INTEGRATED NATURAL AND BUILT ENVIRONMENT STRATEGIES FOR ADAPTING TO SEA LEVEL RISE: CASE STUDIES, EVALUATION FRAMEWORK, AND APPLICATION TO COASTAL SMALL TOWNS IN FLORIDA

By

RONG ZENG

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS IN URBAN AND REGIONAL PLANNING

UNIVERSITY OF FLORIDA

2014

To my parents

ACKNOWLEDGMENTS

I would like to thank my committee chair, Dr. Kathryn Frank, and co-chair, Dr. Joseli Macedo, for their guidance and assistance throughout my thesis work. Dr. Frank is a great mentor who stimulates my interest in environmental planning, especially on adaptation planning for climate change and sea level rise. Without her support, I would not have made this happen. Thank you also to Dr. Macedo for her guidance and insight, particularly with regard to the design part of my thesis. Both professors have influenced my academic research significantly, and I anticipate that they will continue guiding my future professional career. Special thanks to the University of Florida Planning for Coastal Change in Levy County Project, headed by Dr. Kathryn Frank, as well as to the entire project team. They have always provided an indispensable foundation and valuable information source for my thesis. Finally, I would like to thank my beloved parents for their selfless love and support all the time.

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LIST OF ABBREVIATIONS

EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FGDL	Florida Geographic Data Library
IPCC	Intergovernmental Panel on Climate Change
ICLEI	Local Governments for Sustainability
LID	Low Impact Development
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
SLR	Sea Level Rise
SLAMM	Sea Level Rise Affecting Marshes Model
SFHA	Special Flood Hazard Area
TNC	The Nature Conservancy
TDR	Transfer of Development Rights

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Rong Zeng

May 2014

Chair: Kathryn Frank
Cochair: Joseli Macedo
Major: Urban and Regional Planning

Global climate change is happening. The resulting rising sea levels particularly put coastal communities at high risk and threaten the long-term sustainability of both the natural and built environments. Coastal habitats, which are significant connections between the land and water, especially for rural coastal communities, are expected to gradually migrate inland in response to sea level rise. However, human interventions such as buildings, roads, and hard shoreline protection structures will potentially impede this process, therefore becoming a critical factor in habitat loss in the future. Given this consideration, adaptation strategies for sea level rise need to be planned ahead in order to balance the tradeoffs between the linked social and ecological systems.

This thesis focuses on exploring integrated adaptation strategies to address sea level rise impacts for both the natural and built environments. Two primary research questions were generated: (1) How to enhance the social–ecological resilience of a community in coping with climate change and sea level rise? (2) What are sustainable adaptation strategies for both the natural and built environments in long-term planning?

The methodology of this thesis is developed and composed of three parts: first, comprehensive analysis of five case studies to identify the proposed adaptation strategies for different coastal communities and the extent to which an integrated approach was incorporated into each; second, developing an evaluation framework to assess the sustainability of a variety of strategies and the performance of the integrated strategies; third, designing adaptation strategies for the thesis study area Yankeetown-Inglis, Florida, in order to examine the application of integrated strategies.

CHAPTER 1
INTRODUCTION

Although global mitigation measures have been taken, climate change is posing unavoidable risks and consequences to the natural, social, and economic systems. Notably, sea level rise is a remarkable consequence of global warming. In 2007, the Intergovernmental Panel on Climate Change (IPCC) projected the global sea level would rise 0.2 to 0.6 meters by the end of this century, but has still been criticized for underestimating the situation by not fully taking into account the accelerated ice loss in Antarctica and Greenland (IPCC, 2007; U.S. Army Corps of Engineers [USACE], 2011). Sea level rise has become a complex problem affecting the long-term sustainability of both the natural and built environments. Coastal communities are extremely vulnerable to sea level rise impacts, including inundation of low-lying areas, more frequent and intensive flooding due to storm surges, increased erosion, saltwater intrusion, and loss of wetlands (Snow & Snow, 2009).

Coastal habitats, which are significant connections between the land and water, especially for rural coastal communities, are expected to migrate inland in response to sea level rise. However, human interventions such as buildings, roads, and hard shoreline protection structures will potentially impede this process, therefore becoming a critical factor in habitat loss in the future. Although uncertainties remain, the potential changes of these interventions would become an opportunity to help the coastal communities adapt to sea level rise impacts. Some of them may choose to retreat inland with higher elevation, while others prefer to increase the shoreline armoring to protect the developed area (Fuller et al., 2011). All these options would potentially affect the health of coastal habitats, as well as the valuable ecosystem services they provide to the built environment. Given this consideration, adaptation strategies for sea level rise need to be planned ahead in order to balance the tradeoffs between the linked social and ecological systems.

For the time being, adaptation efforts are usually approached from either a built environment or natural environment standpoint, rather than an integrated perspective. This thesis aims to help draw attention to the concept of integrated strategies for adapting to sea level rise. To address this purpose, two primary research questions were generated: (1) How to enhance the social–ecological resilience of a community in coping with climate change and sea level rise? (2) What are sustainable adaptation strategies for both the natural and built environments in long-term planning?

According to this research focus, the methodology of this thesis is composed of three parts: first, comprehensive analysis of five case studies to identify the proposed adaptation strategies for different coastal communities and the extent to which an integrated approach was incorporated into each; second, developing an evaluation framework to assess the sustainability of a variety of strategies and the performance of the integrated strategies; third, designing adaptation strategies for the thesis study area Yankeetown-Inglis, Florida, in order to examine the application of integrated strategies.

CHAPTER 2
LITERATURE REVIEW

This review of literature discusses the current planning efforts and strategies that have been proposed or implemented for adapting to sea level rise. First of all, historical evidence of rising sea levels combined with scientific projections for the continuation of this trend is stated as the reason for addressing sea level rise impacts. Second, this chapter elaborates the definition of adaptation planning and the importance of building resiliency for the linked social–ecological system in achieving sustainable development. Lastly, various existing adaptation strategies for sea level rise are defined and classified into three different contexts as the natural, built, and both natural–built environments. The classification of adaptation strategies helps to identify the current role of integrated strategies in adaptation planning process and the differences to other types of strategies. This in turn will provide a foundation for further assessing the integrated strategies and applying them in practice.

Sea Level Rise

The global mean sea level has risen since the 20th century and is expected to accelerate during the 21th century due to global warming (Nicholls & Cazenave, 2010). The increased sea level is mostly coming from the expansion of seawater as the ocean warms, and the water from melted ice and land water reservoirs (Nicholls & Cazenave, 2010). Though just how much the sea level will rise remains uncertain, scientific measurements and projections can help predict the rate at which it may rise. Sea level rise projections can vary under different greenhouse gas emission scenarios, depend on a variety of factors, and differ from region to region. Figure 2-1 shows a comparison of maximum and minimum projections of the global sea level rise by the year 2100 from diverse authors or publications (U.S. Army Corps of Engineers [USACE], 2011). The U.S. Army Corps of Engineers guidance also estimates a 1.5- to 5-foot rise in sea level by the year 2100 (USACE, 2011).

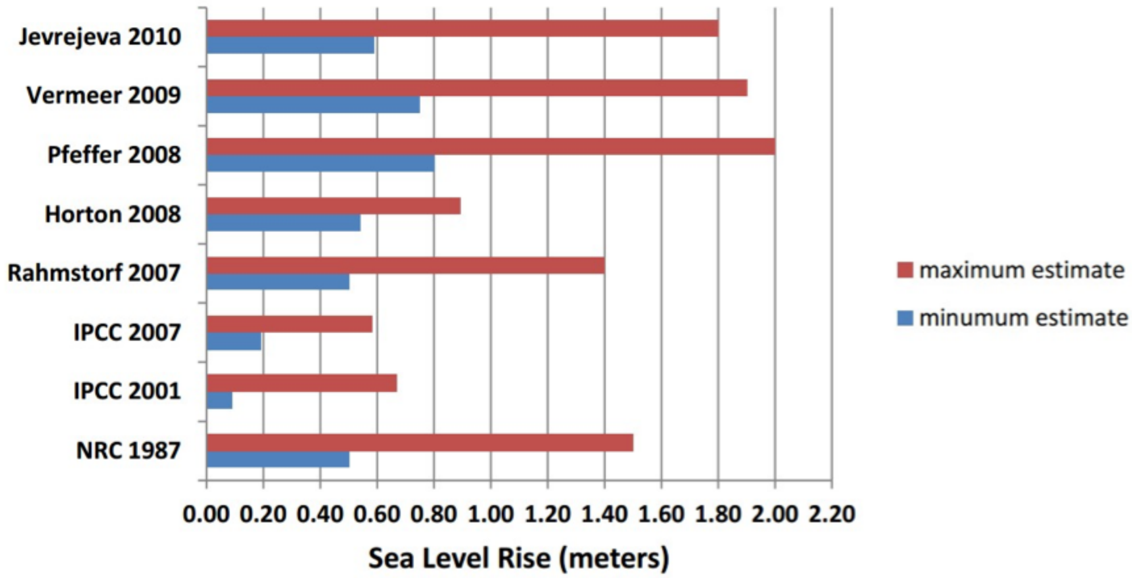


Figure 2-1. Comparison of maximum and minimum projections of global SLR by the year 2100. Source: U.S. Army Corps of Engineers, 2011.

Rising sea level is expected to cause a number of negative effects: inundation of low-lying coastal regions; more frequent and intensive flooding during storm events; increased coastal erosion and saltwater intrusion into groundwater; damage of coastal properties and infrastructure; and losses of coastal wetlands and forests (Bedsworth & Hanak, 2010; Nicholls & Cazenave, 2010; FitzGerald et al., 2008).

Adaptation Planning and Resiliency Building

Two fundamental responses have been initiated to reduce climate change and sea level rise risks: mitigation and adaptation. Mitigation means alleviating the global warming tendency through reducing greenhouse gas emissions (Füssel, 2007). Adaptation is defined as the “adjustment in ecological, social, or economic systems in response to actual or expected climate stimulus and their effects or impacts" (Smit, 2003, p. 879). The adjustments include reducing vulnerability for communities or regions, as well as increasing capacity to accommodate potential impacts. Although traditionally mitigation has received much more attention than adaptation, increasing consideration of adaptation is needed (Füssel, 2007). In addition to employing mitigation approaches globally to alleviate sea level rise risks by reducing greenhouse gas emissions, adaptation measures can be taken at the local or region level to cope with increased impacts. However, sometimes mitigation and adaptation measures will be implemented against each other (e.g., the increased use of air conditioning), but can also benefit each other by alleviating climate change impacts simultaneously (e.g., coastal wetland restoration) (Füssel, 2007; Moser, 2012).

Adaptation planning and strategies usually work by reducing vulnerability to altering conditions or by increasing adaptive capacity or resiliency (Bedsworth & Hanak, 2010). Adaptive capacity refers to "the potential or ability of a system, region, or community to adapt to the effects or impacts of climate change" (Smit, 2003, p. 881). It can be evaluated in terms of the social, economic, technological, and institutional conditions of the environment in which adaptation measures are taken (Smit, 2003). The practices for increasing adaptive capacity or resiliency can be considered the same as those for sustainable development (Smit, 2003). Building resilience is the new framing for adaptation to integrating the dynamic changes in the linked social–ecological system (Boyd & Cornforth, 2013).

Before exploring ways for resiliency building, it is important to understand the link between the social and ecological systems. Many scholars have discussed their interrelationships (Berkes & Jolly, 2002; Folke, 2006; Wilkinson, 2011). For example, ecosystem services is one of the primary bridges between the two systems, which can be defined as “the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life” (Daily, 1997, p. 3), or, put more simply, the benefits people get from ecosystems. This correlation is especially obvious in the rural coastal communities, which typically contain abundant natural resources. The ecosystem services in these areas essentially connect the social and ecological systems through logging, fishing, and other water-related industries.

Building resilience is crucial to adaptation for the linked social–ecological system (Wilkinson, 2011). There are several avenues of research focused on the social–ecological resilience. Walker et al. (2004) defined the social–ecological resilience as the “capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feed backs, and therefore identity, that is, the capacity to change in order to maintain the same identity” (Walker et al. 2004, p. 4). Although it is not a concept lasting for a long time, Wilkinson (2011) argued that planning needs to pay more attention to the social–ecological resilience because it can be another way to achieve sustainable development. Furthermore, building resilience to both social and natural communities is an effective way to address complex problems like climate change (Tompkins, 2004).

Adaptation Strategies for the Natural Environment

Climate change is gradually and increasingly affecting forests and other natural systems, and their biodiversity, ecosystem services, and goods. The United States Climate Change Science Program (CCSP) studied 21 synthesis and assessment products (SAPs) for understanding the changing climate and how societies can mitigate and adapt to its impacts. Among the products they are studying on, SAP 4.4 reviewed and summarized the possible adaptation options for natural environments, including "national forests, national parks, national wildlife refuges, wild and scenic rivers, national estuaries, marine protected areas" (Blate et al., 2009, p. 57). To sum up the key points from SAP 4.4 (Kareiva et al., 2008), it is crucial to start considering climate change adaptation by clarifying and analyzing management goals, assessing climate change impacts, and characterizing uncertainties. A variety of adaptation options have been used to tackle other environmental stressors, but adjustment may be needed when coping with climate change. These adaptation options include:

> Protecting key ecosystem features that form the underpinnings of a system; reducing anthropogenic stresses that erode resilience; increasing representation of different genotypes, species, and communities under protection; increasing the number of replicate units of each ecosystem type or population under protection; restoring ecosystems that have been compromised or lost; identifying and using areas that are "refuges" from climate change; and relocating organisms to appropriate habitats as conditions change. (Kareiva et al., 2008, p. 326)

In order to address climate change, removing or reducing non-climate-related stresses can be the most critical strategy to enhance resilience to climate change (Lawler, 2009). Decreasing anthropogenic stresses such as development, pollution, and overfishing is considered to be an effective approach to promote resilience in response to climate change (Kareiva et al., 2008). For instance, in order to increase the resilience of rivers to protect key riparian zones, shifting or moving existing public access to habitats or waterfronts could be a helpful approach (Kareiva et al., 2008). One way of promoting resilience in national parks is to remove hard structures on coastlines to facilitate natural regeneration and inland migration of wetlands.

Some have suggested expanding existing reserves or protected areas to allow movement of species and systems (Noss, 2001). Coastal systems particularly require larger reserves to allow for the species to migrate inland when the sea level rises (Lawler, 2009). This will not only require larger reserves, but also new reserves in the right locations. Some recent research and discussions explore increasing the connectivity of fragmented habitats for species moving in response to climate change (Noss, 2001; Hulme, 2005). The approaches for increasing connectivity include the designation of wildlife corridors, placing small stepping stone reserves between larger preserves, and enhancing the management of waters or lands between the protected areas to facilitate species movements (Lawler, 2009).

Adaptive management tends to be an important and effective way to implement climate change mitigation strategies (Kareiva et al., 2008; Lawler, 2009). In consideration of the uncertainties of climate change, adaptive management applies a more iterative path through continuous learning and monitoring. The primary process of adaptive management involves assessing potential climate change impacts and implications, designing and implementing management approaches, monitoring and evaluating management effectiveness, and finally redesigning and improving management approaches as needed (Kareiva et al., 2008).

Adaptation Strategies for the Built Environment

Three primary adaptation strategies have been discussed for the built environment in addressing sea level rise impacts specifically. They are protection, accommodation, and retreat.

Protection

Protection strategies currently can be achieved through structural or non-structural approaches to mitigating sea level rise impacts while keeping important structures or infrastructure along the coast that cannot be altered, such as downtown areas, important roadways, and historical districts (FDEO, n.d.; CSA International, 2008). Structural protection uses “hard” erosion control techniques (e.g., seawalls, dikes, bulkheads, and ripraps) to stabilize and protect the shore (CSA International, 2008). Efforts also have been made in many cases to prevent communities from storm surges, flooding, and other hazards, such as installations of protection structures (e.g., levees, floodgates, and storm surge barriers), and improvements of infrastructure (e.g., storm sewers) to control stormwater runoff.

