### Draft Comprehensive Plan Language for the Lee Plan update

As part of the Charlotte Harbor National Estuary Programs Climate Ready Estuaries regional strategy, the University of Florida Fredric G. Levin College of Law Coastal Development and Ecosystem Change Clinic worked to develop the legal and policy framework that reconciles coastal development with eroding beaches, sea level rise and other threats to the coastal environment in Florida in a project to develop draft Comprehensive Plan language for a coastal jurisdiction in southwest Florida.

The purpose of the UF project was to provide selected model comprehensive planning Goals, Objectives, and Policies (GOPs) to address sea-level rise adaptation in Southwest Florida.

Adapting the results of the project for Lee County use, the following is recommended Comprehensive Plan language for the updating of the Lee Plan.

**Goal 1: [General]** To develop the temporal and spatial context for sea-level rise adaptation planning in the County

- **Objective 1.1: [Spatial Overlay]** To identify the **Vulnerable Area** of the County where the protection, accommodation, and retreat strategies should be used.
  - **Policy 1.1.1:** The County shall use data and analysis to establish a sea level rise (SLR) adaptation overlay district encompassing all areas within the County that are vulnerable to SLR consisting of three coastal zones.
    - § SLR Adaptation Overlay Protection Zone
    - § SLR Adaptation Overlay Accommodation Zone
    - § SLR Adaptation Overlay Relocation Zone
  - **Policy 1.1.2: [SLR Notice]** To require all sellers of real property within the SLR Overlay District to provide **notice** that such structures and properties are located in within the SLR Spatial Overlay
- **Objective 1.2: [Temporal]:** To expand planning horizons for sea-level rise adaptation to capture the anticipated impacts of SLR based on current SLR models
  - **Policy 1.2.1:** Utilize a 50 year planning horizon when considering the adoption of any protection, accommodation, and managed retreat strategy.

**GOAL 2: [Protection.]** To ensure adequate protection of the built environment through soft and hard shoreline stabilization that seeks to maintain a static shoreline position within the County.

- **Objective 2.1: [Inventories]** To identify areas of the built environment vulnerable to sea level rise where shoreline stabilization strategies will be appropriate
  - **Policy 2.1.1: [Protection Strategy]** By 20(15), the County shall develop a **comprehensive shoreline stabilization strategy** to address **protection of the built environment where** it has been determined to be **feasible and in the best interest of the County to protect economic investment and infrastructure.**
  - **Policy 2.1.2: [Soft Stabilization Preferred]** The County shall require the **use of soft shoreline stabilization techniques** unless precluded by engineering or regulatory constraints.
  - **Policy 2.1.3 [Public Interest]:** The County shall **prohibit further hardening** of shorelines **unless found to be in the public interest.**
  - **Policy 2.1.4:** Based on projected rates of sea level rise within the SLR planning horizon the County shall **inventory all existing shoreline stabilization structures** and **determine their capacity to maintain functionality throughout the SLR planning horizon.**
  - **Policy 2.1.5:** The County shall **inventory all public buildings and infrastructure** that are vulnerable to sea level rise within the SLR planning horizon and **determine whether such buildings and structure are suitable for protection through shoreline stabilization.**

**GOAL 3: [Accommodation]:** To accommodate increasing sea levels and the additional flooding that will result by **adapting the built environment** and **enhancing the resiliency of the natural environment** where it is economically and ecologically practicable to do so

- **Objective 3.1: [Built Environment]** To assure that all aspects of the built environment within the accommodation zone can **withstand additional permanent or periodic inundation** based on sea level rise projections through structural and non-structural solutions.
  - **Policy 3.1.1: [Performance Standards]** The County shall require **all new construction** within the Accommodation Zone to adhere to performance standards designed to enable development to withstand permanent and/or temporary inundation due to rising sea levels....
- **Objective 3.2: [Land Use]** To reduce the density and intensity of development and redevelopment in the SLR adaptation overlay district landward of unprotected shorelines
  - **Policy 3.2.1 [Down-planning/Down-zoning]** The County shall limit the residential density within the accommodation zone to no more that \_\_ units per acre. The County shall develop design guidelines that promote compact development and redevelopment that maximizes the use of floodways and flood storage within the zone of accommodation.
  - **Policy 3.2.2: [Limitation on Building Footprint]** The County shall limit the building footprint for all new residential structures within the accommodation zone to ( ) square feet and commercial structures to (\_\_\_\_) square feet.
- **Objective 3.5 [The Natural Environment]** To facilitate coastal ecosystem migration through the maintenance and restoration of adequate open space within the zone of accommodation.
  - **Policy 3.5.1: [Riparian Buffers]** The County shall establish riparian buffers that reflect projected rates of sea level rise within the planning horizon for all tidally influenced waterbodies. Such buffers shall be designed to allow the conversion of adjacent uplands to wetlands while retaining transitional ecotones where ecologically feasible.
  - **Policy 3.5.2: [Conservation Land Acquisition Priority]** The County shall develop priority areas for land acquisition based on their strategic capacity to support coastal ecosystem migration.

**Goal 4: [Managed Relocation]:** Reduce vulnerability in the built environment and preserve coastal ecosystems through the orderly abandonment and /or landward relocation of structures and associated infrastructure

- **Objective 4.1:** To **reduce the density and intensity** of future land use along unprotected shorelines at a rate consistent with projected rates of shoreline recession over the SLR planning horizon
  - **Policy 4.1.1:** Within the managed relocation overlay, the County shall **eliminate new investment in public infrastructure** likely to be inundated due to sea level rise within the planning horizon
  - **Policy 4.1.2** Reduce residential land use densities to no more than \_\_ units per acre and commercial structures to \_\_\_\_ square feet per acre within the “Managed Retreat Zone”

- **Objective 4.2:** To **preserve coastal ecosystems** by ensuring that natural shoreline migration processes may continue unimpeded.
  - **Policy 4.2.1:** All **hard shoreline stabilization** techniques are **prohibited** within Managed Relocation Zone
  - **Policy 4.2.2:** Establish an erosion-based minimum setback for shoreline development based upon the **(annual coastal erosion rate ) x (a planning period representing the economic lifetime of the coastal structure) + (an additional buffer)**
- **Objective 4.3:** To develop programs to encourage properties within the “Managed Relocation Zone” to abandon or relocate structures consistent with projected rates of shoreline recession over the SLR planning horizon
  - **Policy 4.3.1:** **Prioritize and seek to acquire properties** or interests in property within the managed relocation overlay
  - **Policy 4.3.2:** Identify and **establish a land bank** for the purposes of relocating critically important infrastructure and municipal support facilities.
  - **Policy 4.3.3:** Create a **mandatory transferrable development rights** program within the managed relocation overlay that transfers densities and intensities
  - **Policy 4.3.4:** Promote the acquisition of **rolling conservation easements** based on the priorities developed in policy 4.3.1.

### ***Best Policy Practices and Comments:***

The following are references identified by the UF researchers for specific policies recommended above.

**Protection:** *Protection means the use of any means of constructed physical barrier or other managed system to prevent the landward migration of tidally influenced water bodies*

**Vulnerable Area:** The vulnerable area represents the area that encompasses the cumulative geographic reach of all sea level rise impacts projected for the planning horizon(s) as determined through data and analysis

### ***Best policy practices***

**Policy 1.1.2:** *Town of East Hampton, New York – Coastal Erosion Overlay District*

**Policy 1.1.3:** *Texas and Florida*

**Policy 1.2.1: Comment:** *Under Florida law local governments must develop planning horizons based on a 10 year interval for most planning purposes. Some transportation and infrastructure planning occurs on longer planning horizons. Current law does not preclude longer planning horizons should a local government choose to ad Best Policy Practice: The Rockingham Planning Commission recommended the Town of Seabrook, New Hampshire to incorporate a minimum of a 50 year planning horizon and assuming a 1.5 foot rise in sea levels within that*

period, and at least a 3 to 5 foot rise in sea level over 100 years for all basic planning, zoning, and permitting decisions.

**Policy 2.1.4 [Public Interest]: Best Policy Practice:** Sarasota County, Florida prohibited shoreline hardening or the construction of shore protection structures unless it's found to be in the public interest.

**GOAL 3: [Accommodation]: Comment:** Accommodation contemplates a suite of policy tools that emphasize maintaining and adapting components of the built environment to periodic and permanent inundation over time. Accommodation policy also emphasizes retention and expansion of existing and potential floodways to manage flooding and to facilitate coastal ecosystem migration. To a significant extent existing floodplain regulations already contemplate, indeed encourage, accommodation within the built environment. **Best Policy Practice:** The Cape Code Commission Model Floodplain District Bylaws explicitly provides that the regulations are intended to address not only current flood hazards, but future flood hazards based on sea level rise projections.

**Policy 3.1.4: [Performance Standards]: Best Policy Practice:** Cape Code Commission's model bylaws require 1 – 2 feet elevation above BFE

**Policy 3.2.1 [Down-planning/Down-zoning] Best Policy Practice:** St. Tammany Parrish in Louisiana undertook a comprehensive rezoning. Flood prone areas that were previously zoned for residential or commercial development were down-zoned to lesser densities or rezoned for conservation and land uses compatible with periodic inundation.

**Policy 3.2.2: [Limitation on Building Footprint] Best Policy Practice:** The Maine Dune Rule (Code of Maine Rules Chapter 355) **requires planning for two feet of sea level rise** over the next one hundred years. Maine's rule requires that no building taller than 35 feet or having a footprint greater than 2,500 square feet can be constructed within the dune system unless the applicant can demonstrate "by clear and convincing evidence that the site will remain stable after allowing for **a two-foot rise in sea level over 100 years**. The rule explicitly states that "[r]eliance upon an existing seawall is not sufficient as evidence of site stability."