Beach nourishment or the building of sand dunes and marshes are common approaches for non-structural protection (CSA International, 2008). Beach nourishment is likely to be an effective “soft” technique to control coastal erosion and can be used with other structural protection. However, since beach nourishment usually requires a large amount of sands with specific sources, the cost of beach nourishment will be very expensive. The building of sand dunes and marshes by reusing dredge material is another option to buffer the rising sea levels. But this strategy needs further studies and demonstration to determine its effectiveness (CSA International, 2008).

Accommodation

Accommodation is a different type of adaptation strategy; it is the attempt to maintain existing pubic infrastructure or private properties at risk from sea level rise. However, unlike protection strategies that rely on external barriers, accommodation strategies usually employ design methods to protect developed areas from sea level rise impacts. Commonly used accommodation strategies include elevated grade surface, elevated structure, and floating structure (Hirschfeld & Holland, 2012). Elevated grade surface involves the raising of building pads or foundation walls, typically in new structures or infrastructure. Elevated structure involves lifting the existing building to allow for water flows beneath the structure. Floating structure is the anchoring of the structure on the water (Hirschfeld & Holland, 2012).

Adaptation strategies can also be achieved through enhancing building codes and resilient designs to maximize the capacity of structures to confront flooding (Grannis, 2011). For example, the National Flood Insurance Program (NFIP) currently requires certain minimum design requirements of construction in zones in Special Flood Hazard Areas (SFHA). However, the resilient design approach will be easier to apply to new construction than to existing development (Grannis, 2011).

Setbacks and buffers are also considered as accommodation strategies in which certain zones are left undeveloped to prevent the adjacent inland from flooding and storm surges. The buffer zones retain natural features and provide important benefits such as water filtration, floodwater buffering, and recreational opportunities (Grannis, 2011). They can be achieved through zoning and land use restrictions (Hirschfeld & Holland, 2012).

Retreat

Retreat strategies generally involve the removal or relocation of existing development to other area with less vulnerability and the prohibition of future new development in the vulnerable area. Feasible options include Transfer of Development Rights, rolling easements, purchase of development rights, and conservation easement (FDEO, n.d.). Transfer of Development Rights (TDR) is a market-based tool shift from “sending areas” where local governments want to discourage development to “receiving areas” where local governments want to increase development. The property owners in sending areas can sell their development rights to other property owners such as those in receiving areas to increase development densities (Grannis, 2011). In addition, governments could also use subdivision ordinances to restrict new development in the vulnerable area and encourage cluster development in the upland and safer area (Grannis, 2011).

Rolling easement is defined by Titus (1998) as a tool that “allows construction near to the shore, but requires the property owner to recognize nature’s right of way to advance inland as sea level rises” (p. 1316). In general, rolling easement acts as law enforcement to remove private structures after a certain length of time, once private structures become public lands, as habitat migrates inland in response to rising sea levels; if properties remain standing, temporary rent will be charged. Rolling easement can be used in combination with other adaptation options such as elevation or setbacks (CSA International, 2008).

As retreat options often relate to the acquisition of private properties in vulnerable areas by public entities, it is essential to consider the current legal framework of property rights at the local level. The costs for compensation and relocation can be very high, so retreat strategies are recommended to use in combination with other protection or accommodation strategies and to apply in the most vulnerable area (CSA International, 2008).

Integrated Adaptation Strategies for the Natural and Built Environment

Adaptation strategies for both the natural and built environments, which can be regarded as integrated adaptation strategies, aim to mitigate sea level rise impacts to developed areas and residents, while minimizing the negative effects to the natural environment. Living shorelines, ecosystem-based adaptation, green infrastructure, and landscape or ecological urbanism are currently proposed integrated strategies. On the other hand, “integrated concept” can refer to the coordination of various natural or built adaptation strategies in a balanced way to reduce negative impacts on both systems simultaneously. Moreover, using natural features to protect a community from sea level rise impacts can in turn help improve the quality of life of the community and enhance its identity and sense of place. And after all, people are likely to live on the coast to enjoy the beaches, vistas, and natural areas.

Living Shoreline

The living shoreline strategy is an erosion control approach to increasing sedimentation or reducing water action through revegetation and restoration with little hard structure protections (CSA International, 2008). Mainly this strategy relies on a variety of plants and vegetation, sands, and rocks to protect coastal habitats and stabilize the shores. The benefits of living shoreline strategy include that it "protects, restores or enhances natural shoreline habitats; and helps maintain costal processes through the strategic placement of plants, stone, sand fill and other structural and organic materials" (Burke & Hardaway, 2007, p. 8).

Ecosystem-Based Adaptation

Ecosystem-Based Adaptation (EBA) has been receiving more attention in recent years. The United Nations Environment Programme (UNEP) provided a general definition of EBA: "The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people and communities adapt to the negative effects of climate change at local, national, regional and global levels" (Travers et al., 2012, p. 8). Specifically, EBA uses natural resources to protect human resources from climate change impacts by delivering ecosystem services continuously (Jones et al., 2012). According to Jones et al. (2012), important services that help human communities to adapt to climate change include disaster risk reduction, sustainable water management, food security, and livelihood diversification. Using nature to reduce impacts of climate change and resulting natural disasters has been proved to be effective in various studies; for example, coastal marshes and mangrove forests can help dissipate storm surge impacts and slow down coastal erosion (The Nature Conservancy, n.d.; Jones et al., 2012). Coral reefs can help reduce more than 85 percent of the wave energy along the coast, substantially protecting coastal communities from erosion and storm surges (The Nature Conservancy, n.d.). Moreover, EBA is likely to be a more cost-effective approach than other hard protections such as seawalls or dams—usually building these structures is more expensive than conserving or restoring existing habitats (Jones et al., 2012).

Green Infrastructure

Green infrastructure basically involves using eco-roofs, green alleys, and urban forestry to increase sustainability and improve quality of life. Green approaches have been seen as a best practice when used in combination with “grey” infrastructure to build resiliency and adapt to climate change impacts (Foster et al., 2011). The benefits of green infrastructure include improving stormwater management, preventing floods and storm surges, conserving water, and reducing urban heat island effects (Foster et al., 2011). Low impact development (LID) is a green technique for stormwater management that relies on natural systems instead of storm sewers to control stormwater.

Landscape and Ecological Urbanism

Landscape urbanism is a relatively new theory that emphasizes the significant role of landscape as an initiative in urban design. Though the exact definition of landscape urbanism is still elusive and examples of this concept are rare, some distinguished projects have used landscape as a critical element in their work, such as Brooklyn Bridge Park's effort to apply ecological treatment for stormwater management. Landscape urbanism offers a new way of thinking to reexamine the connections between nature and place and to provide a more flexible approach to deal with specific problems of urban condition (Gray, 2011). Ecological urbanism is another concept that aims to use a more holistic ecological approach to create a new urban aesthetic that "has the capacity to incorporate and accommodate the inherent conflictual conditions between ecology and urbanism" (Mostafavi & Doherty, 2010, p. 17).

Summary of Literature

The literature review of current adaptation planning and strategies reveals that the integrated approaches to enhancing resiliency for the both natural and built environments is critically important to address sea level rise impacts in a long-term sustainable way. However, the concept of integrated adaptation strategies is still nascent and limited examples have been implemented. The majority of studies researched adaptation strategies for the natural or built environment separately, but few of them identified or considered adaptation strategies with a more social–ecological approach—whereas indeed climate change and sea level rise is affecting the natural and built environments simultaneously. Although some adaptation strategies can protect human communities against sea level rise impacts, they will cause or aggravate negative impacts to the natural environment, such as installation of hard protection structures. These negative impacts, in particular, would be more obvious in rural communities because they hold larger natural areas along the coast.

Therefore, in order to further evaluate the pros and cons of different adaptation strategies and explore the potential of integrated strategies in sustainable adaptation planning, it is necessary to formulate a process and criteria for assessing a series of strategies. The following chapter will discuss the methodology this thesis used to evaluate different adaptation strategies that derive from five ongoing adaptation projects and the process used to develop adaptation strategies in practice for the thesis study area.

CHAPTER 3
METHODOLOGY

This thesis aims to identify and assess integrated adaptation strategies for both the natural and built environments to address sea level rise impacts from a sustainable perspective. Two primary research questions were generated: (1) How to enhance the social–ecological resilience of a community in coping with climate change and sea level rise? (2) What are sustainable adaptation strategies for both the natural and built environments in long-term planning?

Given this research focus, the methodology of this thesis is developed in and composed of three parts: first, comprehensive analysis of five case studies to identify the proposed adaptation strategies for different coastal communities and the extent to which an integrated approach was incorporated into each; second, developing an evaluation framework to assess the sustainability of a variety of strategies and the performance of the integrated strategies; third, designing adaptation strategies for the thesis study area Yankeetown-Inglis, Florida, in order to examine the application of integrated strategies.

Case Studies

Case study is a prevalent qualitative research method, which “is characterized by a very flexible and open-ended technique of data collection and analysis” (Grinnell, 1981, p. 302). In this thesis, a collection of cases were carefully selected to identify their adaptation planning processes and proposed strategies for adaptation to sea level rise. The purpose of analyzing a variety of cases is to illustrate adaptation strategies for the built, natural, and both environments, as well as to understand their applications and feasibilities. According to Kumar (2011), the assumption of case study design is that the selected case is either extremely representative or highly atypical so that a single case can define the prevalence of a certain group of cases. Therefore, the selection of cases is very important to the validity of the final result. Five cases were selected, based upon their geographic locations, vulnerability to sea level rise, and adaptation planning efforts.

The analyses of the five cases include their adaptation planning goals and processes, detailed adaptation strategies, outcomes, and implementation if available. The data and information collected for the analyses generally came from their adaptation plans, government documents, journal articles, and relevant websites.

Selection of Case Studies

Important criteria were considered in the selection of cases, including sea level rise impacts, geographic locations, natural and built conditions, and community characters that are comparable to the thesis study area Yankeetown-Inglis. Five cases that currently have climate change and sea level rise planning in place were examined: the City of Punta Gorda, Florida; the Town of Groton, Connecticut; the City of Lewes, Delaware; the State of Maryland; and San Diego Bay.

The first three cities and towns were selected to analyze the adaptation planning efforts at the local level, while the other two examples were chosen to examine the adaptation strategies from a broader state or regional perspective. As adaptation and management of natural environment are usually undertaken at a larger scale, evaluation of adaptation strategies at the state and regional levels can help to fully understand the integrated concept. Though the five cases are regionally separated, sea level rise has posed similar risks to these communities, including inundation and flooding, degraded water quality and supply, and loss of habitats and properties. Some of the communities, such as the City of Punta Gorda and the City of Lewes, have already implemented adaptation and mitigation strategies in their communities. However, their implemented strategies differ in terms of their own goals and objectives. Identifying various adaptation strategies from a series of cases will help further examine the advantages and disadvantages of different adaptation strategies.

Vulnerability Assessment

Assessing vulnerability to sea level rise impacts is a common process that all five cases have implemented. In examining the methodology and outcome of vulnerability assessment for each community, it is helpful to understand the general concerns and issues these cases have addressed, as well as to examine what strategies they used against each vulnerability. On the other hand, the methodology of vulnerability assessment these cases used could also provide a reference and comparison for analyzing the vulnerability in Yankeetown-Inglis area.

Adaptation Strategies

The analysis of five cases aims to illustrate their proposed adaptation strategies for the built, natural, and integrated natural–built environment at different scales. Although sea level rise threatens coastal communities in a similar way, the design of adaptation strategies can vary due to the characters and specific concerns of an individual community. This analysis also intends to examine if these cities or regions employed any integrated concept in developing their strategies, and if any similarity of conditions that Yankeetown-Inglis may share. An evaluation framework that derived from the literature review will then be used to determine the degree to which the strategy contributes to the sustainable goal.

Adaptation Strategy Evaluation Framework

The purpose of this thesis is to explore integrated adaptation strategies for the linked social–ecological system in addressing sea level rise impacts. The analysis of five cases will offer a variety of adaptation strategies, but not all of them are derived from an integrated standpoint. In order to further explore the pros and cons of different strategies and examine the potential of integrated strategies, an evaluation framework with identified indicators will help assess whether the strategy promotes the resilience building in achieving sustainability. Moreover, understanding the attributes of diverse strategies will assist in designing integrated adaptation strategies for the study area Yankeetown-Inglis.

Adaptation Evaluation

A variety of approaches have been developed for evaluating the success of adaptation. Smit and Lenhart (1996) argued that the effectiveness of adaptation measures can be evaluated by its capacity to reach a set of adaptation goals and objectives. However, Adger et al. (2004) stated that the success of adaptation should not be measured only by the set objectives because one successful action for one objective may generate negative impacts to other spatial scales or systems. They argued that adaptation can be assessed by four policy appraisal principles: effectiveness, efficiency, equity, and legitimacy, while difficulties and uncertainties of assessment remain (Adger et al., 2004). In addition, there are some evaluation methods from other perspectives. Tol et al. (1999) argued that, in terms of a disaster management perspective, policies need to be assessed with regard to economic viability, public acceptability, environmental sustainability, and behavioral flexibility.

With respect to the research focus in this thesis, the methodology of evaluation and criteria setting need to be developed from a more linked social–ecological perspective. The selection of criteria and indicators will also guide the creation of adaptation goals and objectives for the pilot area Yankeetown-Inglis.

Indicators

The key consideration of selecting the indicators is what factors would contribute to the resilience building of the social–ecological system for long-term sustainability. Thus, the sustainability indicators could be critical in shaping the evaluation framework (Tompkins et al., 2010). Three evaluation frameworks were selected and synthesized to design sustainable indicators for this research: the adaptive co-management evaluation framework from Plummer and Armitage (2007), sustainable rural livelihoods indicators from Scoones (1998), and evaluation framework from San Diego Bay Adaptation Strategy (Hirschfeld, 2012).

Plummer and Armitage (2007) identified three components for assessing adaptive co-management in the linked social–ecological system: “an ecological component, an economic component approached using a sustainable livelihoods framework, and process component that draws attention to the role of institutions and power” (Plummer & Armitage, 2007, p. 65). Scoones (1998) identified five primary indicators for evaluating sustainable rural livelihoods. They are “creation of working days, poverty reduction, well-being and capabilities, livelihood adaptation, vulnerability and resilience, and natural resource base sustainability” (Scoones, 1998, p. 5–6).

Furthermore, according to specific issues and conditions of climate change and sea level rise, another evaluation framework from the San Diego Bay Adaptation Strategy (Hirschfeld, 2012) was referenced to fill gaps in the previous two frameworks.

A set of questions was considered to create indicators: Does the strategy can help to reduce GHG emissions? Is the strategy flexible enough to respond to changing circumstances? Does the strategy create opportunity for the public to access shorelines, beaches, and recreational facilities? Will the strategy maintain community character?

Given the consideration of all factors discussed above of enhancing social–ecological resilience for the community under climate change stresses, the author synthesized a list of indicators as shown below in Table 2-1. The indicators for evaluating sustainable adaptation planning and strategies can be classified into three components: ecosystem, livelihood, and process. A series of specific indicators will contribute to the target components.

Table 2-1. Indicators for evaluating sustainable adaptation strategies

Ecosystem	Livelihood	Process
Ecological components	Increase economic and social well-being	Diverse stakeholders involvement
Relationships and functions	Decrease vulnerability	Communication and negotiation
Diversity	Public safety and health	Transactive decision making
Memory and continuity	Increase food security	Social learning
	Sustainable resource use	
	Reduce GHG emissions	
	Flexibility	
	Public access	
	Community character	

Source: Adapted from Plummer & Armitage, 2007; Scoones, 1998; Hirschfeld, 2012.

Ecosystem is a focal component in the complex social–ecological system. The resilience of the ecological system can depend on four indicators: ecological components, relationships and functions, diversity, and memory and continuity (Plummer & Armitage, 2007). Ecological components refer to specific species, habitats, and biophysical features that consist of ecological systems. Relationships between components and their environment are important in maintaining irregular functions. Another key element is diversity, which can promote regeneration of and innovation in a system. Ecological memory and continuity indicates the capacity of a system to continue its self-organization (Plummer & Armitage, 2007).

Livelihood component associates with the outcomes of socio-economic, ecological, and institutional drivers. A livelihood consists of capabilities, assets, and activities needed for living, and a sustainable livelihood means the system has the ability to recover from disturbances while increasing its assets (but not sabotaging its natural resources) (Scoones, 1998). In an effort to evaluate the sustainable livelihoods outcome of adaptation strategies, a list of factors can be used to evaluate the strategies, including improving economic and social well-being by increasing income and decreasing poverty, decreasing vulnerability, promoting public safety and health, using resources sustainably, and increasing food security. In addition, specific climate change concerns can be measured, including reducing GHG emissions, providing public access, maintaining community character, and the flexibility of the strategy (Scoones, 1998).

Process component, in the context of this thesis, refers to the adaptation planning process that contributes to the strategy development. As the process inextricably links the final outcomes, there is a need to evaluate how the adaptation strategies are created. The following indicators are considered when evaluating the adaptation planning process: diverse stakeholders' involvement, communication and negotiation at different scales, transactive decision-making by reaching consensus through diverse inputs and opinions, and social learning (Plummer & Armitage, 2007). In this study, the process indicators will be used to assess the overall adaptation planning process for cases, instead of individual strategy.

Clearly, the three components and corresponding indicators are quite different, ranging from very specific to very diffuse indicators. Given the fact that precisely measuring these indicators will require an amount of qualitative techniques and data, the author preferred to use a more concise way to evaluate potential strategies. An evaluation rating scale will be assigned to assess the extent to which the strategy contributes or conflicts with the identified indicators: "++" means the strategy strongly contributes the indicator; "+" indicates the strategy somewhat contributes to the indicator; "0" shows the strategy has no effect on the indicator; "-" states the strategy is somewhat in conflict with the indicator; and "--" reveals the strategy significantly conflicts with the indicator (Hirschfeld, 2012). Then the values of each strategy can be calculated to determine its sustainability. This evaluation method will be used for analyzing adaptation strategies from case studies, as well as from the adaptation strategies scenarios for Yankeetown-Inglis.

Yankeetown-Inglis Analysis and Strategy Design

The purpose of conducting analysis and strategy design for the study area Yankeetown-Inglis is to test the integrated approach and the evaluation framework. Yankeetown-Inglis was chosen as the study area for several reasons. First, Yankeetown-Inglis is a rural community along the Florida western coast with valuable natural resources and unique rural character, which is appropriate for studying integrated adaptation strategies for sea level rise. Furthermore, as the author has participated in the sea level rise project of the University of Florida and Florida Sea Grant: Planning for Coastal Change in Levy County, especially the Yankeetown-Inglis part, this thesis has gotten great help and support from this project and could be considered as further research for designing adaptation strategies for Yankeetown-Inglis.

Data Collection

A variety of methods have been used for data collection for Yankeetown-Inglis vulnerability analysis and strategy design. Both primary and secondary sources of data served as a foundation in forming an understanding of the community. Secondary data sources consist of documents from governments and agencies, as well as spatial Geographic Information System (GIS) data obtained from the Florida Geographic Data Library (FGDL), which include environmental features, conservation lands and priorities, land use, private property, and demographics. They help to examine the character of the study area in terms of its social, economic, cultural, environmental, and geographic contexts. On-site observation as a primary data source was also used to identify the place and its potential role in applying adaptation strategies.

Other essential data collected were sea level rise projection models. Two primary models have been considered and applied in this research: the bathtub inundation model and Sea Level Rise Affecting Marshes Model (SLAMM). The bathtub inundation model projects that all land under a given elevation would be inundated by raising sea levels based on local topography, while SLAMM, generated by The Nature Conservancy (TNC), is a relatively dynamic model that predicts the coastal habitat changes under different sea level rise scenarios and their influence on developed or undeveloped dry land. Because of the abundant natural features along the Yankeetown-Inglis coast, SLAMM is likely to be a more suitable projection for analyzing sea level rise impacts for the study area.

Vulnerability Assessment

Sea level rise vulnerability assessment for the study area generally consists of two parts: natural environment vulnerability and built environment vulnerability. To understand sea level rise impacts to the natural environment, the SLAMM output will show through specific data on how many changes would occur on different types of habitat and land use. Changes in developed and undeveloped dry land can also be calculated by SLAMM result. With the projected sea level rise model, the vulnerability of the built environment can be further assessed through spatial analysis in GIS mappings. For instance, with the spatial overlaying of SLAMM output on land use or property data, the types of land use or structures that would be affected by changing habitats can be visually perceived. In addition, the vulnerability to the built environment can also be assessed based on other relevant qualitative and quantitative data collected ahead, such as demographic and economic data, as well as the data from the observation of community workshops conducted by the Planning for Coastal Change in Levy County Project.

Adaptation Strategies

Analysis and design of adaptation strategies for Yankeetown-Inglis is a synthesis process taking into account diverse components of previous research, including literature review of different types of adaptation strategies, evaluation of strategies from case studies by an evaluation framework, and vulnerability analysis of the study area.

Two adaptation strategies scenarios will be conducted for Yankeetown-Inglis, based on different goals and considerations. Adaptation Strategies Scenario I focuses on sea level rise adaptation planning for both the natural and built environments by applying more integrated strategies, while Scenario II intends to select adaptation strategies that would increase the resilience of the built environment. Though strategies for the two adaptation scenarios differ in the light of different goals and objectives, they share some common desires: to protect the community from sea level rise impacts, to meet the basic needs, and to maintain the rural character. The two adaptation scenarios will then be assessed and compared by the evaluation framework created early on in this research. The purpose of conducting and comparing two adaptation scenarios is to explore and identify the significance and potential of integrated strategies in promoting sustainable adaptation to sea level rise impacts.

CHAPTER 4
CASE STUDIES ANALYSIS

Case Study I: City of Punta Gorda, Florida

Introduction

The City of Punta Gorda is located on the Florida southwest coast, which is exposed to the negative impacts of climate change and sea level rise. Hurricanes and storms have visited the community several times in recent years, causing severe damage to private property, the loss of mangrove forests, and threats to public safety. One of the triggers of Punta Gorda's involvement in climate change planning projects was Hurricane Charley in 2004, which led to expensive property damage in the city (National Oceanic and Atmospheric Administration [NOAA], 2010). Although Punta Gorda had already adopted some adaptation strategies to deal with climate change impacts in its Comprehensive Plan, such as structure elevations, drainage systems improvements, and the relocation of important infrastructures and facilities, the city still aims to build resiliency for the community through long-term adaptation planning (Beever et al., 2009).

The City of Punta Gorda, Florida initiated a climate change planning project in 2008 with the support of the Charlotte Harbor National Estuary Program and Florida's Southwest Regional Planning Council. This project was part of the Climate Ready Estuaries program developed by the National Estuary Programs and the U.S. Environmental Protection Agency (NOAA, 2010).

In November 2009, the project published the City of Punta Gorda Adaptation Plan, which contained a physical vulnerability assessment and prioritized adaptation strategies for the city. Public participation was their efforts to identify the most vulnerable areas and prioritize adaptation strategies. This approach identified, by a variety of citizen stakeholders in the public workshops, eight key vulnerabilities and 104 acceptable recommended adaptation options (Beever et al., 2009). The plan contains three major components: vulnerability assessment, considerations for selecting priorities and actions, and communication with stakeholder and decision makers (Beever et al., 2009).

Vulnerability Assessment

The City of Punta Gorda contains significant low-lying areas with wetlands and open lands along Charlotte Harbor and Alligator Creek. The major vegetation categories include coastal wetlands, transition zones, and inland prairie. The city has general flat elevations from sea level to about 15 feet over sea level (Beever et al., 2009).

The project conducted a risk analysis and vulnerability assessment to identify the most significant impacts of climate change, the timeline for the predicted impacts, and other factors and considerations needed to set priorities (Beever et al., 2009). As a result of communication between stakeholders and decision makers, 54 vulnerabilities falling into eight categories were identified by the citizens of the City of Punta Gorda in the public workshops, in priority order:

1. Fish and wildlife habitat degradation
2. Inadequate water supply
3. Flooding
4. Unchecked or unmanaged growth
5. Water quality degradation
6. Education and economy and lack of funds
7. Fire
8. Availability of insurance (Beever et al., 2009, p.46)

Adaptation Strategies

Given the eight identified vulnerabilities of Punta Gorda, corresponding adaptation strategies to mitigate each problem were then discussed. The workshops finally accepted 104 for adaptation planning, rejecting an additional 34 (Beever et al., 2009). Seven adaptation options were prioritized for the community to address climate change impacts:

1. Protect and restore seagrasses
2. Use native plants in landscaping to improve water supply and drought
3. Identify the areas of remaining natural shorelines in local master plans
4. Constrain location for certain high risk infrastructure to address unmanaged and unchecked growth
5. Restrict fertilizer use to maintain water quality
6. Promote green building alternatives to address education, economic, and finance issues
7. Implement drought preparedness planning to address fire vulnerability (Beever et al., 2009)

In particular, the Adaptation Plan discussed adaptation to coastal erosion and sea level rise. The City of Punta Gorda has already applied three adaptation strategies for the built environment to address flooding and coastal erosion issues: protection, managed retreat, and accommodation (Beever et al., 2009). For the protection strategy, the Adaptation Plan did not rely on hard protection approaches, such as seawalls and dikes, as it determined that they would be less financially sustainable in the long run, and were less ecologically sustainable. But the plan did suggest that a passive protection approach could be applied in the historic downtown district of Punta Gorda, by elevating existing buildings or adding additional height to new buildings. Adding 8 to 10 feet of height would be sufficient to protect against rising sea levels through 2200

(Beever et al., 2009). Another option the Adaptation Plan provided to protect the shoreline was establishing ecosystems seaward of the existing shoreline (Beever et al., 2009). Under this circumstance, the shoreline may be maintained statically while coastal ecosystems are protected.

For the managed retreat strategy, the Adaptation Plan argued that it is a financially and ecologically sustainable option. However, many problems could occur when applying this strategy, including in-migration land use conflicts, property loss, “taking” issues, short-term relocation costs, and negative tourism effects (Beever et al., 2009). Therefore, the City of Punta Gorda proposed a comprehensive shoreline assessment to determine the appropriate lands for protection or relocation based upon estimates of sea level rise, coastal erosion, and storm surges. Rolling easement and other similar policies can be employed to encourage shoreline retreat inland and discourage hard structure protection. In addition, there is a need to identify the areas likely to be inundated according to the hazard projections, so new investment will be minimized in those areas and inundated buildings and infrastructures will be removed or relocated. Finally, good waterfront design principles are still needed to adapt existing structures to new requirements anticipating sea level rise (Beever et al., 2009).

For the accommodation strategy, the Adaptation Plan suggested that accommodation would be better applied in combination with the managed retreat strategy, and for areas where retreat is finally planned (Beever et al., 2009). In addition, special guidelines are needed for these areas to support water-dependent land uses, adapt to rising sea levels, allow habitat migration, and incorporate good waterfront design principles (Beever et al., 2009, p. 203).

Moreover, the City of Punta Gorda has applied for funding from the U.S. Department of Transportation for the Downtown Infrastructure Protection Seawall Replacement Project to preserve its important railroad corridors in the Punta Gorda Community Redevelopment Area (Beever et al., 2009). Innovative “inland” seawalls will be created at about 3 feet higher than the existing elevation to protect critical transportation infrastructure from rising water tables and storm surges. Also, the project will designate sufficient space for ecosystem processes (Beever et al., 2009).

Conclusions

The City of Punta Gorda Climate Change Adaptation Plan documents the critical vulnerabilities of the city and adaptation strategies to address each area of vulnerability. The adaptation strategies were generally created in considerations of ecological and financial sustainability. Protection, managed retreat, and accommodation are the major adaptation strategies for the built environment to address sea level rise issues. On the other hand, the plan also proposes some integrated strategies to relieve sea level rise concerns to the natural–built environment, such as using landscaping to improve the water supply, preserving natural shoreline to protect against flooding, and suggesting green building alternatives. As a result, Punta Gorda seems illustrate the successful application of the integrated climate change adaptation approach.

Public participation was the key approach used to prioritize vulnerabilities and adaptation strategies. Although the city has not yet reported how these adaptation strategies have been implemented, the Adaptation Plan detailed specific implementation actions and plans for the monitoring and evaluation of strategies. It particularly emphasized the importance of monitoring and evaluation to assess the successfulness of the adaptation process. Detailed monitoring measurements, data needed, and primary target goals were displayed in the plan. The plan will be updated during the adaptive management process and will incorporate new knowledge and techniques from the monitoring and evaluation of implementation results.

Case Study II: Town of Groton, Connecticut

Introduction

The Long Island Sound Study, in conjunction with the Local Governments for Sustainability (ICLEI) and Connecticut Department of Environment Protection, is creating a Coastal Adaptation Plan for the Town of Groton, Connecticut (Gregg, 2010). In April 2011, the entities presented a final report about the adaptation plan to the Town of Groton (Stults & Pagach, 2011).

The major adaptation planning process was formed through three essential workshops, which were conducted to convene diverse stakeholders from the governments of different levels to develop adaptation strategies for Groton and the Northeast (ICLEI, n.d.). The goal of the workshops was to educate different stakeholders about climate change impacts and adaptation planning; to identify vulnerabilities and corresponding adaptation strategies; and to develop implementation plans (Gregg, 2010). To be specific, three workshops focused on different objectives:

1. Climate adaptation planning process and projected global, regional, and local climate changes
2. Identification of vulnerabilities based on global and regional projection
3. Identification of adaptation action to increase resilience in addressing climate change impacts (Stults & Pagach, 2011, p. 4)

The final report describes the adaptation planning process, outcomes, and suggestions for future studies, which provided recommendations for the Town of Groton and other communities, especially coastal communities, in addressing climate change impacts.

Vulnerability Assessment

The Town of Groton is located on the Thames River. Climate change is already affecting Groton through shoreline erosion, intensive storms and hurricanes, sea level rise, and tidal marsh migration (Stults & Pagach, 2011). In order to assess the existing and potential climate vulnerabilities in the future, the project used scientific information and the COAST tool to evaluate the potential economic damage caused by climate change. This tool helps decision makers select adaptation strategies based on implementation costs.

The project identified the following vulnerabilities for Groton as potential climate change impacts during the workshop:

- Increased coastal flooding and overflows of sewers
- Loss of coastal habitats
- Salt water intrusion affecting drinking water quality and supply
- More frequent flooding could hamper important roads, access, and other infrastructures
- Impacts on marina facilities and docks
- Increased economic impacts
- Reduced shell-fishing and fish spawning
- Reduced overall quality of life (Stults & Pagach, 2011, p. 7)

Workshop participants also identified key areas or infrastructures as vulnerable to sea level rise and flooding, including specific roads and bridges, a water treatment plant, schools, residential and commercial locations, ecological resources, and emergency services (Stults & Pagach, 2011).

Adaptation Strategies

According to the vulnerability assessment, workshop participants then identified a series of strategies:

- Install of flood/tide gates at specific locations
- Beach nourishment
- Flood-proof existing buildings
- Designate more stringent building and engineering design standards
- Convert upriver land to wetlands
- Guarantee emergency access through elevating or relocating vulnerable infrastructures
- Create retreat zoning, implement of redevelopment restrictions, and change building codes to avoid development in the most vulnerable areas
- Designate vulnerable areas as buffer zones
- Identify the safest transportation routes for the school district and other agencies during extreme events through improved road condition reports
- Develop stormwater runoff reduction program
- Create a comprehensive watershed management plan
- Educate residents about climate change and its impacts
- Identify available funding from local, state, and federal agencies to improve important infrastructures
- Integrate climate preparedness into the Capital Planning process, Master Plan of Conservation and Development update process, the zoning regulations revision, and streetscape project (Stults & Pagach, 2011, p. 9–10)

The potential adaptation strategies for the Town of Groton can also be classified into the following categories: protection, accommodation, and managed retreat. The majority of the strategies discussed here intend to address flooding and sea level rise impacts to the built environment; however, limited strategies have been considered and proposed for the natural environment or even both the natural and built environments. Furthermore, the project emphasized the economic assessment of different strategies in order to determine the best cost–benefit choices.