**Policy 3.5.2: [Conservation Land Acquisition Priority] Best Policy Practice:** The State of Connecticut's Coastal and Estuarine Land Conservation Program provides for consideration of landward migration of wetlands due to sea level rise in its land acquisition program priority ranking system. (Note: Florida does not provide for a similar consideration in its own Program)

**Policy 4.1.3: Comment:** This may require downzoning or down planning current densities and intensities with the proposed overlay zone.

**Policy 4.2.1: Best Policy Practice:** Sarasota

**Policy 4.2.2: Best Policy Practice:** *Kaua'i Shoreline Setback, Kaua'i County, Hawaii; Structural lifetime multiplier = 70 or 100 years; Storm and safety buffer = 40 feet*

## **Monitoring and evaluation of results**

The following discussion of monitoring and the monitoring plan for this resiliency plan follow the standards and suggestion outline in Perez and Yohe (2004) for ***Monitoring: Continuing the Adaptation Process.***

The purpose of monitoring is to keep track of progress in the implementation of a resiliency strategy and its various components in relation to the targets. This enables management to improve operational plans and to take timely corrective action in the case of shortfalls and constraints. As part of the management information system, monitoring is an integral part of the function of management, and should be conducted by those responsible for the project/program implementation. The resulting data, in whatever form, must be archived so that they can be readily accessed for internal or external evaluation. Monitoring should be carried out during implementation, as well as during the lifetime of the project. Both the selection of indicators for monitoring and the frequency of monitoring can evolve over time as the resiliency process matures; this evolution may continue as the resiliency process is incorporated into a county's overall policy mix. The most important point is that monitoring continues.

Monitoring and Evaluation (M&E) must go hand-in-hand. In the context of resiliency, evaluation is a process for systematically and objectively determining the relevance, efficiency, effectiveness and impact of a resiliency strategy in light of its objectives. Whereas monitoring is carried out only during implementation, evaluation is carried out during implementation (ongoing evaluation), at the completion of a project (final evaluation) or some years after completion (post evaluation). Much of the evaluation activity can be based on self-assessment of the responsible operational staff, but external evaluation is also a common practice. Formal M&E processes should be practical. In principle, a network of concerned institutions and stakeholders (data suppliers and users) could be established. Increasingly, the trend in this field is towards participatory M&E, which includes the most vulnerable group(s) in decision-making. The concept of a central M&E unit to co-ordinate all of the functions could be established within, or under the jurisdiction of, a strategic government agency (e.g., Public Works, Planning or Environment). While institutional barriers can impede M&E, these barriers can be assessed during project design and addressed during its implementation. Comprehensive resiliency strategies consist of policies, measures and projects. Appropriate M&E processes may be quite different for each strategic level. Furthermore, gaps in the structure and design of the strategy can impede progress toward long-term goals of sustainability. Policies that exist without tangible measures are paper tigers; conversely, projects that exist outside of a clear policy context can be redundant or contradictory. Monitoring for gaps of this sort can pay enormous dividends.

Monitoring alone is useless if the raw data and basic information it generates are not analyzed in the evaluation process. M&E processes depend on carefully developed sets of indicators by which the performance of resiliency activities can be assessed. These indicators provide the basis for before-and-after analyses and describe the effects (positive and negative) of project interventions – anticipated and unanticipated, intended and unintended. Indicators are

quantitative or qualitative measures that can be used to describe existing situations and measure changes or trends over time.

Performance indicators developed by the County will be the criteria for success. In the context of the logical framework approach, at least one indicator should be defined as a performance standard for each resiliency to be reached in order to achieve an objective (GEF 2002). Indicators should include both outputs and outcomes (impacts), with explicit statements of how the indicator demonstrates that the project goal has been met, and what the functional relationship is between a change in the indicator and the outcome of a project.

Exploring the success or failure of the resiliency process depends on more than just the success or failure of implemented projects. More critically, it depends upon the concept of learning by doing. This approach enables users to undertake midcourse corrections in implemented resiliencies, so that they meet their objectives more efficiently; and improve their understanding of the determinants of adaptive capacity so that capacity development activities can be more successful from the start. To accomplish these tasks, two earlier insights can be revisited.

First, establish the necessary criteria for evaluation. Second, the M&E process will eventually have historical evidence of what actually happened over a period of time; this can be compared to the conjectural characterization of future conditions. To learn from mistakes and successes, it is important to combine these insights to: compare actual experience with the initial characterization, and with the criteria; and construct a revised resiliency baseline that describes how the system would have performed in the absence of the implemented resiliency. This revised resiliency baseline will differ from the resiliency baseline. It will be more accurate, based on actual experience and on the evolution of the structural, economic, and political context. This can be critical, since it will suggest whether a resiliency to climate is “swimming uphill” against some non-climatic impediment or “being carried along” by other reforms. Thus, an evaluation could improve the team’s forecasting capability. A review of the criteria used for making the original implementation decision will yield insights about needed changes, and will improve the next resiliency decision.

Participatory processes in support of resiliency can add value and enhance feasibility. Engaging as many stakeholders as possible can democratize the overall process of adapting to climate change, including variability. It follows that participatory M&E can be productive, but care must be taken to note the potential pitfalls. Stakeholder engagement can uncover obstacles, including a healthy degree of initial skepticism on the part of the public about the information provided by the government.

In the context of resiliency, mainstreaming refers to the integration of resiliency objectives, strategies, policies, measures or operations such that they become part of the County’s development policies, processes and budgets at all levels and stages. The idea is to make the resiliency process a critical component of existing development plans. Likely entry points for mainstreaming climate resiliency include: environmental management plans (particularly when they incorporate environmental impact assessments), conservation strategies, disaster preparedness and/or management plans and sustainable development plans for specific sectors (e.g., agriculture, forestry, transportation, fisheries, etc.). Moreover, working through the

determinants of adaptive capacity makes it clear that promoting capacity can complement or even advance the broader objectives of improved economics and sustainable development. The issue is to recognize an opportunity for mainstreaming and to use it.

The ability of resiliency to ameliorate climate impacts is fundamentally path-dependent and site-specific. As a result, a resiliency that works well in one place and time may or may not work in a different place or time. Whether it does or does not is essentially an empirical question, and M&E can inform the framing of such a question. This diversity should not, however, discourage mainstreaming.

While evaluation can occur at any stage in the resiliency process, the final evaluation may require additional funding following the project's completion. To enable the lessons learned to feed back into and inform subsequent actions, it is essential that the necessary resources (e.g., human, financial, technical) be factored in during the project design phase. This step is recommended, but is often neglected.

For successful continuation of the resiliency process, isolated evaluations are not sufficient. The notion of opportunity cost, expressed as monetary units, is really an observation that any action occurs at the expense of another. These costs are diminished if resiliencies complement one another either directly or by promoting synergies across the underlying determinants of adaptive capacity; they are exaggerated when resiliencies contradict and/or create obstacles for each other or with other developmental objectives (maladaptation). Careful evaluation of any resiliency will therefore contemplate the interaction of a suite of resiliencies in the context of a more general pursuit of social and economic objectives.

Current thinking assumes that stand-alone adaptations are neither desirable nor cost-effective. In developing countries, one group of stakeholders responsible for facilitating resiliency includes the international development agencies and donor governments. Like other environmental issues, this group has collectively agreed that climate change resiliency would be cost-effective if mainstreamed into the development processes. As the term "mainstreaming" implies, the approach places environment squarely in the center of development poverty reduction. This approach is warranted because global environmental issues remain marginalized in all but a few countries – even ten years after Rio – leading to conclusion that rather than introducing additional environmental plans at this stage, governments should renew effort on implementing those plans. Note that mainstreaming is not unique to resiliency; it is a policy principle for introducing all multilateral environmental issues onto the policy agenda.

M&E supports opportunistic review of resiliency processes, particularly if a learning-by-doing approach is adopted, and if significantly informed by engaged stakeholders. The stakeholders can be important players in an assessment of the effectiveness of any resiliency strategy or suite of strategies. The stakeholders can provide valuable information about whether the proposed interventions have been successful in achieving the strategic objectives. They also provide insight into how existing social, economic, institutional and political factors have supported or impeded implementation. More importantly, substantial findings from the M&E process will point to corrective action for the resiliency strategies, measures or policies. The inclusion of resiliency into the development mainstream must focus not only on the pre-decision stages of the

process (i.e., project design stage, climate risk assessment), but also on M&E in the implementation and post-implementation stages. Neglecting these important steps can prevent the resiliency process from being an effective management tool. On a larger scale, it could cause the County to miss important opportunities to correct past mistakes and improve current practices.

## Summary Conclusion

In combination, the Lee County Climate Change Vulnerability Assessment (CCVA) and the Lee County Climate Change Resiliency Strategy (CCRS) have addressed resiliency measures and strategies that will integrate the most likely time frame for various climate change impacts in Lee County. The planning horizons for the CCVA and CCRS are the years 2050 and 2100.

Climate change avoidance, minimization, mitigation and adaptation (AMMA) action options are identified and could be developed in order to be implemented based on the timing of the desired management response (prior to or after a climate event has occurred) and the type of action (e.g., physical, technological, institutional). Three different time frames should be considered:

- 1) Reactive responses: immediate responses initiated once climate change impacts are observed;
- 2) *Ad hoc* reactive responses: actions implemented after climate change impacts have been observed; and
- 3) Proactive responses: measures to preserve and protect resources in anticipation of climate change impacts.