Conclusions

The Town of Groton coastal climate change planning report essentially documented the adaptation planning process and identified the vulnerabilities and adaptation strategies for the town. It also provided recommendations for the next steps of climate preparedness, including conducting a town-wide vulnerability assessment and climate action plan, facilitating coordination and communication with pubic and stakeholders, and pursuing funding sources. It also suggested that state, federal, and other stakeholders need work together to help and support the town for climate change data and knowledge updating (Stults & Pagach, 2011).

In addition, Groton learned valuable lessons from this adaptation planning process that are not only directing Groton's further planning steps, but also providing recommendations for other communities. It is very important to understand a community's vulnerabilities and needs through face-to-face meetings with different stakeholders, which was critical to Groton's process. The collaboration across levels and sectors can also support better planning and implementation for resilience building. Last but not least, the plan also pointed out several problems and challenges in the planning process, such as planning despite uncertainties, the difficulty of valuing ecosystems, and the need to decrease incentives to build in vulnerable areas (Stults & Pagach, 2011).

Case Study III: City of Lewes, Delaware

Introduction

The City of Lewes, Delaware, is exposed to the natural hazards such as storm surges and floodings, and over 30% of the parcels within the Federal Emergency Management Agency (FEMA) 100-year floodplain (Delaware Sea Grant & ICLEI, 2011). Lewes has already focused on the hazard mitigation planning and has a Hazard Mitigation Strategy (Delaware Sea Grant & ICLEI, 2011). In cooperation with Delaware Sea Grant and ICLEI, Lewes launched the Hazard Mitigation and Climate Adaptation Pilot Project in 2011. The purpose and goals of this pilot project were to further assist and guide the City of Lewes in incorporating climate adaptation into its hazard mitigation planning, thereby improving community resiliency and sustainability (City of Lewes, 2011; Delaware Sea Grant& ICLEI, 2011).

The project team acknowledged that stakeholder and public input are important to the planning process. Four workshops and several meetings have been conducted to engage local officials and residents in identifying Lewes's biggest vulnerabilities and feasible actions to reduce these vulnerabilities (Delaware Sea Grant & ICLEI, 2011). Public participation was involved in all the steps that the project processed:

1. Identify existing hazards and associated vulnerabilities
2. Assess climate change impacts on existing hazards
3. Identify two key vulnerabilities
4. Select hazard mitigation and climate adaptation actions
5. Create implementation plans (Delaware Sea Grant & ICLEI, 2011, p. 7–8)

The products of these five steps were detailed in the project's Hazard Mitigation and Climate Adaptation Action Plan that released in June, 2011. The plan further documented the methods used and the outcomes produced during the project process (Delaware Sea Grant & ICLEI, 2011).

Vulnerability Assessment

The City of Lewes is the oldest town in Delaware with a historic and special relationship with the sea. The community consists of residential areas, a central business district, a beachfront area, and an abundant natural environment including tidal wetlands, tidal creeks, and sandy beaches (Delaware Sea Grant & ICLEI, 2011). Due to its geographic location and generally flat topography, Lewes is very vulnerable to the natural hazards such as flooding, storms, severe thunderstorms, wind, drought, erosion, and tornadoes. Climate change could multiply the negative effects of these natural hazards (Delaware Sea Grant & ICLEI, 2011). In particular, more significant threats to Lewes will come from sea level rise, such as change of flood pattern, losses of dry lands, erosion, and saltwater intrusion (Delaware Sea Grant & ICLEI, 2011). The State of Delaware is currently working on planning for a projected future sea level rise of between 1.6 and 4.9 feet (Delaware Sea Grant & ICLEI, 2011).

Current and future vulnerability self-assessments were conducted for Lewes. The current vulnerability self-assessment concentrated on flooding problems. The future vulnerability self-assessment was conducted according to the information gathered from workshops. Participants engaged in a vote to select key vulnerabilities in terms of the three components of the vulnerability assessments: exposure, sensitivity, and adaptive capacity (Delaware Sea Grant & ICLEI, 2011). As a result, two key vulnerabilities were identified by the community:

- Saltwater intrusion into aquifers and potential changes of precipitation patterns caused by sea level rise
- Homes and City infrastructure threatened by flooding and higher water levels (Delaware Sea Grant & ICLEI, 2011, p. 37)

Adaptation Strategies

With the consideration of key vulnerabilities identified by the community, potential adaptation strategies were identified that focused particularly on addressing flooding and water resource concerns. In order to identify the most important actions for the City to implement in advance, participants from the last two workshops engaged in a ranking exercise to score potential strategies in terms of their social, administrative, technical, political, economic, and environmental feasibility. As a result, six actions for hazard mitigation and climate change adaptation were recommended to the City for implementation (in priority order):

1. Integrate climate change issues into the comprehensive plan as well as the building and zoning codes
2. Improve outreach and education particularly focused on successful behavior changes related to home building and retrofits
3. Integrate aquifer information into all planning efforts
4. Determine road levels and evacuation risk using elevation data
5. Evaluate the City and the Board of Public Works infrastructure's flood vulnerability from direct flood impacts, as well as from indirect flood impacts to access routes
6. Improve the City's Community Rating System (CRS) (Delaware Sea Grant & ICLEI, 2011, p. 49)

Conclusions

The City of Lewes Hazard Mitigation and Climate Adaptation Pilot Project aimed to protect public safety and reduce loss from natural hazards, as well as increase the general resiliency of the community. Lewes already has significant experience in hazard planning for many years, which can be a strength and opportunity for the City to better integrate hazard mitigation and climate change adaptation. So proposed strategies were more focused on flooding and water resource issues in light of planning and policy standpoints. The primary concern of the Lewes Adaptation Project is protection of existing properties and infrastructures from natural hazard impacts. Although the plan did mention using ecosystem-based tools such as creating buffer zones for habitat inland migration, these integrated strategies were not the priority. In order to help monitor the implementation of proposed strategies, the project outlined the guidance for each strategy, including key implementation steps, possible timelines, administration and staffing, and indicators for monitoring.

The important lessons learned from the Lewes' project is the integration of climate change adaptation planning and hazard mitigation by combining two different processes—ICLEI's Climate Resilient Communities Five Milestones for Climate Adaptation planning framework and a natural hazard mitigation planning framework from FEMA (Delaware Sea Grant & ICLEI, 2011). The work of Lewes showed that these two approaches can be integrated, especially for communities that already have hazard mitigation efforts.

Case Study IV: The State of Maryland

Introduction

The State of Maryland, which contains over 4,000 miles of shoreline, would be extremely vulnerable to sea level rise. Maryland has already experienced 1 foot of sea level rise during the past century, and 13 bay islands have been inundated as a result (Johnson, 2010; Maryland Department of Natural Resources [DNR], n.d.). Recognizing the negative impacts of climate change and sea level rise, the Maryland Department of Natural Resources (DNR) cooperated with the Maryland Commission on Climate Change (MCCC), Governor Martin O'Malley, and the State Legislature to address climate change issues through engaging and educating the public, developing adaptation strategies and policies, and building capacity for local governments (Johnson, 2010).

MCCC developed the Climate Action Plan in 2008 to discuss climate change impacts, economic cost, and a series of strategies to reduce GHG emissions and the negative effects of sea level rise. Chapter Five, “Comprehensive Strategy for Reducing Maryland’s Vulnerability to Climate Change” (MCCC, 2008, p. 1), is an essential element of the Plan that researched sea level rise vulnerabilities and developed adaptation strategies to increase Maryland’s overall resiliency (Feifel & Papiez, 2010). This chapter includes two phases: Phase 1 focused on developing strategies to address sea level rise impacts (Boicourt & Johnson, 2010), and Phase 2 researched adaptation strategies in terms of different sectors, including “ Human Health; Agriculture; Forest and Terrestrial Ecosystems; Bay and Aquatic Environments; Water Resources; and Population Growth and Infrastructure” (Boicourt & Johnson, 2010, p. 2).

Additionally, in December, 2009, DNR initiated a project of “Integrating Climate Change Adaptation Strategies into Maryland’s Coastal Land Conservation Targeting” (Feifel & Papiez, 2010, p. 1), aiming to prioritize adaptation strategies for conservation land and identify coastal lands of significant climate change vulnerability and adaptation opportunities through selected criteria (Feifel & Papiez, 2010). One of the key adaptation strategies is facilitating the inland movement of high priority coastal ecosystems. In public workshops conducted by DNR and NOAA, three key criteria were selected to identify climate change targeted areas: coastal lands with little to no hardened shorelines and other barriers; suitable undeveloped uplands 0 to 5 feet above sea level; and intact wetland migration corridors (Papiez, 2009). These efforts finally helped Maryland to identify coastal lands that need conservation (Feifel & Papiez, 2010).

Vulnerability Assessment

A vulnerability assessment of climate change impacts have been developed by the MCCC Scientific and Technical Working Group to analyze the likely impacts on different sectors, including water resources, aquatic ecosystems, farms and forests, coastal zone and ecosystems, and human health. The assessment was established according to model projections and literature review (Boesch, 2008). In general, due to climate change, the average temperature in Maryland tends to increase significantly, as well as the precipitation (Boesch, 2008). As a result, the following impacts are projected to occur in Maryland and are identified as the most important vulnerabilities of the State to climate change impacts:

- Increased precipitation will likely affect water supply and increase urban flooding events
- Aquatic ecosystems are likely to be degraded by increased salinity and habitat loss
- Northern hardwoods and pines will likely to diminish as climate-related stresses
- Species shifts and decrease of biodiversity
- Hundreds of square miles of land and wetlands will likely be lost due to sea level rise
- Water quality in the Chesapeake and Coastal Bay would decrease and restoration goals would hardly to be attained
- Living resources in the Chesapeake Bay are likely to change in terms of species composition
- Heat-related health risks are likely to increase if under higher emission scenarios (Boesch, 2008).

In particular, sea level rise is a critical threat to coastal Maryland. The Technical Working Group from the MCCC projected that in the future the sea level may rise 2.7 to 3.4 feet in Maryland by the end of this century under different emission scenarios (MCCC, 2008). Rising sea levels are likely to generate many negative impacts to Maryland's coastal zones, including shore erosion, coastal flooding, inundation, impacts to barrier and bay islands, and higher water tables and salt water intrusion (MCCC, 2008).

Adaptation Strategies

Maryland recognized the complexity of planning for climate change and sea level rise, so the state applied an integrated approach to integrate climate change adaptation planning to existing state and local sector-based planning, management, and regulatory efforts (MCCC, 2008). Detailed adaptation strategies were identified for different sectors.

Aquatic and terrestrial ecosystems

- Preserve habitat migration corridors and native biodiversity hotspots
- Facilitate coastal ecosystems moving inland by sea level rise impacts
- Protect suitable habitat for endangered and threatened species
- Conserve riparian corridors and areas adjacent to shoreline habitats

Agriculture

- Protect soil and freshwater resources
- Reduce nutrient and sediment runoff
- Maintain abundant area for agricultural productions and investigate production alternatives in demonstration areas

Human habitat and health

- Protect and expand natural flood storage areas
- Preserve and increase natural buffers to protect inland from storm surge
- Protect potential relocation areas
- Preserve potable water supply

Resource based industries

- Provide upland relocation and access opportunities
- Maintain public access to beaches and open spaces
- Facilitate aquaculture development in appropriate areas
- Maintain tourism and outdoor recreational opportunities

Transportation and land use

- Prevent ecosystem fragmentation
- Promote relocation and prevent development in high risk coastal areas
- Protect human settlements and other historic and cultural properties
- Conserve habitats sequestering carbon and maintain habitat integrity through corridors (Papiez, 2009)

In particular, Maryland initiated the Living Shoreline Protection Act in 2008 to require the use of non-structural coastal protection approaches except when proven infeasible. Additionally, the Plan also suggested adapting to climate change and reducing vulnerability through coastal land conservation, for example, using a green infrastructure approach to address climate change impacts (Johnson, n.d.).

Conclusions

The State of Maryland identified the climate change vulnerabilities and adaptation strategies on a state scale, thereby providing appropriate direction to local governments in addressing these potential threats to the communities. A number of towns and cities in Maryland have been working on adaptation planning at the local level to assess climate change vulnerabilities and develop adaptation strategies. It has been noted that Maryland particularly emphasized the preservation of ecosystems and habitats and the use of various integrated strategies to assist in mitigating sea level rise impacts to the natural–built environment, such as planting living shorelines, preserving natural buffers to mitigate storm surges, and implementing green infrastructure methods. Maryland's adaptation planning efforts demonstrate the effective application of integrated strategies at the state level.

Case Study V: San Diego Bay

Introduction

San Diego Bay is in Southern California, with a vibrant coast and livable communities, but rising sea levels and other climate impacts threaten the overall well-being of the region. It is predicted that sea levels could increase as much as 5 feet in the San Diego region by 2100 (Hirschfeld & Holland, 2012). In order to plan for these changes in advance and enhance community resiliency, a Public Steering Committee was constituted to develop policy responses and recommendations (Hirschfeld & Holland, 2012). Other project partners were ICLEI, the San Diego Foundation, and the Tijuana River National Estuarine Research Reserve-Coastal Training Program, all of whom contributed to the development of sea level rise adaptation strategies through a collaborative process (Hirschfeld & Holland, 2012).

The Adaptation Strategy project was started based on the ICLEI's climate adaptation planning framework, which included conducting climate vulnerability assessment, setting goals, and developing policy recommendations. After developing adaptation strategies, the project recommended that an implementation plan should be developed and monitored (Hirschfeld & Holland, 2012). Besides learning from ICLEI, the project also conducted a series of workshops and meetings to enhance participants' understanding of climate change issues, build collaboration, and generate important feedback to inform the Adaptation Strategy. The Adaptation Strategy outlined a comprehensive vulnerability assessment and broad strategies for building community resiliency, as well as detailed sector-based vulnerabilities and targeted strategies (Hirschfeld & Holland, 2012).

Vulnerability Assessment

The vulnerability assessment began by identifying the problems of sea level rise on San Diego Bay. Based upon the scientific predictions of sea level rise, the vulnerability assessment assumed a rising sea level of 20 inched by 2050 and 59 inched by 2100 (Hirschfeld & Holland, 2012). The impacts of sea level rise identified by the project included inundation, flooding, rising water table, coastal erosion, and saltwater intrusion. Three elements of exposure, sensitivity, and adaptive capacity were used to assess various vulnerabilities (Hirschfeld & Holland, 2012). As a result, the project evaluated the primary vulnerabilities for different sectors in detail.

- The habitats of ecosystems and critical species are likely to migrate inland
- Contaminated sites will be subject to inundation and flooding, releasing more contamination into flood waters or area soils
- Storm sewers are vulnerable to inundation and flooding on the Bay that would exacerbate the flooding
- Sanitary sewers in low-lying areas could be affected by floodwater inflow that would result in discharge of wastewater into the Bay
- Water distribution components will be affected by inundation and flooding, affecting the potable water
- Energy facilities will be vulnerable to erosion, inundation, and flooding

- Local transportation facilities such as access and roads will be vulnerable to flooding and inundation
- Residential buildings will be highly vulnerable to inundation and flooding by 2100
- Emergency response facilities will be moderately vulnerable to flooding
- Shoreline parks, recreation and public access will be extremely vulnerable to inundation and flooding
- Parts of the airport will be affected by inundation and flooding, and airport operations will be highly subjected to inundation and flooding by 2100
- Low-income residents, the elderly, the homeless, and ethnic minorities will be more vulnerable to sea level rise. Additionally, people who work in these vulnerable sectors will become vulnerable populations (Hirschfeld & Holland, 2012, p. 20–21)

Adaptation Strategies

Both comprehensive and targeted strategies were considered by the project in the Adaptation Strategy. The comprehensive strategies were recommended for implementation at regional and local levels. For implementation at the regional level, it was suggested that a regional adaptation working group of public agency representatives can be created to facilitate stakeholder engagement in the implementation. It was recommended that education, training, and outreach programs should be enhanced for diverse stakeholders and the public. Furthermore, it was determined that scientific research into sea level rise should be continued to better understand sea level rise vulnerabilities. Finally, a need was identified to engage other agencies such as regulatory agencies and FEMA to work collaboratively addressing sea level rise impacts (Hirschfeld & Holland, 2012).