The CCRS outlines the processes that can be used to periodically monitor and evaluate: (1) climate-driven changes in Lee County, and (2) the effectiveness of resiliency strategies in lessening the negative impacts of those climate-driven changes. To monitor and evaluate climate-driven changes in Lee County a simple approach can be developed based on readily available information regarding changes in basic climate parameters (e.g., temperature, precipitation, storm intensity, etc.) and observed impacts (e.g., annual occurrence of reproduction for select species, spring flowering dates for plants, etc.). In addition, more-sophisticated “sentinel systems” that track changes in key indicator species and other environmental indicators developed by the CHNEP can be utilized.

The CCRS reflects the need for regular evaluation of resiliency effectiveness and incorporation of newer or better information on climate effects, and will consider the dynamic nature of information and climate interactions, building in a regular process to revisit the plan’s specified priorities and actions. This can take the form of a standing or *ad hoc* workgroup consisting of stakeholders and decision makers to ensure that the plan stays up-to-date and effective.

## Citations

- American Farmland Trust 2007. Cost Of Community Services Studies, Farmland Information Center, One Short Street, Suite 2 Northampton, MA 01060  
[www.farmland.org](http://www.farmland.org)
- 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.
- Beever, III, J.W., W. Gray, D. Trescott, D. Cobb, J. Utley and L. B. Beever 2009. Comprehensive Southwest Florida/ Charlotte Harbor Climate Change Vulnerability Assessment. Southwest Florida Regional Planning Council and Charlotte Harbor National Estuary Program, Technical Report 09-3, 311 pages.
- Beever III, J.W., W. Gray, D. Trescott, D. Cobb, J. Utley, D. Crawford, and D. Hutchinson 2010. Lee County Climate Change Vulnerability Assessment. Southwest Florida Regional Planning Council. 226 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.
- Bradley, J.T. 1972. Climate of Florida. Pages 45-70 in Climate of the States. Environmental Data Service, No. 60-8. Silver Springs, Md.
- California Department of Public Health 2008 Draft Public Health Climate Change Adaptation Strategy *incorporated in the 2009 California Climate Adaptation Strategy*
- 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.
- Cool Roof Rating Council. (Cool Roofs) 2009. What is a Cool Roof?  
<http://www.coolroofs.org/HomeandBuildingOwnersInfo.html> (accessed March 29, 2009)
- Dean, R. 2007b. Personal communication with F. Ackerman, in, 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.
- Doyle, T.W., G.F. Girod, and M.A. Brooks. 2003. Chapter12: 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.
- 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.
- 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.
- Efficient Windows Collaborative. 2009. Solar Heat Gain Coefficient (SHGC). <http://www.efficientwindows.org/shgc.cfm> (accessed March 29, 2009)
- Energy Information Administration 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.
- Environmental Protection Agency 2006. *Emissions and Generation Resource Integrated Database (eGRID), 2006*. Available online at <http://www.epa.gov/cleanenergy/egrid/index.htm27>
- Federal Emergency Management Agency (FEMA) 1998. Homeowner's Guide to Retrofitting: Six Ways to Protect Your House from Flooding. Washington, DC, Federal Emergency Management Agency: 173.
- FEMA 2003. Elevating on the Myakka - A Tale of Two Elevations, Full Mitigation Best Practice Story, Sarasota County, Florida, <http://www.fema.gov/mitigationbp/bestPracticeDetailPDF.do?mitsId=4032>
- FEMA. *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).
- Fiedler, Jeff, Fred Mays, and Joseph Siry, eds. 2001. Feeling the heat in Florida: Global warming on the local level. Orlando: Natural Resources Defense Council and Florida Climate Alliance. 27 pp.
- 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 2007d. Wildfire report, July 10, 2007. Tallahassee, Florida Department of Agriculture and Consumer Services, Forestry Division.
- 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 Institute 2006 Florida Fish and Wildlife Conservation Commission Florida Statewide Environmental Sensitivity Index Maps, <http://ocean.floridamarine.org/esimaps/>

- Florida Natural Areas Inventory (FNAI) 2008.**
- 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.
- Hela, I. 1952.** Remarks on the climate of southern Florida. *Bull. Mar. Sci.* 2(2):438-447.
- Intergovernmental Panel on Climate Change (IPCC) 2001a.** *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. Cambridge UK, Cambridge University Press.
- IPCC 2001b:** *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
- IPCC 2007a.** *Climate change 2007: Synthesis report* (L. Bernstein, P. Bosch, O. Canziani, C. Zhenlin, R. Christ, O. Davidson, and W. Hare et al., CoreWriting 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).
- 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>.
- 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.
- IPCC 2007d.** *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.
- IPCC 2007e.** Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds. Cambridge University Press, Cambridge, UK, 976 pp, 2007. <http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-app.pdf>

- Jordan, C.L. 1973. Climate. Pages II A-1 to II A- 14 in J.J. Jones, R.E. Ring, M.O. Rinkel, and R. E. Smith, eds. A summary of the knowledge of the eastern Gulf of Mexico-1973. State University System of Florida, Institute of Oceanography, St. Petersburg, Florida
- Kirshen, P., M. Ruth, W. Anderson and T. R. Lakshmanan 2004. CLIMB Final Report: Infrastructure Systems, Services and Climate Change: Integrated Impacts and Response Strategies for the Boston Metropolitan Area. Boston, MA, Tufts University, University of Maryland, Boston University, and the Metropolitan Area Planning Council: 165.
- 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.
- 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. Mausel, 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.
- 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.
- National Ocean Economics Program. (2007b). "Fisheries Statistics." Retrieved 27 July, 2007, from <http://noep.mbari.org/LMR/fishSearch.asp>.
- Perez, R. T. And G. Yohe with B. Lim, E. Spanger-Siegfried, D. Howlett, and K. Kishore 2004. Continuing the Adaptation Process Chapter 9 in *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*, Edited by B. Lim and E. Spanger-Siegfried, United Nations Development Programme, Cambridge University Press Pages 205-224.
- 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.
- Riebsame, W.E., W.L. Woodley, and F.D. Davis. 1974. Radar inference of Lake Okechobee rainfall for use in environmental studies. *Weatherwise* 27(5):206-211.

- Rockefeller Foundation 2009, White Paper: Building Climate Change Resilience, Posted: August 4, 2009, <http://www.rockefellerfoundation.org/uploads/files/c9725eb2-b76e-42eb-82db-c5672a43a097-climate.pdf>**
- South Florida Water Management District (SFWMD) Water Resources Advisory Committee 2006. *PICAYUNE STRAND RESTORATION PROJECT PUMP STATIONS PRELIMINARY DESIGN* Power Point Presentation April 6, 2006**
- 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., Fort Myers, Florida**
- SWFRPC 2008 Land Use Impacts SWFRPC, Fort Myers, Florida**
- (SWFRPC 2009. Economic Views 2008: The year in Review, March 2009, Fort Myers, Florida (<http://www.swfrpc.org/content/EcoDev/Views/2009/0309.pdf> )**
- 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.**
- 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. 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.**
- Titus, J. G. and E.M. Strange (eds.). 2008. Background Documents Supporting Climate Change Science Program synthesis and Assessment Product 4.1 Coastal Elevations and Sensitivity to Sea-Level Rise. EPA 430R07004. U.S. EPA, Washington, DC. 354 pp. <http://www.epa.gov/climatechange/effects/coastal/background.html>**
- Titus, J. G. , Eric K. Anderson, Donald R. Cahoon, Stephen Gill, Robert E. Thieler, Jeffress S. Williams (Lead Authors). 2009. Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region. A report by the U.S. Climate Change Science**

- Program and the Subcommittee on Global Change Research. U.S. Environmental Protection Agency, Washington D.C., USA.  
<http://www.climate-science.gov/Library/sap/sap4-1/final-report/default.htm>
- Titus, J. G. 2009 Personal Communication during teleconference review of Beaver, III, J.W., W. Gray, D. Trescott, D. Cobb, J. Utley and L. B. Beaver 2009. Comprehensive Southwest Florida/ Charlotte Harbor Climate Change Vulnerability Assessment. Southwest Florida Regional Planning Council and Charlotte Harbor National Estuary Program, Technical Report 09-3, 298 pages.
- 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
- Transportation Research Board. 2008. Potential impacts of climate change on U.S. transportation. Washington, D.C.: National Research Council . 4 pp.
- Treasure Coast Regional Planning Council (TCRPC) 2005. Sea Level Rise in the Treasure Coast Region, *For Submission to Southwest Florida Regional Planning Council* 1926 Victoria Avenue Fort Myers, Florida 33901 *In Fulfillment of “Local Government Review and Approval of Sea Level Rise Maps “Subagreement Executed October 24, 2002, Extended October 21, 2003 41 pp.*
- 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)
- United State National Oceanic and Atmospheric Administration (USNOAA), Climatic Data Center. 2008. Draft Climate Change handbook. Asheville, NC: NOAA Climatic Data Center.
- 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 (USCCSP) 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 Department of Agriculture (USDA) 2003. Florida Supplements to National Engineering Handbook, Part 652—Irrigation Guide. Washington, D.C., United States Department of Agriculture, Natural Resources Conservation Service.
- USDA 2005. Florida State Agriculture Overview—2005 United States Department of Agriculture: 2.
- United States Environmental Protection Agency (USEPA) 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 (USEPA CRE) 2008. *Draft synthesis of adaptation options for coastal areas*. Distributed at NEP National Meeting, 26 February 2008. 26 pp.

- United States Fish and Wildlife Service. 1999. South Florida multi-species recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia.
- United States Geological Survey (USGS) 2000. National Assessment of Coastal Vulnerability to Future Sea level Rise. Washington, D.C., United States Geological Survey: 2.
- USGS 2007. *NOAA Medium Resolution Digital Vector Shoreline*, Coastal and Marine Geology Program Internet Map Server—Atlantic and East Coast USGS.
- 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 National Oceanic & Atmospheric Administration (USNOAA) (2000). *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.
- USNOAA (2008). *Draft Climate Change Handbook*, National Oceanic and Atmospheric Administration, National Marine Fisheries Service
- USNOAA. (2007b). “National Climatic Data Center.” 2007, from <http://www.ncdc.noaa.gov/oa/ncdc.html>.
- University of Florida Bureau of Economic and Business Research (2009) *Florida County Perspective* -Lee, BEBR, University of Florida, Gainesville, Florida 32611-7145
- Urban Land Institute 2010. *Connecting Florida: Transit and Florida’s Economy*. Washington, D.C. 28pp.
- 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.
- Wood, R. 2006 *Pump Station 362. From Underneath the Mango Tree*. <http://therandymon.com/content/view/109/59/>
- Woodley, W. L., 1970: *Precipitation results from pyrotechnic cumulus seeding experiment*. *J. Appl. Meteor.*, 9, 109-122.
- 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.

## Appendix I. Glossary

**Climate:** encompasses the statistics of temperature, humidity, atmospheric pressure, wind, rainfall, atmospheric particle count and other meteorological elements in a given region over long periods of time.

**Climate Change Adaptation:** is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, an adjustment that moderates harm or exploits beneficial opportunities

**Climate change resilience:** is the capacity of an individual, community, or institution to dynamically and effectively respond to shifting climate impact circumstances while continuing to function at an acceptable level. It is the ability to survive, recover from, and/or live with the effects of climate change. It includes the ability to understand potential impacts and to take appropriate action before, during, and after a particular consequence to minimize negative effects and maintain the ability to respond to changing conditions.

**Protection:** is the use of any means of constructed physical barrier or other managed system to prevent the landward migration of tidally influenced water bodies

**Resilience:** Resilience (in Ecology) means building the capacity of a system to withstand perturbations and shocks and to rebuild and respond to change, including unanticipated change. Resilience (in Planning) as the capacity of a system to absorb disturbance, undergo change and still retain essentially the same function, structure, identity, and feedbacks

**Vulnerable Area:** represents the area that encompasses the cumulative geographic reach of all sea level rise impacts projected for the planning horizon(s) as determined through data and analysis

**Weather:** is the present condition of temperature, humidity, atmospheric pressure, wind, rainfall, atmospheric particle count and other meteorological elements in a given region and their variations over periods up to two weeks.

## Appendix II. 2009 Construction Costs

<b>2009 Construction Bare Unit Costs for coastal armoring</b> (LF = linear foot; CY = cubic yard; SY = square yard) <i>SFWMD</i> <i>2009</i>	<b>Unit</b>	<b>Unit Cost (\$)</b>
Concrete seawalls, reinforced concrete, up to 6' high, include footing and tie-backs, maximum	L.F.	425.00
Concrete seawalls, reinforced concrete, to 12' high, include footing and tie-backs, maximum	L.F.	625.00
Concrete seawalls, pre-cast concrete bulkhead, complete, using 16' vertical piles, includes vertical and battered piles, face panels, and cap	L.F.	660.00
Concrete seawalls, pre-cast concrete bulkhead, complete, using 20' vertical piles, includes vertical and battered piles, face panels, and cap	L.F.	705.00
Steel sheet piling seawalls, steel sheeting, 12' high, shore driven	L.F.	465.00
Steel sheet piling seawalls, steel sheeting, 12' high, barge driven	L.F.	810.00
Steel sheet piling seawalls, crushed stone, placed behind bulkhead by clam bucket	C.Y.	60.50
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, coarse compact sand, 4'-0" high, 2'-0" embedment, includes concrete cap and anchor	L.F.	161.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, coarse compact sand, 4'-0" high, 3'-6" embedment, includes concrete cap and anchor	L.F.	201.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, coarse compact sand, 4'-0" high, 6'-0" embedment, includes concrete cap and anchor	L.F.	275.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, coarse compact sand, 6'-0" high, 2'-6" embedment, includes concrete cap and anchor	L.F.	206.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, coarse compact sand, 6'-0" high, 4'-0" embedment, includes concrete cap and anchor	L.F.	252.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, coarse compact sand, 6'-0" high, 5'-6" embedment, includes concrete cap and anchor	L.F.	330.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, coarse compact sand, 8'-0" high, 3'-6" embedment, includes concrete cap and anchor	L.F.	260.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, coarse compact sand, 8'-0" high, 5'-0" embedment, includes concrete cap and anchor	L.F.	286.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, medium compact sand, 3'-0" high, 2'-0" embedment, includes concrete cap and anchor	L.F.	199.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, medium compact sand, 3'-0" high, 4'-0" embedment, includes concrete cap and anchor	L.F.	259.00

Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, medium compact sand, 3'-0" high, 5'-6" embedment, includes concrete cap and anchor	L.F.	320.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, medium compact sand, 5'-0" high, 3'-6" embedment, includes concrete cap and anchor	L.F.	295.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, medium compact sand, 5'-0" high, 5'-0" embedment, includes concrete cap and anchor	L.F.	355.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, medium compact sand, 5'-0" high, 6'-6" embedment, includes concrete cap and anchor	L.F.	450.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, medium compact sand, 7'-0" high, 4'-6" embedment, includes concrete cap and anchor	L.F.	430.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, medium compact sand, 7'-0" high, 6'-0" embedment, includes concrete cap and anchor	L.F.	480.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, loose silty sand, 3'-0" high, 3'-0" embedment, includes concrete cap and anchor	L.F.	294.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, loose silty sand, 3'-0" high, 4'-6" embedment, includes concrete cap and anchor	L.F.	360.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, loose silty sand, 3'-0" high, 6'-0" embedment, includes concrete cap and anchor	L.F.	425.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, loose silty sand, 4' 6" high, 4'-6" embedment, includes concrete cap and anchor	L.F.	395.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, loose silty sand, 4'-6" high, 6'-0" embedment, includes concrete cap and anchor	L.F.	465.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, loose silty sand, 4'-6" high, 7'-0" embedment, includes concrete cap and anchor	L.F.	550.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, loose silty sand, 6'-0" high, 5'-6" embedment, includes concrete cap and anchor	L.F.	510.00
Breakwaters, bulkheads, residential canal, residential canal, aluminum panel sheeting, loose silty sand, 6'-0" high, 7'-0" embedment, includes concrete cap and anchor	L.F.	570.00
Rip-rap and rock lining, random, broken stone, machine placed for slope protection	C.Y.	77.50
Rip-rap and rock lining, random, broken stone, 3/8 to 1/4 C.Y. pieces, machine placed for slope protection, grouted	S.Y.	163.00
Rip-rap and rock lining, random, broken stone, 18" minimum thickness, machine placed for slope protection, not grouted	S.Y.	118.00
Rip-rap and rock lining, random, broken stone, 50 lb. average, dumped	Ton	44.50
Rip-rap and rock lining, random, broken stone, 100 lb. average, dumped	Ton	63.50

Rip-rap and rock lining, random, broken stone, 300 lb. average, dumped	Ton	73.50
Gabion boxes, galvanized steel mesh mats or boxes, stone filled, 6" deep	S.Y.	59.50
Gabion boxes, galvanized steel mesh mats or boxes, stone filled, 9" deep	S.Y.	84.00
Gabion boxes, galvanized steel mesh mats or boxes, stone filled, 12" deep	S.Y.	92.00
Gabion boxes, galvanized steel mesh mats or boxes, stone filled, 18" deep	S.Y.	133.00
Gabion boxes, galvanized steel mesh mats or boxes, stone filled, 36" deep	S.Y.	201.00

**Appendix II. Presentation to Lee County Community Sustainability  
Advisory Committee**

# LEE COUNTY

## Climate Change Vulnerability Assessment and Resiliency Strategy

2010



### CLIMATE

× Long term, accumulated trends in atmospheric conditions – not less than decades or longer.

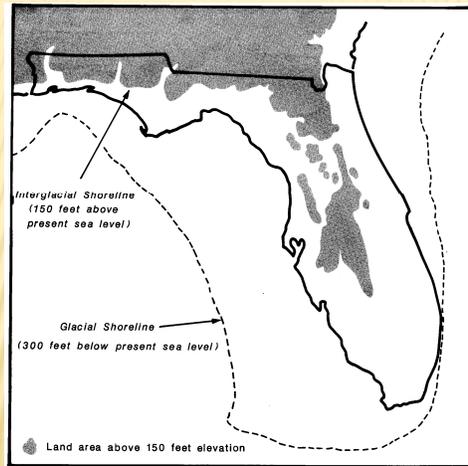
### WEATHER

× Atmospheric conditions over a short period of time.

- Subtropical/ tropical savanna
- Alternating wet season flooding and dry season drought
- Frequent thunderstorms
- Prevailing easterly trade winds
- Temperatures moderated by maritime influences
- Mean annual temperature is 74°F
- More than 120 days per year over 90°F

## CURRENT CLIMATE

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.