For local implementation, Adaptation Strategy recommended four strategies for implementation at the agency level: incorporate sea level rise issues into local and regional plans and projects; take advantage of support from the State of California

Climate Action Team; assess detailed vulnerabilities at a locational level; and develop decision-making frameworks for each jurisdiction (Hirschfeld & Holland, 2012).

Additionally, a series of targeted adaptation strategies were developed for identified vulnerable sectors corresponding to the vulnerability assessment. A summary of the strategy options for San Diego Bay is listed below.

Ecosystems and critical species

- Develop habitat migration projects and provide opportunities for habitat inland migration through preserving or expanding ecological buffers
- Facilitate low-impact development (LID) strategies to protect water quality and reduce stormwater runoff
- Protect habitat corridors to promote species migration
- Undertake research on sediment transport dynamics and improve the health of wetlands

Contaminated sites

- Develop an assessment for high-risk contaminated sites and conduct an improved regional assessment for prioritizing adaptation strategies

Stormwater management

- Prioritize LID stormwater practices and improve stormwater management plans and capital improvement programs to address sea level rise impacts
- Conduct a detailed vulnerability assessment for stormwater management at facility level
- Enhance capacity of stormwater management facilities

Wastewater

- Improve existing wastewater management plans and capital improvement programs to take into account sea level rise impacts
- Conduct a detailed vulnerability assessment for wastewater facilities
- Improve wastewater emergency response, maintenance procedures, and facility design

- Assure that new sewer mains and manholes are sealed against floodwater and groundwater

Potable water

- Conduct a detailed vulnerability assessment for potable water facilities

- Improve potable water emergency response and maintenance procedures

Energy facilities

- Work with San Diego Gas and Electric to develop a detailed vulnerability assessment of energy infrastructure for specific sites and to design new facilities to cope with sea level rise

Local transportation facilities

- Create new transportation projects at the local level

- Work with San Diego Association of Governments and Caltrans to conduct a detailed vulnerability assessment of regional transportation facilities in order to improve existing infrastructure and design new facilities to account for sea level rise impacts

- Supervise changes in design standards relating to drainage, and consider applying floodplain-level standards in vulnerable areas

Building stock

- Enhance floodplain management regulations for areas in the 100-year floodplain and other areas that will be vulnerable to sea level rise

- Work with FEMA to account for future sea level rise in Flood Insurance Rate Maps

- Initiate financial incentives for higher standards in buildings

- Enhance education and outreach for property owners in flood-prone areas

- Facilitate better understanding of the existing building elevation through obtaining more specific data

- Consider applying FEMA's National Flood Insurance Program (NFIP) minimum requirements to new development for areas that are vulnerable to the projected sea level rise but not in existing 100-year floodplains

Emergency response facilities

- Create higher standards for all emergency response facilities and collect more detailed information about critical facilities

Parks, recreation, and shoreline public access

- Prioritize the most vulnerable parks, open spaces, and habitat vulnerable to flooding, and promote public access as shoreline changes

- Identify specific vulnerabilities for sites and buildings and develop adaptation responses

Regional airport operations

- Integrate sea level rise flood scenarios into the Regional Aviation Strategic Plan and consider alternative sites

- Explore potential alternatives for airport access to avoid vulnerable roads that may be impaired by inundation and flooding (Hirschfeld & Holland, 2012, p. 28–53)

Conclusions

The San Diego Bay adaptation effort is one of the first sea level rise adaptation plans generated at a regional level. The collaboration of stakeholders from various agencies and property owners is a key element in the planning process. The Adaptation Strategy provides general vulnerability assessment for different sectors and suggests targeted strategies for each vulnerability. The Public Steering Committee's first steps were to learn about how sea level rise would affect the community by the end of this century, educate the community about its findings, and assist further efforts to incorporate sea level rise planning into local policy and programs. The proposed adaptation strategies can be generally classified into those addressing natural, built, and both environments. The integrated concept has been incorporated into their strategies such as using LID for stormwater management and water quality protection, facilitating habitat migration, and preserving ecological buffers. The project will continue the adaptation planning efforts to engage stakeholders and coordinate implementation at the local level.

Strategy Classification

These five cases represent initiative adaptation planning for climate change and sea level rise at different scales both locally and regionally. Although the plans differ due to the varying characteristics of each region or area, there are similarities in their adaptation planning. One of the important similarities is that they all integrated scientific projections and information into their planning and developed vulnerability assessments of climate change in the first place, either for the region or local community. Even though some of their vulnerability assessments are not very detailed, they all present major concerns for climate change planning, which directed their strategy developments. These adaptation strategies address certain common concerns:

1. Natural environment
2. Water resources
3. Built environment
4. Flooding and stormwater management
5. Resource-based industries
6. Public outreach and education

Although a few strategies may not be included in these six categories above directly—for example, the San Diego Bay Adaptation Strategy has been addressing adaptation planning for contaminated sites and regional airport operations—they all relate to the built environment to some extent. In addition, these issues all generally relate to the specific impacts of sea level rise, and will also guide the vulnerability assessment and strategy design for Yankeetown-Inglis, detailed in the next chapter. The author will discuss each concern and corresponding strategies in the following paragraphs, as well as the similarities and differences of the five strategies. A detailed comparison of the five cases and their strategies will be showed in Table 4-1.

Nature Environment

The five adaptation strategies for the natural environment addressed three elements: terrestrial ecosystems, aquatic ecosystems, and critical species. Generally, all five cases have recognized the negative impacts of sea level rise on coastal ecosystems such as habitat loss and inland migration. The City of Groton, the State of Maryland, and San Diego Bay all consider the strategy of protecting or expanding coastal ecological buffers to facilitate inland habitat migration. Moreover, preserving habitat migration corridors and suitable habitat is a common strategy for maintaining habitat integrity and protecting endangered species. As coastal wetlands are particularly important for the City of Punta Gorda and San Diego Bay, all three strategies recommend enhancing wetlands protection and restoration. Groton and Lewes strategies also mention creating a comprehensive watershed management plan or integrating aquifer information into all planning efforts to maintain a health aquatic ecosystem.

Water Quality and Supply

Another important issue these five strategies considered was water resources. Most of them emphasized the importance of preserving water quality and water supply. To achieve this goal, San Diego Bay suggested applying LID, while Punta Gorda recommended using native plants in landscaping to improve the water supply. Punta Gorda also proposed the restriction of fertilizer use to maintain water quality. Maryland pointed out that facilitating water management and implementing conservation practices will ensure an adequate and safe water supply for humans and ecosystems. In addition, San Diego Bay identified strategies for wastewater management facilities to address flooding and inundation, for example, incorporating sea level rise issues into wastewater management plans and creating a detailed vulnerability assessment for the most vulnerable facilities.

Built Environment

All five cases addressed adaptation strategies for the built environment, which can be classified into three categories: protection, accommodation, and managed retreat. For protection approaches, Groton suggested applying beach nourishment and hard flood or tide gates for shoreline protection, while Maryland planned to expand soft natural buffers to protect inland areas from storm surges. Maryland also pointed out the importance of preserving vulnerable historic and cultural properties. Under accommodation approaches, Punta Gorda recommended applying green building alternatives through taxation initiatives, education, and green lending. Gorton advocated enhancing the building and engineering design standards to prepare for to future climate conditions. San Diego Bay also considered applying floodplain-level design standards in vulnerable areas. The introduction of financial incentives to improve buildings and infrastructures was recommended as well. In terms of managed retreat approaches, Punta Gorda, Gorton, and Maryland all advocated for promoting relocation of important buildings and infrastructures in the most vulnerable areas, and to limit development in those areas.

In addition, Punta Gorda, Gorton, and Lewes mentioned that there is a need to incorporate climate change concerns and preparedness into existing local plans and legislation. San Diego Bay has discussed adaptation strategies for regional airport and energy facilities. Regional collaboration is the key to strategy development and implementation.

Flooding and Stormwater Management

Another important issue all of the cases dealt with is flooding and stormwater management. Some of the strategies referred to the protection of and accommodation approaches for the built environment discussed above, such as the installation of floodgates at specific locations, protection of natural flood storage areas, and flood-proofing of existing buildings. Furthermore, Lewes mentioned the need to evaluate the city's infrastructure vulnerability to direct and indirect flood impacts. Collaboration with FEMA to account for future sea level rise in existing plans was also recommended by San Diego Bay.

Additionally, the five cases proposed enhancing stormwater capacity and reduce stormwater runoff to address the flooding of structures. San Diego Bay also suggested prioritizing LID stormwater practices and improving capital improvement programs and stormwater management plans to address sea level rise impacts. For emergency preparedness, Gordon and Lewes advocated identifying evacuation routes for extreme events, and San Diego Bay recommended improving standards for all emergency response facilities.

Resource-Based Industries

Maryland and San Diego Bay both emphasized the significance of adapting resource-based industries to climate change problems. Maryland suggested the protection of agriculture and aquaculture development through protecting soil and freshwater, reducing nutrient and sediment runoff, and maintaining abundant areas. San

Diego Bay advocated prioritizing the parks, open spaces, and habitat most vulnerable to flooding, thereby developing specific adaptation responses.

Public Outreach and Education

Public outreach and education is one of the key elements for all five cases in adaptation planning. Conducting workshops was a common approach the cases used to facilitate stakeholder participation and collaboration. Recommendations were made to further enhance education and outreach for property owners and residents about climate change and its impacts.

Strategy Evaluation

Evaluation of the strategies above was based on the methodology described in the last chapter, using an evaluation rating scale to assess the performance of the strategy on each indicator. Two components and 13 indicators were examined for each strategy, and the process component was examined generally for each case. A detailed evaluation result is displayed as Table 4-2.

The purpose of this evaluation of adaptation strategies from case studies was to assess the sustainability of different strategies, and therefore to identify best practices. Although limitations and deviations remain in the evaluation, the result can at least reveal the characters of different strategies to some extent. In conclusion, more integrated strategies that account for the natural environment (e.g., facilitated inland habitat migration by preserving or expanding ecological buffers and restored and protected wetlands) tend to be more sustainable as they can not only enhance the ability of ecosystems in adaptation to climate change impacts, but also somehow decrease the vulnerability of humans to flooding and storm surge impacts. Conversely, hard shoreline protection approaches (e.g., flood/tide gate) for the built environment seem less integrated and sustainable because habitats and species would be disturbed by this kind of approach. The result also reveals a set of integrated strategies, including LID strategies, use of native plants in landscaping to improve water supply and drought, soft shoreline protection approaches, green building alternatives, the protection and expansion of natural flood storage areas, and the protection of resource-based industries. Last but not least, the assessment of the process of adaptation planning for the five cases indicates that they shared common characteristics that assured the final outcomes. These characteristics included the involvement of multiple types of stakeholders across scales and fields, the conduction of workshops for communication and negotiation of diverse perspectives, reaching decisions through group consensus, and promoting further public outreach and education.

In addition, classifying and evaluating a number of adaptation strategies from the five cases aid in a deeper understanding of the pros and cons of different strategies and identifying the more integrated strategies among them. The cases also illustrate the conditions in which integrated strategies are suitable to apply in order to reduce certain vulnerabilities to sea level rise. This process will further provide information and a foundation for developing integrated strategies for the study area Yankeetown-Inglis, explored in the next chapter.

Table 4-1. Comparison of cases and adaptation strategies

Adaptation Strategy	Cases				
	Punta Gorda	Groton	Lewes	Maryland	San Diego Bay
Natural environment					
1 Facilitate habitat inland migration by preserving or expanding ecological buffers		X		X	X
2 Protect habitat migration corridors and suitable habitats for species migration				X	X
3 Protect and restore wetlands	X				X
4 Create a comprehensive watershed management plan		X			
5 Integrate aquifer information into all planning efforts			X		
Water quality and water supply					
1 Facilitate LID strategies to protect water quality and reduce stormwater runoff					X
2 Use native plants in landscaping to improve water supply and drought	X				
3 Restrict fertilizer use to maintain water quality	X				
4 Facilitate water demand management and conservation practices to ensure an adequate and safe water supply				X	
5 Incorporate sea level rise issues into wastewater management plans					X
Built environment					
1 Use hard shoreline protection methods (e.g., flood/tide gate)		X			
2 Integrate shoreline protection methods (e.g., expand natural buffers)				X	
3 Protect historic and cultural properties				X	
4 Implement accommodation methods (e.g., enhance building and engineering design standards)		X			X

Table 4-1. Continued

Adaptation Strategy	Cases				
	Punta Gorda	Groton	Lewes	Maryland	San Diego Bay
5 Implement green building alternatives	X				
6 Use relocation methods	X	X		X	
7 Incorporate climate change concerns into local comprehensive plans and other related legislations	X	X	X		
8 Initiate financial incentives to improve buildings and important infrastructures		X			X
Flooding and stormwater management					
1 Install flood/tide gates at specific locations		X			
2 Flood-proof existing buildings		X			
3 Protect and expand natural flood storage areas				X	
4 Work with FEMA to account for future sea level rise in existing plans					X
5 Enhance stormwater capacity and reduce stormwater runoff	X	X	X	X	X
6 Prioritize LID stormwater practices and improve stormwater management plans and capital improvement programs to address sea level rise impacts					X
7 Identify evacuation risk and safest routes during extreme events		X	X		
Resource-based industries					
1 Protect agriculture and aquaculture development				X	
2 Prioritize the parks, open space, and habitat most vulnerable to flooding, and promote public access as shorelines change					X
Public outreach and education					
1 Educate residents about climate change and its impacts		X			
2 Enhance education and outreach for property owners in flood-prone areas					X
3 Facilitate public education and outreach on changing behaviors			X		

Table 4-2. Strategy evaluation for case studies

	Adaptation Strategy	Evaluation Indicator																	
		Ecosystem				Livelihood									Process				
		Ecological components	Relationships and functions	Diversity	Memory and continuity	Econ/Social well-being	Decrease vulnerability	Public health and safety	Increase food security	Sustainable resource use	Reduce GHG emissions	Flexibility	Public access	Community character	Diverse stakeholders	Communication and negotiation	Transactive decision making	Social learning	Value
Natural environment																			
1	Facilitate habitat inland migration by preserving or expanding ecological buffers	++	++	++	++	+	+	+	+	0	+	+	+	+					16
2	Protect habitat migration corridors and suitable habitats for species migration	++	++	++	++	+	0	0	0	0	0	+	0	+					11
3	Protect and restore wetlands	++	++	++	++	+	+	+	0	0	+	+	0	+					14
4	Create a comprehensive watershed management plan	+	+	+	+	+	+	+	+	0	0	+	0	+					10
5	Integrate aquifer information into all planning efforts	+	+	+	+	+	0	0	0	0	0	+	0	0					6
Water quality and supply																			
1	Facilitate LID strategies to protect water quality and reduce stormwater runoff	+	+	+	+	+	+	++	++	+	+	+	0	0					13
2	Use native plants in landscaping to improve water supply and drought	+	+	+	+	+	+	++	++	+	+	+	0	+					14
3	Restrict fertilizer use to maintain water quality	0	0	0	0	+	+	++	++	0	0	+	0	0					7
4	Facilitate water demand management and conservation practices to ensure an adequate and safe water supply	0	0	0	0	+	+	++	++	0	0	+	0	0					7
5	Incorporate sea level rise issues into wastewater management plans	0	0	0	0	+	+	++	+	0	0	+	0	0					6
Built environment																			
1	Use hard shoreline protection methods (e.g., flood/tide gate)	-	-	-	-	0	++	++	0	0	-	0	-	0					-2
2	Integrate shoreline protection methods (e.g., expand natural buffers)	+	+	+	+	+	+	+	+	0	+	+	+	0					11
3	Protect historic and cultural properties	0	0	0	0	+	0	0	0	0	0	+	0	++					4
4	Implement accommodation methods (e.g., enhance building and engineering design standards)	0	0	0	0	+	+	+	0	0	0	+	0	+					5
5	Green building alternatives	+	+	+	+	+	+	+	0	+	0	+	0	+					10

Table 4-2. Continued

	Adaptation Strategy	Evaluation Indicator																	
		Ecosystem				Livelihood									Process				
		Ecological components	Relationships and functions	Diversity	Memory and continuity	Econ/Social well-being	Decrease vulnerability	Public health and safety	Increase food security	Sustainable resource use	Reduce GHG emissions	Flexibility	Public access	Community character	Diverse stakeholders	Communication and negotiation	Transactive decision making	Social learning	Value
6	Use relocation methods	+	+	+	+	0	++	++	0	0	-	0	+	0					8
7	Incorporate climate change concerns into local comprehensive plans and other related legislations	0	0	0	0	+	+	+	0	+	+	+	0	0					6
8	Initiate financial incentives to improve buildings and important infrastructures	0	0	0	0	+	+	+	0	0	0	+	0	+					5
Flooding and stormwater management																			
1	Install of flood/tide gates at specific locations	-	-	-	-	0	++	++	0	0	-	0	-	0					-2
2	Flood-proof existing buildings	0	0	0	0	+	+	+	0	0	0	+	0	+					5
3	Protect and expand natural flood storage areas	+	+	+	+	+	+	+	+	0	+	+	+	0					11
4	Work with FEMA to account for future sea level rise in existing plans	0	0	0	0	+	++	++	0	0	0	0	0	0					5
5	Enhance stormwater capacity and reduce stormwater runoff	0	0	0	0	+	++	++	0	+	0	0	0	0					6
6	Prioritize LID stormwater practices and improve stormwater management plans and capital improvement programs to address sea level rise impacts	+	+	+	+	+	+	++	++	+	+	+	0	0					13
7	Identify evacuation risk and safest routes during extreme events	0	0	0	0	+	++	++	0	0	0	+	0	0					6
Resource-based industries																			
1	Protect agriculture and aquaculture development	+	+	+	+	+	+	0	++	+	0	+	0	+					11
2	Prioritize the parks, open space, and habitat most vulnerable to flooding, and promote public access as shoreline change	+	+	+	+	+	+	+	0	0	+	+	++	++					13

Table 4-2. Continued

	Adaptation Strategy	Evaluation Indicator																	
		Ecosystem				Livelihood									Process				
		Ecological components	Relationships and functions	Diversity	Memory and continuity	Econ/Social well-being	Decrease vulnerability	Public health and safety	Increase food security	Sustainable resource use	Reduce GHG emissions	Flexibility	Public access	Community character	Diverse stakeholders	Communication and negotiation	Transactive decision making	Social learning	Value
Public outreach and education																			
1	Educate residents about climate change and its impacts	0	0	0	0	+	+	+	0	0	0	0	0	+					4
2	Enhance education and outreach for property owners in flood-prone areas	0	0	0	0	+	+	+	0	0	0	0	0	+					4
3	Facilitate public education and outreach on changing behaviors	0	0	0	0	+	+	+	0	0	0	0	0	+					4
Cases																			
1	Punta Gorda														++	++	++	++	
2	Groton														++	++	++	++	
3	Lewes														++	++	++	++	
4	Maryland														++	++	++	++	
5	San Diego Bay														++	++	++	++	

CHAPTER 5
RESULTS AND RECOMMENDATIONS FOR YANKEETOWN-INGLIS ADAPTATION STRATEGIES

This chapter discusses current conditions of the study area Yankeetown-Inglis in terms of its natural and built environments, social and economic background, and potential role in adaptation planning. Through a detailed analysis of sea level rise impacts to the study area using scientific projections, more specific vulnerabilities will be ascertained as to what and where the impacts are likely to occur to the natural and built environments. In addition, the public input from the two community workshops that held by the Planning for Coastal Change in Levy County Project will also contribute to the goals and objectives in developing adaptation strategies for the community. Finally, two adaptation strategies scenarios will be introduced and compared by the evaluation framework in order to examine the potential of integrated adaptation strategies.

Study Area Overview

The two adjacent rural towns of Yankeetown and Inglis lie in the south of Levy County and beside the Gulf of Mexico (Figure 5-1). The Withlacoochee River glides through the south of both towns, connecting them with Citrus County. Coastal habitats form a natural buffer between the Gulf and developed areas. The combined area of Yankeetown and Inglis is about 7,222 acres, and 29% of the land is developed area. According to the U.S. Census data of 2010, the population of Yankeetown is 502 and of Inglis, 1,325. The populations are denser along the west of the Withlacoochee River and the east of Inglis. Coastal rural communities like Yankeetown and Inglis will be particularly vulnerable to rising sea levels because of their relatively low topography and limited financial capacity. As a result, planning for climate change and sea level rise should take place now to prepare for the impacts from these changes.

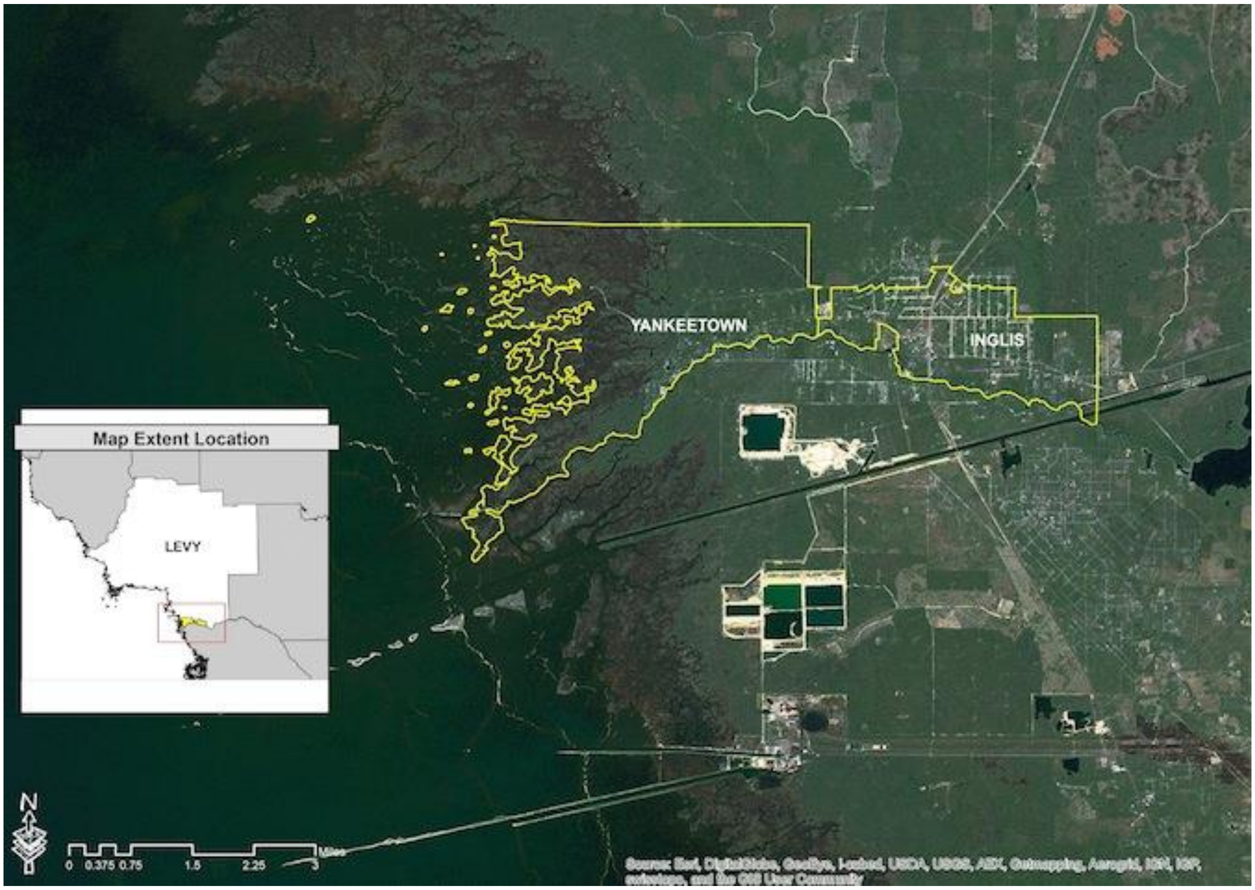


Figure 5-1. Study area of Yankeetown-Inglis.

Natural Environment

Yankeetown-Inglis and the surrounding area in Levy County have a gradually sloping topography that bulges from the Gulf of Mexico (Figure 5-2). Yankeetown includes much more low-lying area than Inglis and nearly half of its land is less than 3 feet above sea level. This area contains significant natural habitat that supports a wide variety of flora and fauna. It is generally dominated by coastal saltwater marsh, swamp, freshwater marsh, freshwater wetland forests, flatwoods, upland hardwoods, and a number of undeveloped dry land. Although Inglis is much more developed than Yankeetown, there is still a lot of undeveloped dry land and swamp, freshwater marsh, and cypress swamp around the developed area. The area's coastal wetlands and other natural resources, especially those in Yankeetown, have also been identified as high conservation priorities by the Critical Lands and Waters Identification Project (CLIP). These areas are very important to the community on account of not only the ecosystem services and aesthetic values they provide.

The U.S. Fish and Wildlife Service also identified a series of endangered and threatened species in the Yankeetown area, including ten reptiles, one amphibian, two fish, thirteen bird, two plant, and two mammal species. One of the mammals on the list that inhabits the Withlacoochee River is the West Indian manatee; this river was identified by the U.S. Fish and Wildlife Service as a “Core Area” for the manatees (Town of Yankeetown, 2009). Because of this and other reasons, the Withlacoochee River, which flows through the edges of the two towns and finally into the Gulf of Mexico, is considered a critical natural resource of the area. It provides numerous resources for marine and fishing, supporting the Town’s economy and providing recreational opportunities. The lower Withlacoochee River has been designated an Outstanding Florida Water (OFW) due to its significant ecological value and recreational function (Town of Yankeetown, 2009). Another critical area designated as OFW and needing special protection is the area along the Yankeetown shoreline comprised of wetlands and open water. This area is part of the Big Bend Seagrasses Aquatic Preserve and has exceptional scientific, recreational, biological, and aesthetic value (Town of Yankeetown, 2009).

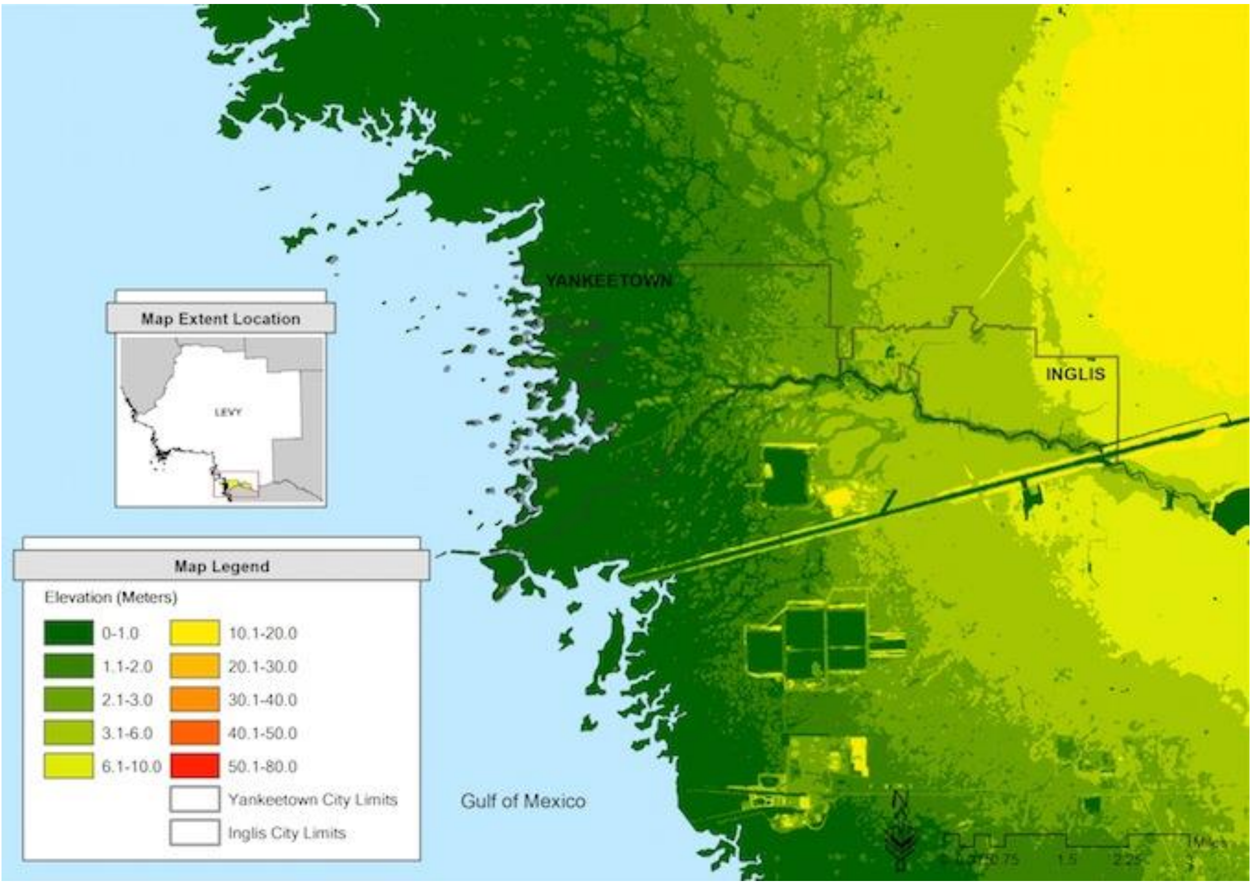


Figure 5-2. Yankeetown-Inglis 10-meter digital elevation model.

Built Environment

In general, Yankeetown and Inglis can be entered by three major roads: US-19 and CR-40 from the northeast and east of Inglis, respectively, and North Suncoast Boulevard, which runs through Citrus County in south. CR-40 is also the important road that runs through and links Yankeetown and Inglis. Southeast 193rd Place is another major road branching from US-19, entering Yankeetown and extending to the coast of Gulf of Mexico.

According to land use data from FGDL, Yankeetown-Inglis is currently composed of developed areas, wetland, upland forests, agriculture, and utility land (Figure 5-3). The developed areas generally consist of low- and medium-density residential area with fewer than five dwelling units per acre, and a couple of parcels with high density; as a result, single-family homes are the dominant housing type in Yankeetown-Inglis. Residential density is relatively higher along the Withlacoochee River and around the commercial and services area in Inglis. The two towns are equipped with town halls, police and fire stations, schools, churches, a water plant, and other public services, as well as several marina facilities and recreational spots along the river.