## IN THE LAST 100 YEARS, SOUTHWEST FLORIDA HAS:

- Experienced increased average air temperature of 1.2°F (Ft. Myers)
- Had 12 more days each year over 90° F
- Had no change in total annual rainfall
- Had a 6% increase in rain during rainy season
- Measured an 8 inch increase in sea level

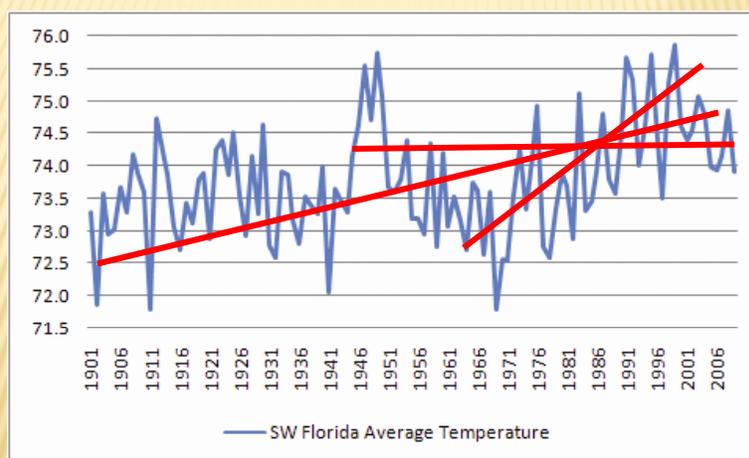


**Climate change is currently occurring and more change is to be expected.**

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.

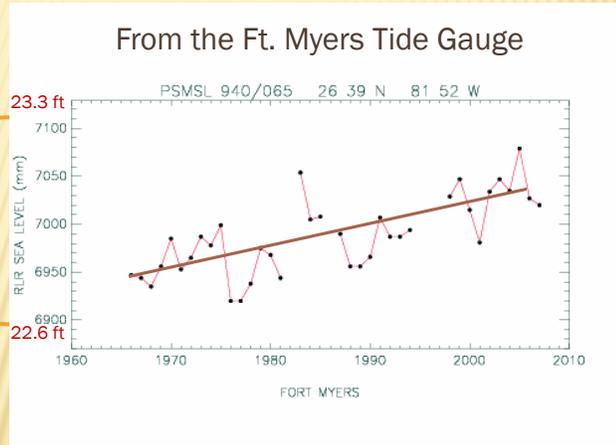


## PATTERNS OF AVERAGE TEMPERATURE



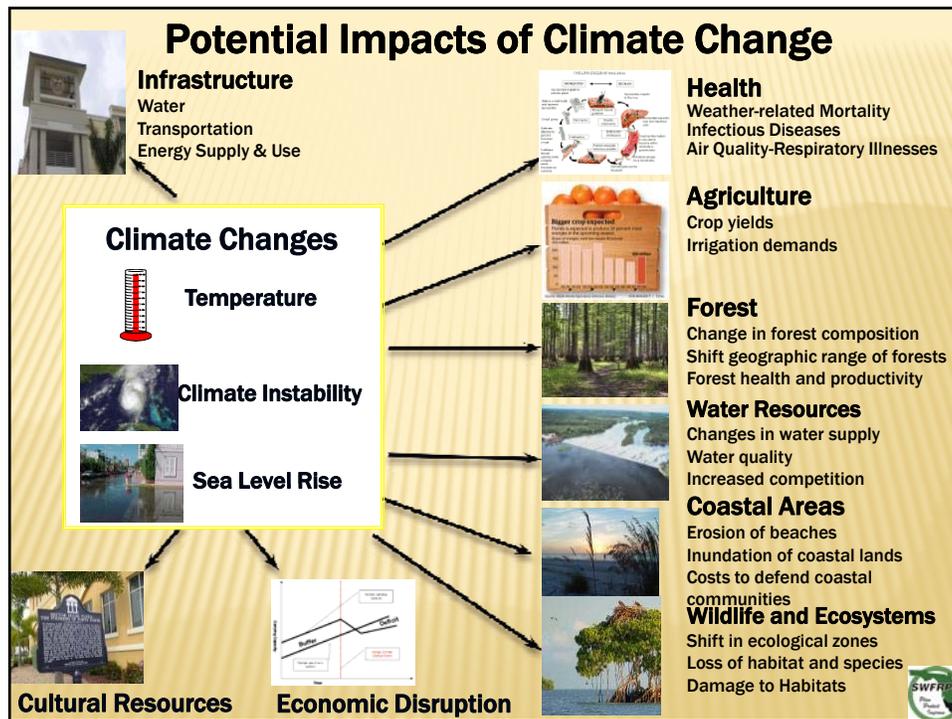
## PATTERNS OF AVERAGE SEA LEVEL

The difference between the high and low on this scale is about 8 inches.



Probability (%)	2025		2050		2075		2100		2150		2200	
	cm	inches										
<b>Rapid Stabilization Case</b>												
90% chance	7	2.8	13	5.0	20	7.7	26	10.4	40	15.7	53	21.0
80	9	3.6	17	6.6	26	10.1	35	13.9	53	20.8	71	28.1
70	11	4.4	20	7.8	30	11.6	41	16.3	63	24.7	85	33.6
60	12	4.7	22	8.6	34	13.2	45	17.8	72	28.3	99	39.1
50% chance	13	5.1	24	9.4	37	14.4	50	19.8	80	31.4	112	44.2
40	14	5.5	27	10.6	41	16.0	55	21.8	90	35.4	126	49.7
30	16	6.3	29	11.3	44	17.1	61	24.1	102	40.1	146	57.6
20	17	6.7	32	12.5	49	19.1	69	27.3	117	46.0	173	68.2
10	20	7.9	37	14.5	57	22.3	80	31.6	143	56.2	222	87.5
5% chance	22	8.7	41	16.1	63	24.6	91	35.9	171	67.2	279	110.0
2.5	25	9.9	45	17.6	70	27.4	103	40.7	204	80.2	344	135.6
1	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 Stanton and Ackerman 2007



## AIR TEMPERATURE AND CHEMISTRY

Climate Scenario	Pre-development (°F)	1891-1995 (°F)	2009 (°F)	2025 (°F)	2050 (°F)	2100 (°F)
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

Mean annual temperature changes for Lee County and 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

- ❖ Addition of carbon dioxide and other greenhouse gases contributes to increasing air temperatures and acidity of precipitation.
- ❖ Warmer air temperatures increase evaporation of rain, exacerbating drought.
- ❖ Warmer air temperatures have heat-related health effects.
- ❖ Warmer air temperatures can change which plants and animals can live here.

## WATER TEMPERATURE AND CHEMISTRY

- ✘ 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 30% more acidic (Archer 2005).
- ✘ Water temperatures at the sea surface rose by an average of 0.54°F between the 1950s and 1990s in tropical and subtropical waters (Wilkinson and Souter 2008).
- ✘ The year 2005 was the warmest in the wider Caribbean than any in the last 100 years.
- ✘ Warmer water temperatures cause water to expand.
- ✘ Warmer water temperatures change which plants and animals that can live here.
- ✘ Warmer water temperatures cause corals to “bleach” and become diseased.
- ✘ Warmer water hold less oxygen, causing “dead zones”.
- ✘ More acidic water makes it harder for mollusks to produce shells.
- ✘ More acidic water changes which plants and animals can live here.

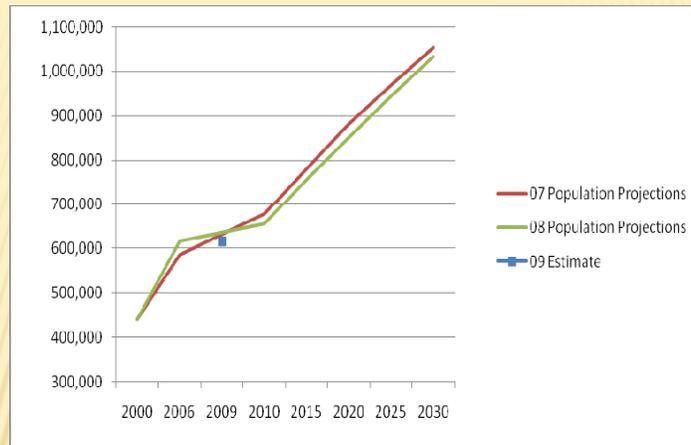


## CLIMATE CHANGE VULNERABILITIES



## VULNERABILITY ASSESSMENT

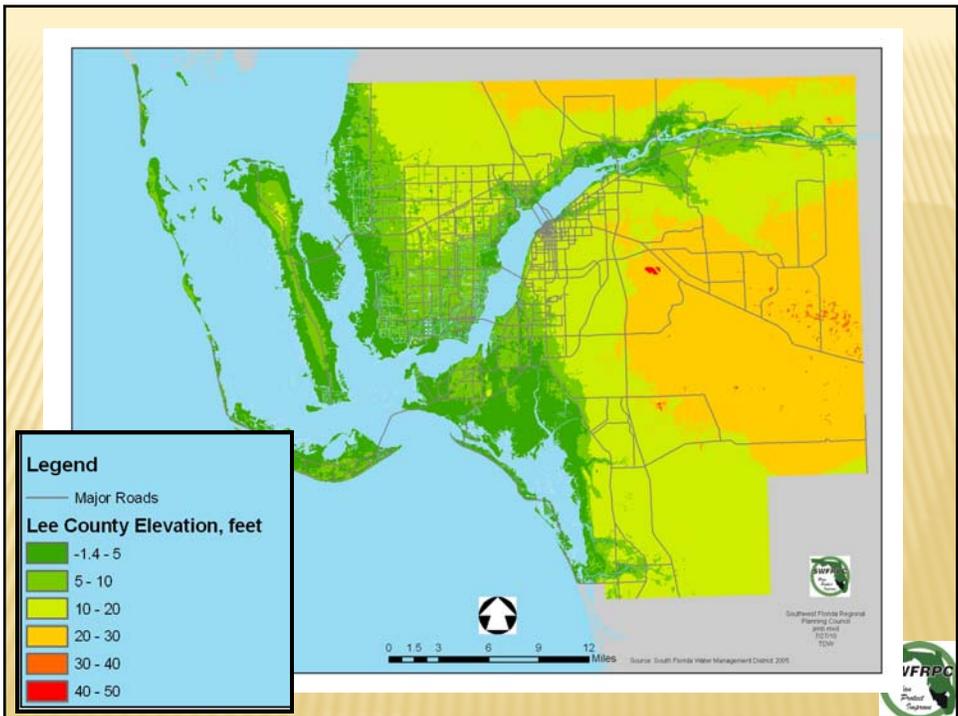
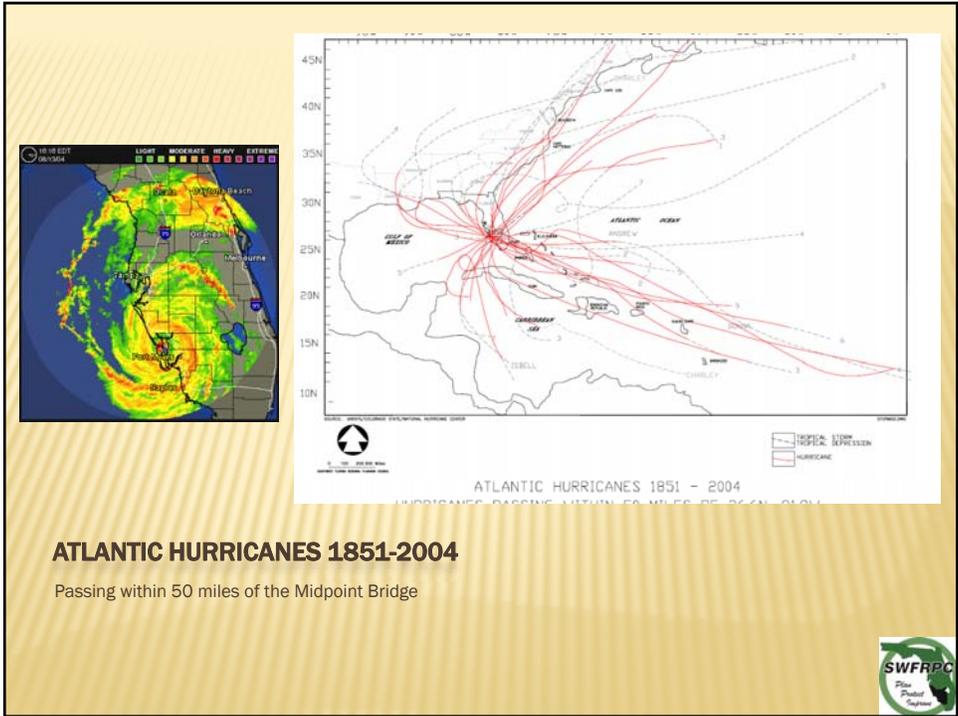
- Characterizes current Lee County climate
- Assesses significant potential climate changes and their effects in Lee County
  - Air temperature and chemistry
  - Water temperature and chemistry
  - Climate instability
  - Sea level rise
  - Altered hydrology
  - Geomorphic changes
  - Habitat and species changes
  - Land use changes
  - Human economy
  - Human health
  - Infrastructure
  - Variable risk
- Suggests methods for prioritizing vulnerabilities

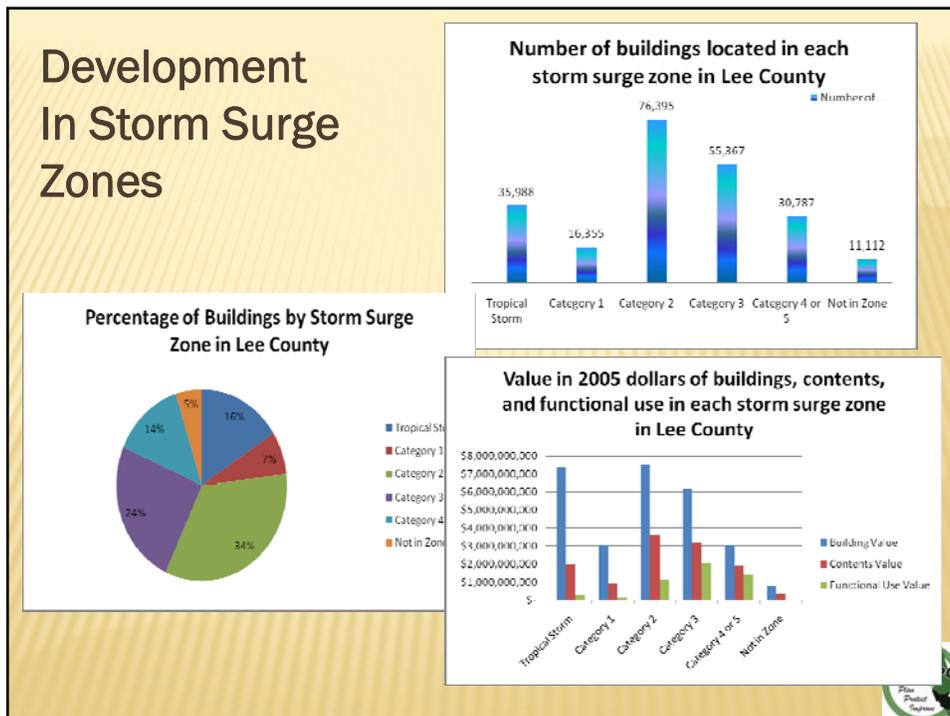
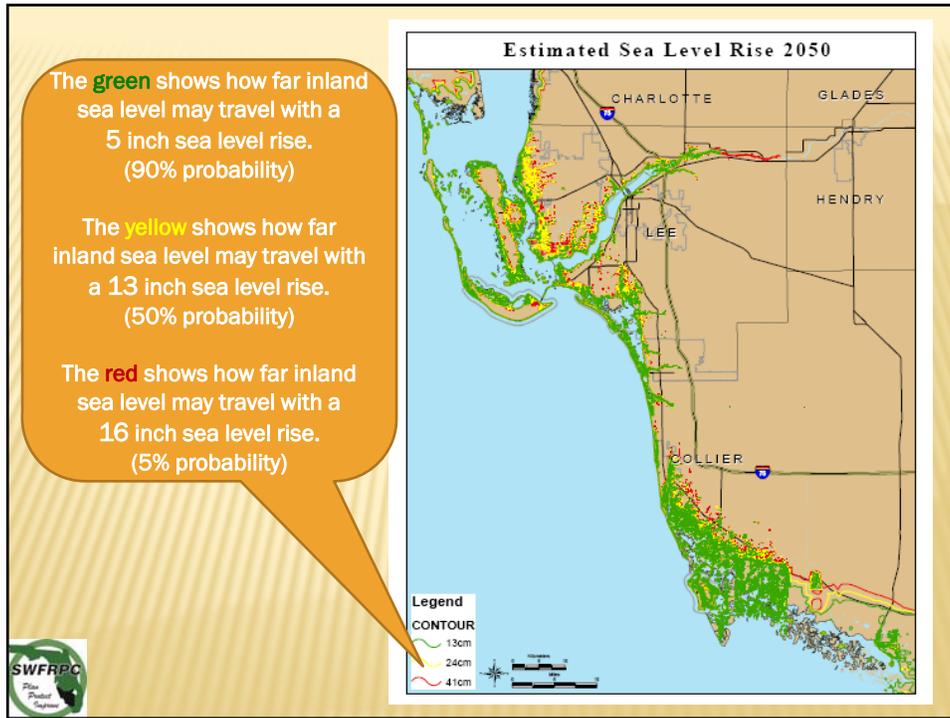


### LEE COUNTY POPULATION PROJECTIONS

From the Bureau of Business and Economic Research  
University of Florida





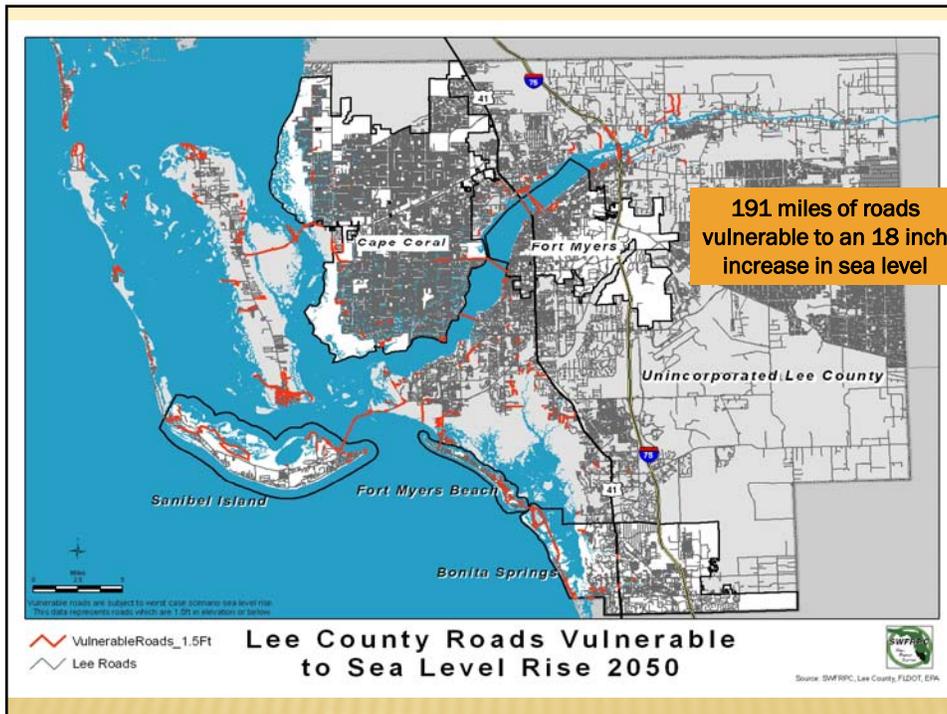


## CRITICAL FACILITIES

Ports	1
Community Colleges	1
Hospitals	1
Boat Locks	2
Clinics	2
High Schools	2
Landfills	2
Airports	3
Police/Sheriff Facilities	3
Emergency Medical Services	3
Middle Schools	3
Communication Towers	9
Elementary Schools	11
Hurricane Shelters	12
Drinking Water Facilities	13
Electrical Facilities	14
Fire Stations	19
Nursing Facilities	26
Government Facilities	27
Sewage Treatment Facilities	43