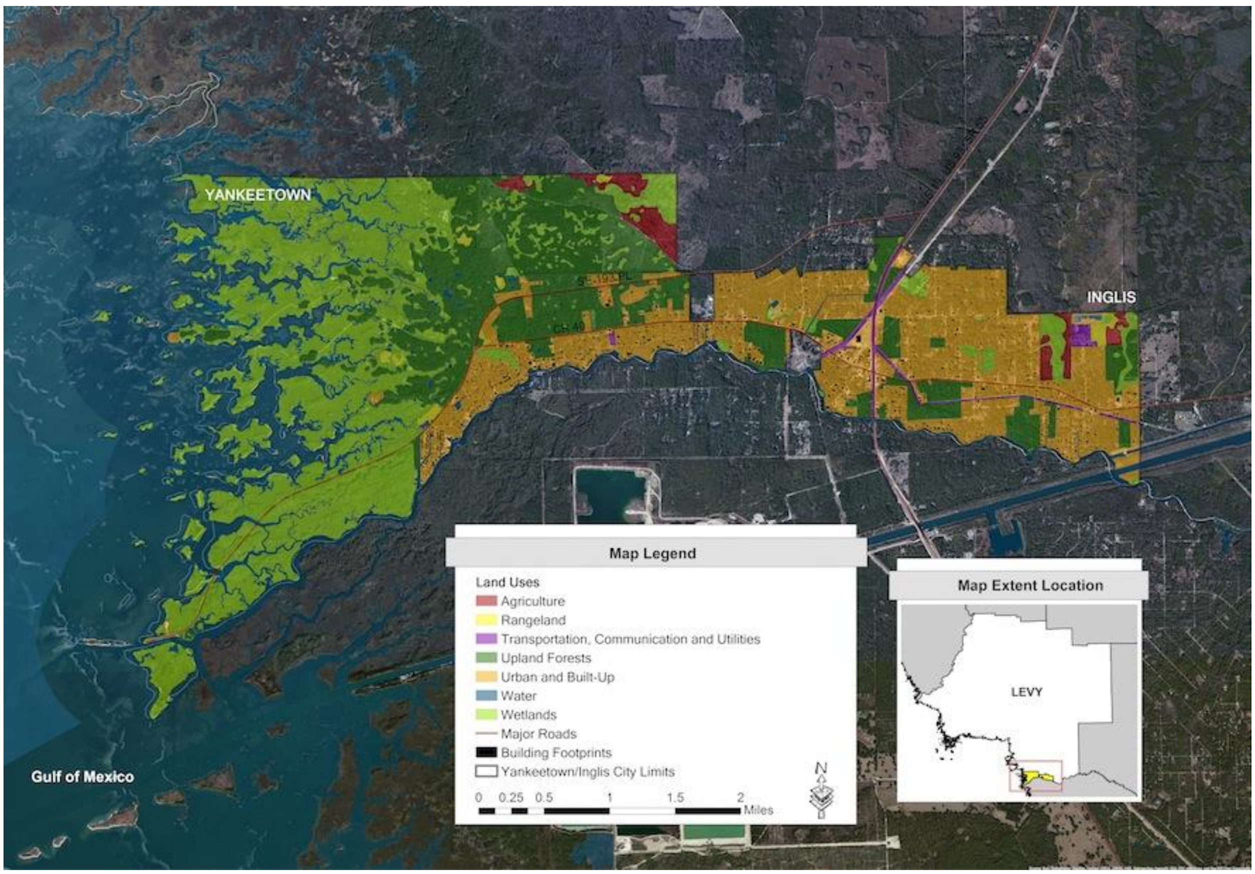


Figure 5-3. Yankeetown-Inglis existing land uses.

For public facilities and infrastructures, septic tanks have been widely used in Yankeetown for collecting and treating wastewater, and there is no public wastewater facility in town. The existing drainage system in Yankeetown consists of ditches that are maintained by the Levy County Mosquito Control Department, but no facilities are used to treat or hold stormwater before it is discharged into the Withlacoochee River. This lack of a stormwater management program probably aggravates erosion and flooding problems (Town of Yankeetown, 2009). Yankeetown also owns a potable water system which has the capacity to serve the existing developed area and the demand projected for the future projected, but a current practice of dredging manmade canals to provide river access from residential areas could potentially affect the water quality and potable water supply in Yankeetown at some point (Town of Yankeetown, 2009).

Social and Economic Data

According to the U.S. Census data, the populations of Yankeetown and Inglis in 2010 were 502 and 1,325, respectively (U.S. Census Bureau, 2010). The decennial census data from 1970–2010 shows that Yankeetown and Inglis grew steadily from 1970 to 2000, when their populations began to shrink, while Levy County as a whole and the state of Florida have shown a steady growth since 1970 (Economic and Demographic Research [EDR], 2007). The age distribution data of Yankeetown and Inglis shows a significant proportion of the towns' population in aged 65 or older. The median age of Yankeetown's population was 60.9 in 2010, and Inglis', 52.0 (EDR, 2012). The slow-growing population and the high proportion of older people are mainly due to the relocation of retirees from elsewhere. This trend has also had an impact on the average household income for both towns to some extent. Based on the data from 2011 U.S. Census economic reports, Inglis has a significant percentage—23.4%—of households with a yearly income less than $10,000, and the median household income is lower than Levy County's as a whole (U.S. Census Bureau, n.d.). This significant low-income and elderly population could potentially influence future housing planning and preparedness for coastal change or emergency events.

In addition, the data on the employed civilian population reveals that the largest industry in Yankeetown in 2011 is construction (22%), followed by manufacturing (14%), entertainment and recreation (12%), and transportation and utilities (11%). In Inglis, the largest industry is educational and social services (13%), followed by 11% in construction, entertainment and recreation services, transportation, and utilities. Public administration is the smallest sector, employing 3% of the population (U.S. Census Bureau, n.d.).

The above social and economic data analysis indicates that Yankeetown and Inglis possess the general characteristics of rural communities with small and aging populations, low average incomes, and poverty rates higher than the state average. These conditions could potentially increase the difficulties of preparing for coastal change adaptation; however, appropriate adaptation strategies could also provide opportunities for the towns' redevelopment and the creation of new jobs, improving the overall economy.

Vulnerability Analysis

Typically the economies and quality of life of coastal communities like Yankeetown-Inglis are inextricably linked to their natural environment and geographical features. These communities also typically face more risks than inland areas. Hurricanes, storm surges, flooding, coastal erosion, and other issues potentially threaten coastal assets and public safety at any time. In addition, over the course of history, coastal habitats and species have migrated causing habitable lands to be lost. According to historical topographic surveys, the area between Cedar Key and the Withlacoochee River has experienced a kilometer or more of inland marsh migration since the creation of this coastal forest (Raabe et al., 2004). This migration could increase exponentially due to climate change and sea level rise. Because of their location and relatively low elevation, Yankeetown and Inglis will be particularly vulnerable to sea level rise and its impacts, including the loss of low-lying lands due to inundation, increased flooding, saltwater intrusion, and habitat changes. In order to plan for these impacts in advance and develop effective strategies, it is important to understand what impacts could occur and where.

The fundamental step of this vulnerability analysis was to obtain sea level rise projections for the study area. In this thesis, the author uses the projection from the U.S. Army Corps of Engineers (Figure 5-4), which estimates a 1.5- to 5-foot sea level rise by year 2100, and concentrates on the 3 feet scenario, which is commonly accepted under current climate conditions.

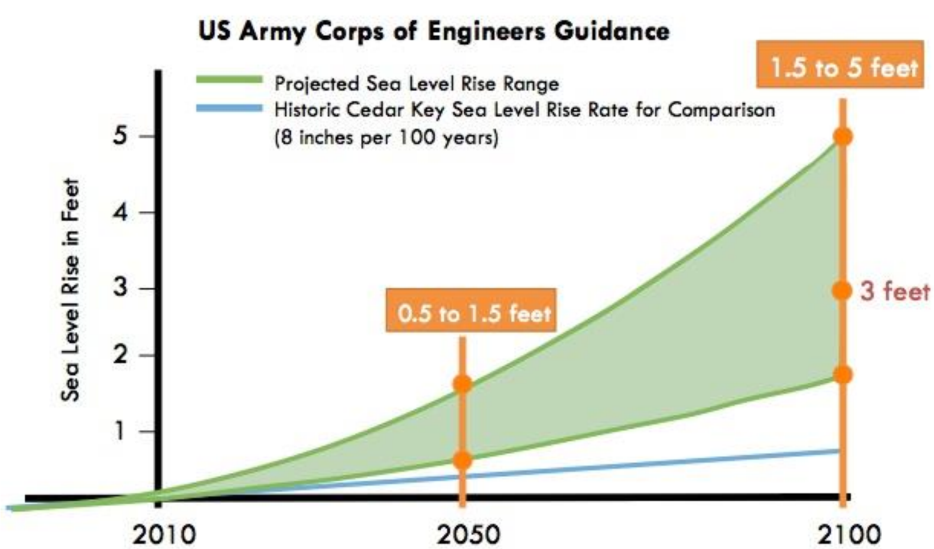


Figure 5-4. U.S. Army Corps of Engineers projection of SLR. Source: Frank, 2012.

Natural Environment Vulnerability

Directly visualizing the results of sea level rise in terms of inundation of low-lying areas is possibly by relying on the so-called bathtub model, which is a static model solely based on the geographic elevation. Figure 5-5 shows the result of low-lying areas in Yankeetown and Inglis under different sea level rise scenarios using this model. However, sea level rise is a relatively slow and gradual process, and this model is unable to take into account the changes along shorelines, especially how natural communities will be affected. Coastal Yankeetown contains abundant wetlands, including saltwater marsh, swamp, freshwater marsh, and freshwater wetland forests. These habitats will be the first in the area to experience sea level rise impacts. As a result, a more dynamic model called Sea Level Affecting Marshes Model (SLAMM), which addresses inundation, overwash, erosion, and salinity tends to be more accurate for forecasting changes that would likely to occur in coastal communities such as the Yankeetown-Inglis area covered by this study.

Figure 5-6 is a projection using SLAMM that shows the changes in habitats and land uses under a 3-foot sea level rise scenario in Yankeetown and Inglis through the year 2100. Generally, the coastal natural community will respond to rising sea levels by migrating inland. In this model, swamps will be gradually replaced by saltwater marshes and transitional saltmarshes; saltwater marshes, transitional saltmarshes, and tidal flats would expand to the developed and undeveloped dry lands if there are no barriers in place; uplands forests would be replaced by saltwater marshes and transitional marshes; new open water and beaches would be created within city limits due to a rising water table. Table 5-1 shows the changes, in acres, of specific habitats in a 3-foot sea level rise scenario.

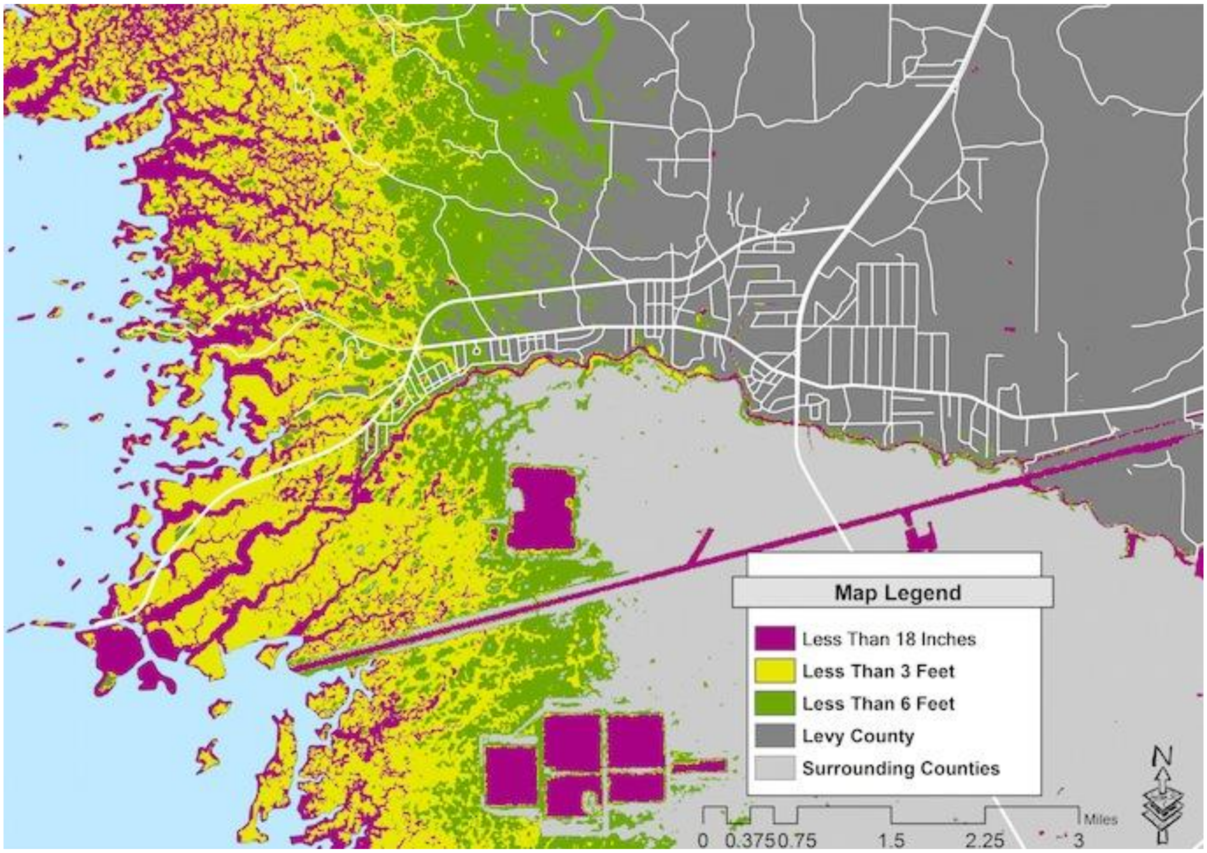


Figure 5-5. Low-lying areas of Yankeetown-Inglis.

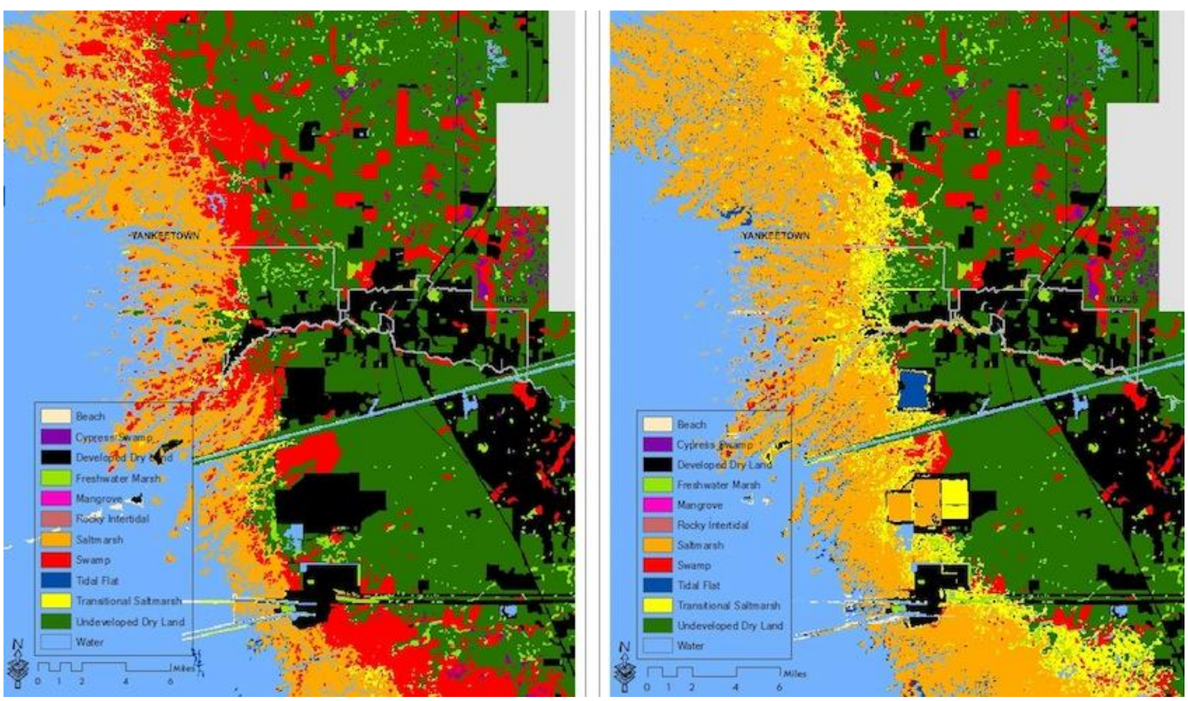
A  B

Figure 5-6. SLAMM results of habitat changes by a 3 feet SLR scenario: A) Current habitats and land uses; B) habitat and land use changes

Table 5-1. Yankeetown-Inglis habitat and land use changes by 3 feet SLR

	Current Habitats and Land Uses (Acres)	Habitats and Land Uses by 3 Feet SLR (Acres)	Changes (Acres)
Saltmarsh	1,951.05	2398.90	447.85
Swamp	709.57	277.30	-432.27
Transitional Saltmarsh	155.28	625.90	470.62
Freshwater Marsh	118.90	111.27	-7.63
Cypress Swamp	8.69	8.12	-0.57
Tidal Flat	0.14	152.26	152.12
Beach	4.50	24.62	20.12
Water	473.24	596.30	123.06
Developed Dry Land	1,897.40	1,708.85	-188.55
Undeveloped Dry Land	1899.30	1311.65	-587.65

Source: SLAMM data from The Nature Conservancy.