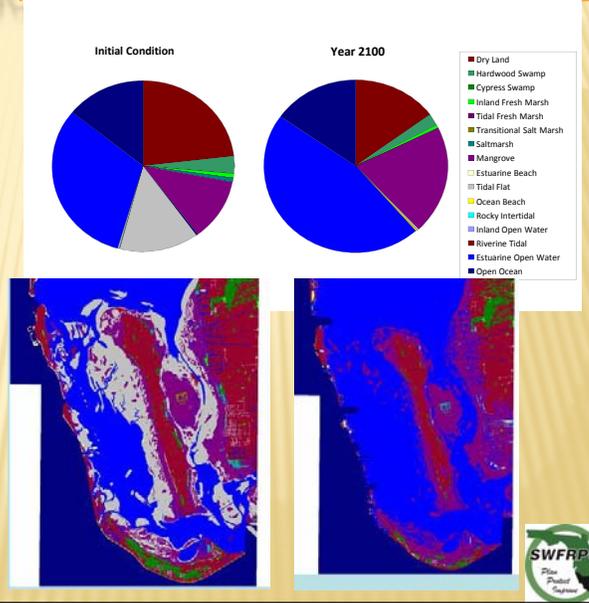
Critical facilities in Lee County that are vulnerable to tropical storm and hurricane flooding and sea level rise

Total: 197

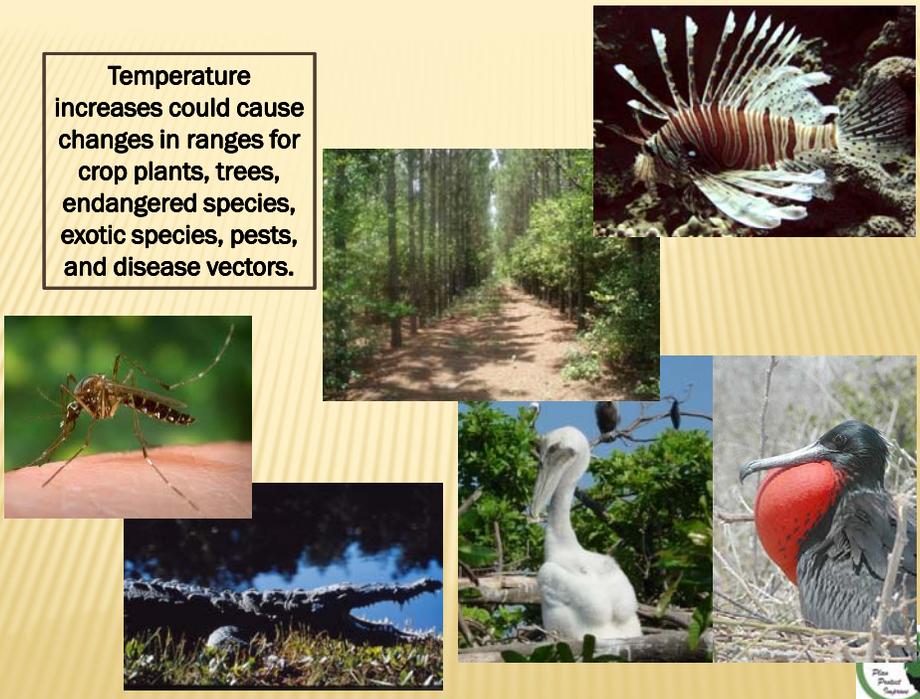


# VULNERABLE HABITAT

SLAMM 4.1 modeling shows that, with a moderate sea level rise of 18 inches by 2100, habitats will change.



Temperature increases could cause changes in ranges for crop plants, trees, endangered species, exotic species, pests, and disease vectors.





## RESILIENCY STRATEGY

Lee County Climate Change Resiliency Strategy  
(CCRS)



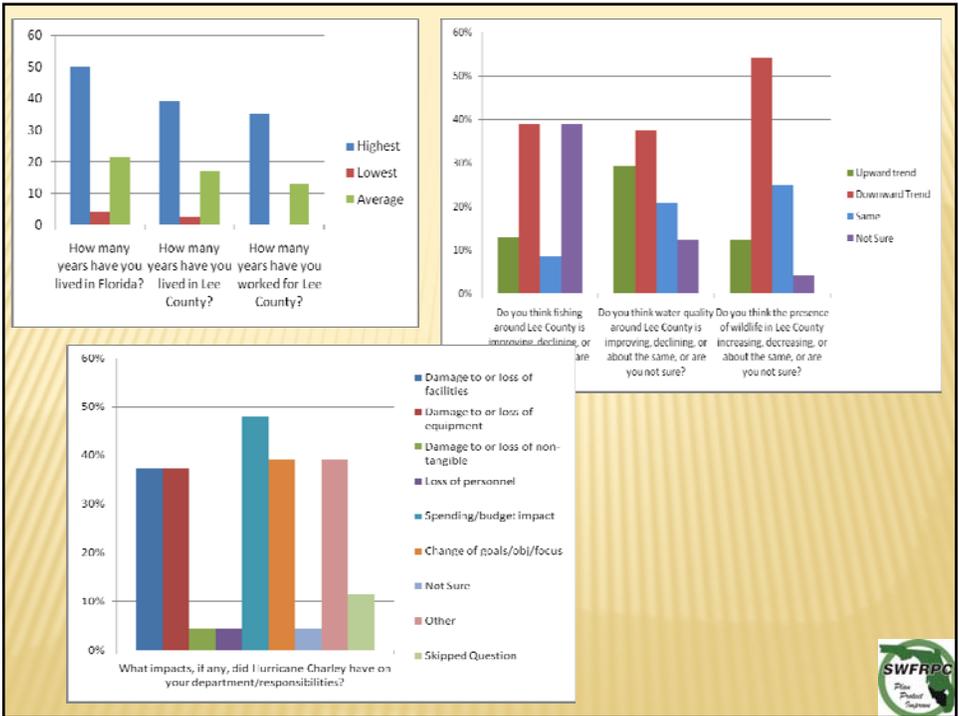
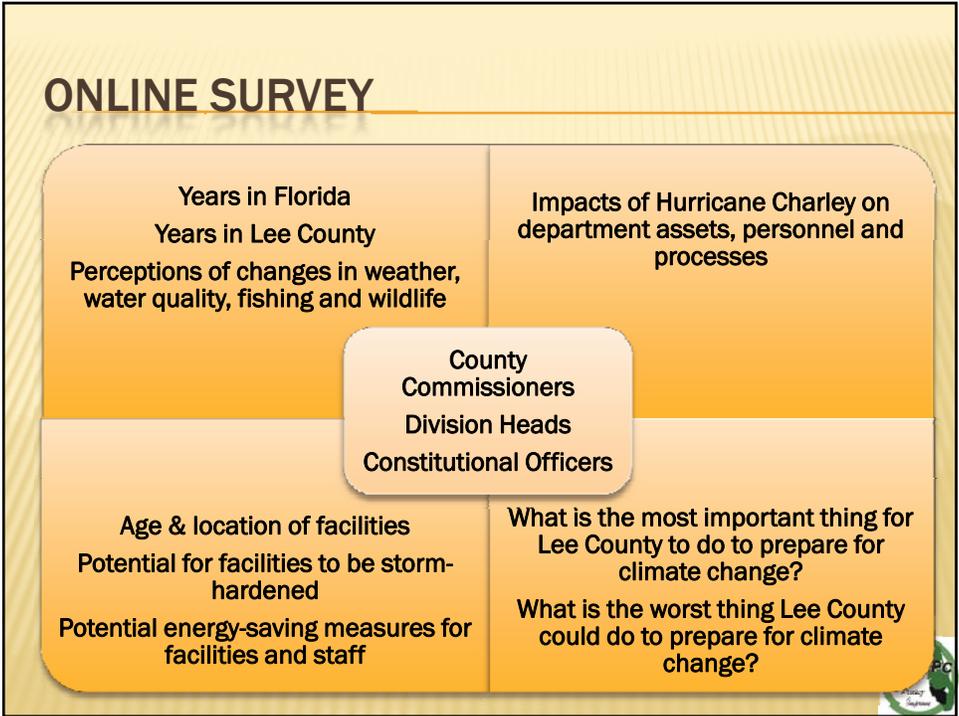
Southwest Florida Regional Planning Council  
DRAFT July 30, 2010  
James W. Dewey III, Whitney Gray, Jason Utley, David  
Hutchinson, Tim Walker, Dan Cobb

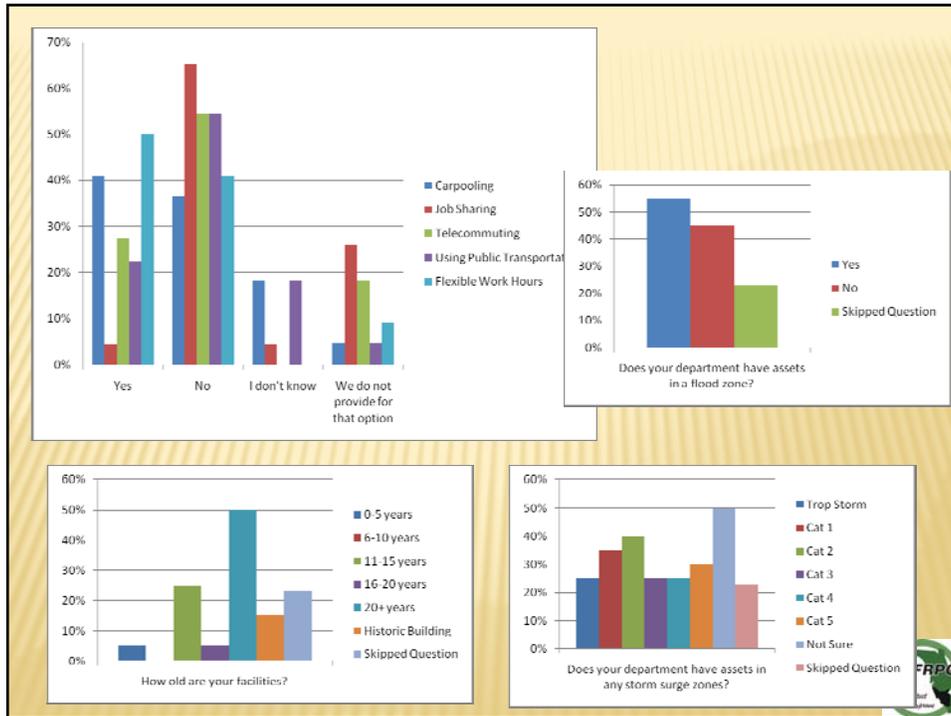
1926 Victoria Avenue  
Fort Myers, FL 33901  
(239) 338-2550  
[www.SWFRPC.org](http://www.SWFRPC.org)



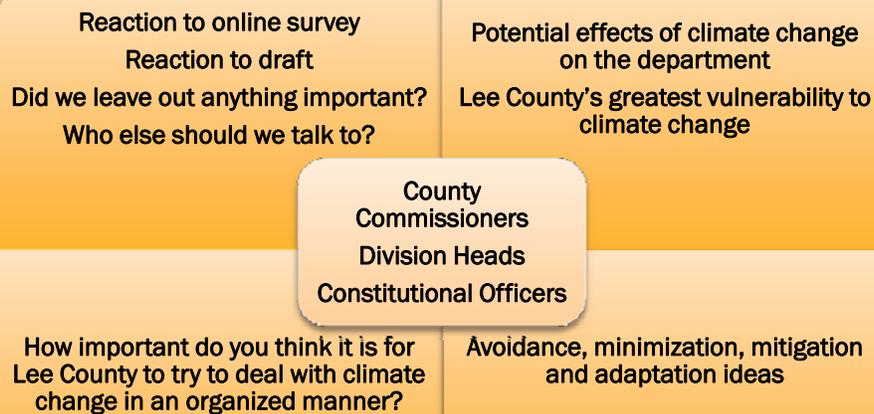
Southwest Florida Regional Planning Council

- Outlines the essential elements of a resiliency strategy
- Summarizes vulnerabilities
- Summarizes input received from Lee County leadership and constitutional officers
- Identifies strategies that Lee County could pursue to increase resiliency to the identified vulnerabilities
- Identifies ways to incorporate climate change resiliency into the LeePlan
- Outlines monitoring and evaluation strategies





## INTERVIEWS



## VULNERABILITIES IDENTIFIED BY INTERVIEWEES

### Buildings and County Infrastructure

- Impacts to roads from increased creek and stream flows
- More frequent replacement of materials

### Coastal Economies

- Declining property values impacting the County's ability to maintain infrastructure and provide adequate services
- Impact on tourism.
- Hotter temperatures will increase the cost of workers' compensation.

### Land Use Planning and Growth Management

- Possible reduction of migration into the area and a possible increase in migration out of the area.
- Residents may experience increased response times for emergency services

### Economic Development

- Higher utility bills
- More frequent adverse working conditions for outdoor workers

### Education and Outreach

- Could impact nearly every area of how the County functions impacting the budget and demanding more interdepartmental and intergovernmental coordination
- Potential for increased variability of weather – more rainfall during and longer periods of drought

### Coastal Protections

- Impacts to beaches and the demand for beach renourishment
- More frequent storm events with associated erosion

### Health and Human Services

- Increased impact on the economically disadvantaged
- Possible modification of work hours due to hotter temperatures.

### Water and Wastewater

- Could experience strains on our freshwater aquifers
- Surface water management issues

### Natural Systems and Resources

- Concerns regarding Lake Okeechobee flows
- Could experience impacts to landscaping and plants
- Could impact sea life and the estuary
- Destruction of ecological systems which could severely impact our tourism industry



Building to LEED certification standards.  
Offsite data storage and protection.

Converting buses to hybrids.

Identify Lee County's energy goals.

## RESILIENCY STRATEGIES

Build or modify structures where they can function in areas with higher surface waters.

Technology infrastructure reduces the need for driving the fleet of automobiles to property locations for valuations.

Building and development codes should be reviewed in light of vulnerabilities/to address strategies

Native plants and reduced irrigation for County facilities

Widening of Alico Road to accommodate business interested in energy research.

Incentivize development and redevelopment within the urban area. Update Comprehensive Plan to reflect changing conditions.

Development of a Solar Strategy for inclusion in the comprehensive plan.

Need more policy analysis regarding land use regulations.

Reduce automobile dependence.

Limit the placement of county facilities and infrastructure in flood prone and storm surge areas. This can be problematic since the facilities and infrastructure should be community-based.

Land acquisition for carbon sequestration

Conservation 20/20

Locating healthcare facilities out of vulnerability zones.

Modify County dress codes

Observation of Coastal Control Line and not allowing building seaward of the coastal construction control line.

Encourage behavior change in employee trips (carpooling, transit, bicycling, walking, teleworking, four day work weeks, reduction of VMTs, etc)

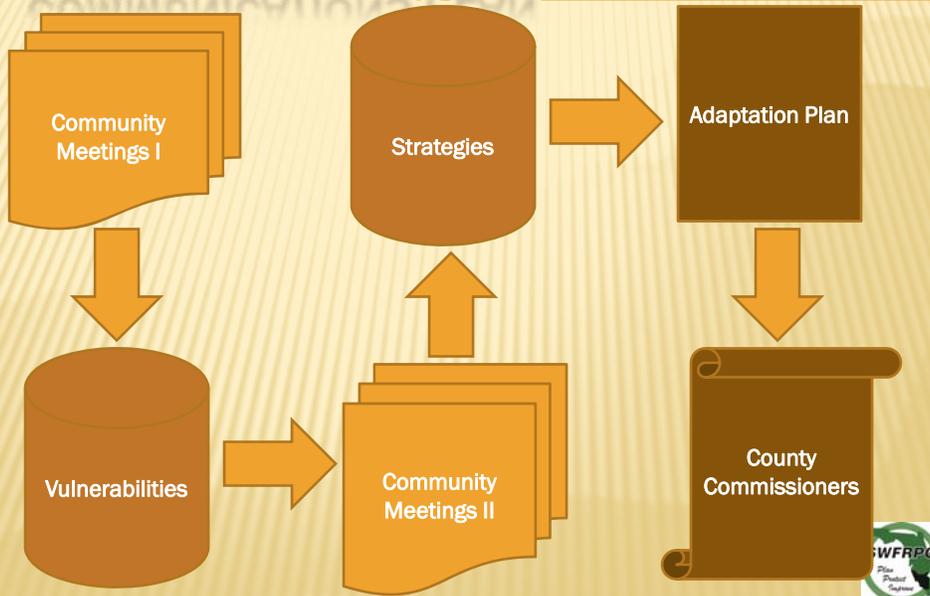


## CONCLUSIONS

- Monitor climate change effects to avoid passing a tipping point
- Consider climate change effects in planning for infrastructure and development
- Continue to set aside natural areas, especially mangroves, as a buffer against climate change effects

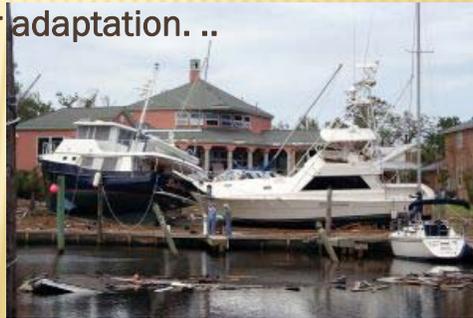


## COMMUNICATIONS PLAN



## THE BOTTOM LINE

“The likely effects of climate change and particularly sea level rise on Lee County and 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 climate.”



## REQUEST FOR FEEDBACK AND CONTACT INFO

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website [www.swfrpc.org](http://www.swfrpc.org)