Under this scenario, the biggest threat to natural communities from sea level rise could be human intervention on developed or undeveloped dry land. However, SLAMM is not a very sophisticated model and uncertainties and limitations remain. For example, it is difficult to predict the frequency and intensity of storms that might be caused or aggravated by sea level rise, so the additional vulnerability of coastal wetlands in these circumstances is hard to predict. The changes caused to natural communities due to sea level rise could also affect existing conservation priorities. Better understanding of the vulnerabilities caused by sea level rise can assist in identifying lands that may provide adaptation opportunities in advance.

Built Environment Vulnerability

As wetlands migrate inland due to rising sea levels in the Yankeetown coastal area, a large number of developed areas are likely to be affected. Figure 5-7 shows the area likely to be changed by 3 feet sea level rise based on the SLAMM results; the parcels in purple are developed lands that would be threatened by gradually migrating wetlands. According to Table 5-2, a significant amount of developed and undeveloped dry lands will be overtaken by saltmarsh and transitional saltmarsh if barriers are removed, and about 8 acres of land that lie mostly along the Withlacoochee River would be converted to open water. These areas generally consist of low- and medium-density residential neighborhoods, marina facilities, civic buildings (i.e., Yankeetown Town Hall and a fire station), community parks, and commercial structures. Table 5-3 shows which existing developed areas would be affected in this scenario. Figure 5-8 also shows the 100-year storm surge map of Levy County, and in this scenario the Yankeetown-Inglis area would experience a medium to high level of water. With a rising sea level, storm surges could be more intense and threaten the upper inland areas of Yankeetown-Inglis.

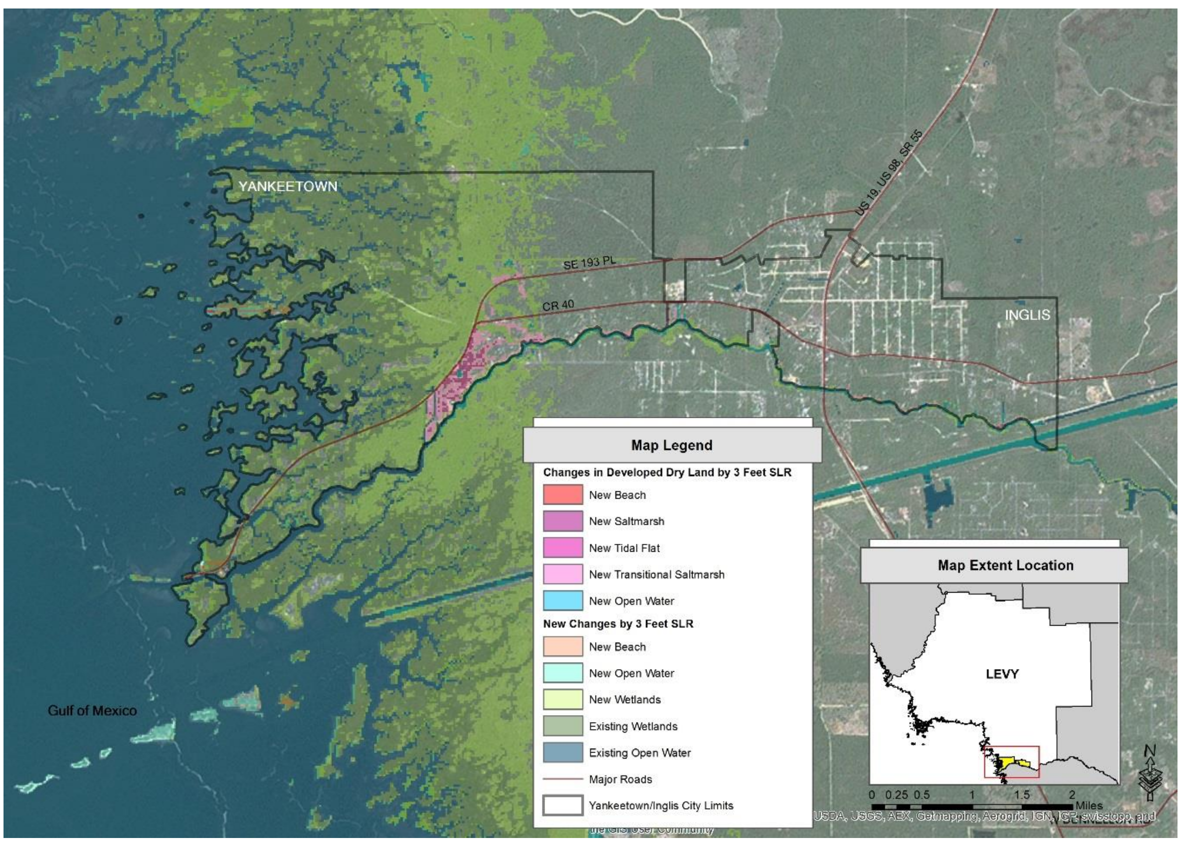


Figure 5-7. Yankeetown-Inglis areas likely to be changed by 3 feet SLR.

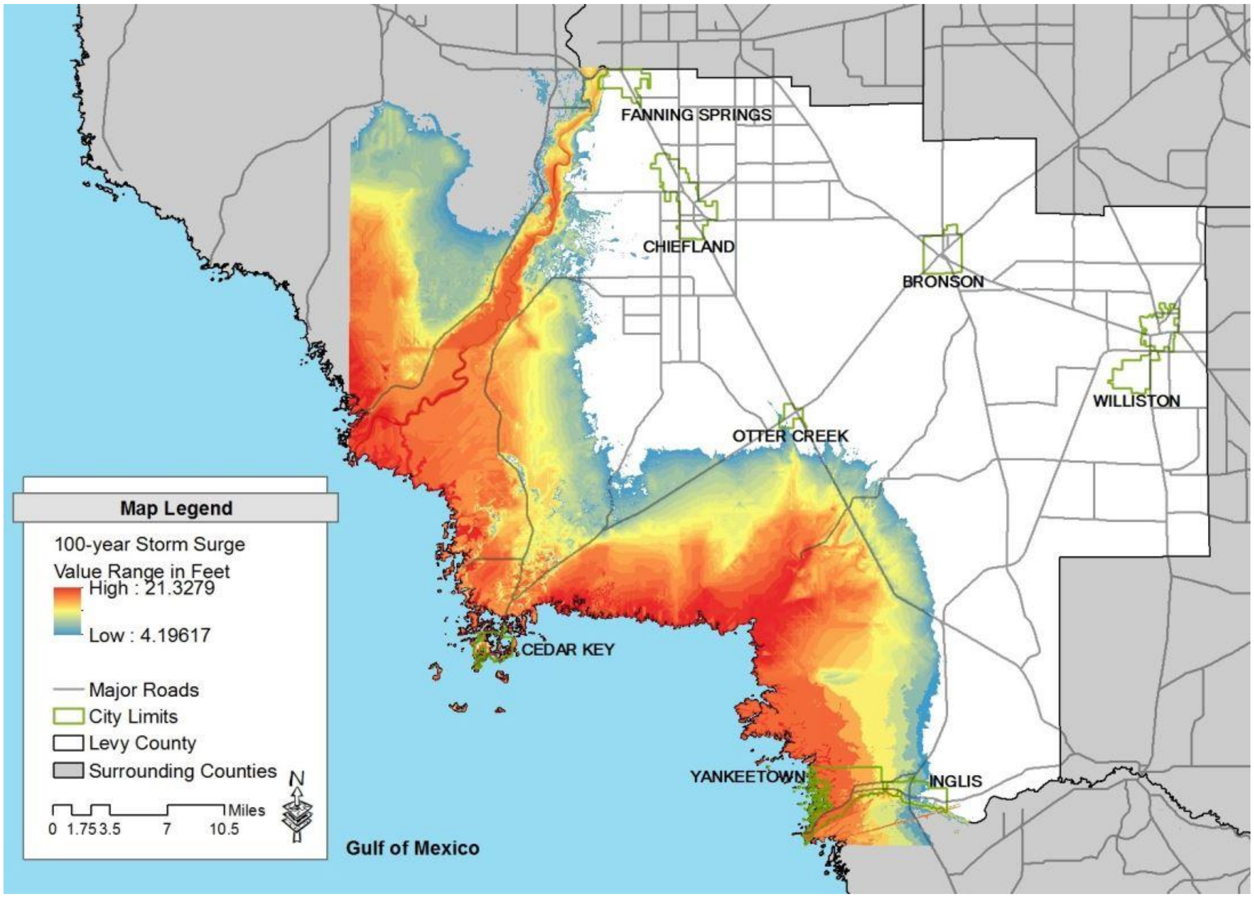


Figure 5-8. Levy County 100-year storm surge.

Rising sea levels will likely affect critical infrastructure in the built environment, especially water-related facilities such as wastewater systems and drinking wells. Figure 5-9 shows that at least one irrigation well and two monitor wells would be affected by the SLAMM-predicted scenario. Currently Yankeetown and Inglis rely on individual septic tanks for wastewater treatment, which could be vulnerable to coastal change and sea level rise for future need. Rising water tables tend to increase the failure of septic systems, potentially degrading water quality and damaging public health. Saltwater intrusion is another possible impact that could contaminate drinking wells. Water-related facilities play a significant role in the basic life of the community, and effectively adapting to these water-related issues will be crucial to determining the community's future quality of life.

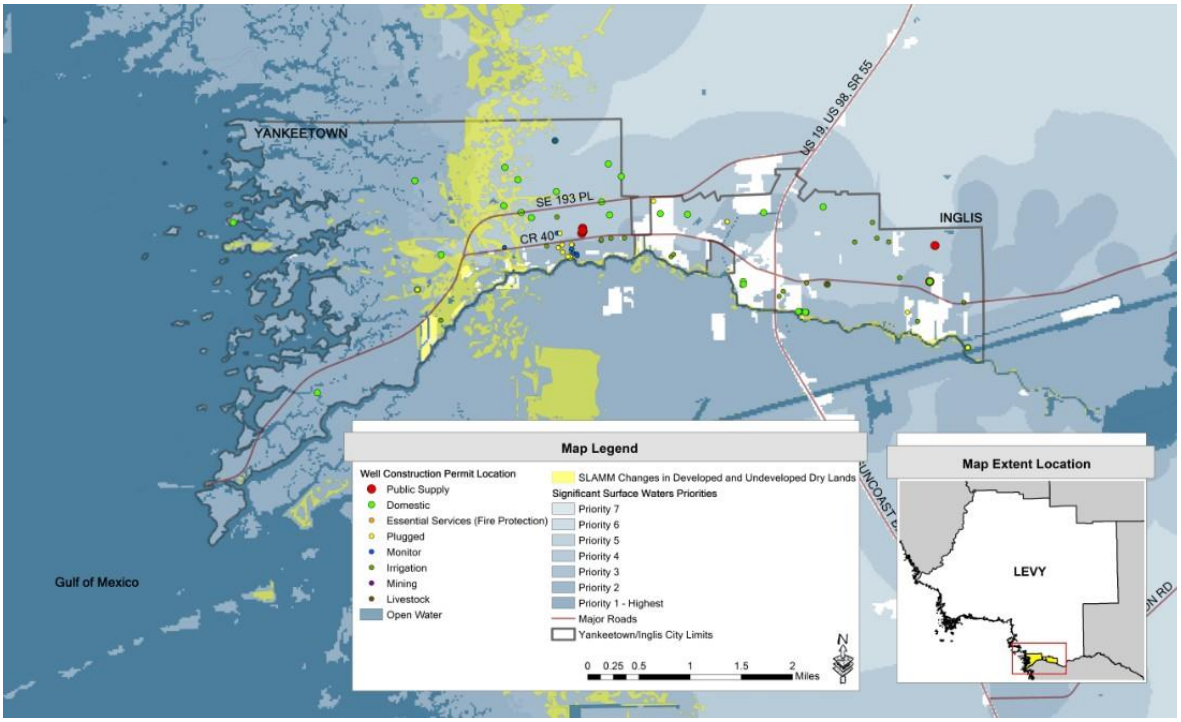


Figure 5-9. Yankeetown-Inglis water supply with 3 feet SLR impacts.

Table 5-2. Yankeetown-Inglis habitat changes in developed and undeveloped dry lands by 3 feet SLR

Type of habitat	Developed land change to (Acres)	Undeveloped dry land change to (Acres)
Saltmarsh	43.70	176.18
Transitional Saltmarsh	124.94	372.85
Tidal Flat	0.81	1.52
Open Water	1.90	6.10
Beach	1.86	7.07
Total	173.21	563.72

Source: SLAMM data from The Nature Conservancy.

Table 5-3. Yankeetown-Inglis existing developed area affected by 3 feet SLR

Developed area in land use	Acres affected by 3 feet SLR
Low density residential	93.25
Medium density residential	106.66
Recreational	9.59
Institutional	3.85
Open land	2.12

Source: SLAMM data from The Nature Conservancy.

Observation of Community Input

During the summer of 2013, the author participated in the Yankeetown-Inglis part of the Planning for Coastal Change in Levy County Project. Two public workshops held by the project were observed by the author to collect community feedback and input on coastal change issues. The first workshop introduced the vulnerability of community to sea level rise, while the second workshop focused on providing adaptive design strategies for sea level rise impacts. Participants in these two workshops included planners, community leaders, and residents. They were generally concerned about saltwater intrusion, water quality and supply, and other water-related issues. Incorporating sea level rise adaptation into long-term planning while maintaining its rural character was important to the community. Moreover, participants identified the needs to get support and help from the state and other agencies when initiating adaptation planning, as well as to purse funding resources to facilitate further implementation.

Adaptation Strategies Scenarios and Recommendations

This section provides two scenarios of sea level rise adaptation planning for the study area Yankeetown and Inglis, and elaborates detailed strategies for each adaptation scenario. These two alternatives are based on different goals and objectives, aiming to explore relatively more integrated and sustainable solutions to increase social and ecological resilience of the community. The literature review and five case studies serve as the basis for developing the following adaptation strategies scenarios and recommendations. The six concerns derived from the case studies will guide the general direction for recommendation development. The strategy evaluation framework created for the case studies will also be used to evaluate and compare the two adaptation strategies scenarios, in order to find more sustainable alternatives.

Adaptation Strategies Scenario I

Adaptation Strategies Scenario I was created with the consideration of the ecological, social, and economic impacts of sea level rise to the study area, and tries to explore the balance among these contexts by developing integrated strategies to help the built environment cope with these impacts while minimizing the negative impacts on the natural environment. This integrated strategy not only takes into account social and ecological correlations but also calls for the incorporation of adaptation and mitigation strategies into climate change planning.

Goals and objectives

Considering the conceptual needs of the Adaptation Strategies Scenario I with the integration of the natural and built environments, the following list of goals and objectives are offered to guide the proposed strategies.

1. Enhance the resilience of the natural environment so it can adapt to sea level rise impacts
2. Build resiliency of the built environment while minimizing negative impacts on the natural environment
3. Protect water quality and water supply
4. Adapt to emergency events including storm surges and flooding
5. Preserve the rural community character and enhance cohesion and resiliency
6. Provide opportunities for economic development to adapt to future changes and growth
7. Educate and engage public with adaptation planning and information

Strategies and recommendations

As discussed in the vulnerability analysis section for Yankeetown and Inglis, the large amount of wetlands in coastal Yankeetown and the surrounding area would gradually migrate inland with rising sea levels. Therefore, the composition of habitats in these areas would also alter: swamps would be gradually replaced by saltwater marshes and transitional saltmarshes; upland forests would be lost and covered by saltwater marshes and transitional marshes; saltwater marshes, transitional saltmarshes, and tidal flat would expand into developed and undeveloped dry lands if no barriers are in place. In general, a significant portion of wetlands, forests, and their related flora and fauna would be lost. This disappearance would not only affect the ecosystem services these habitats provide to coastal communities, but also increase the risk of flooding and other storm effects to the existing development. As such, Adaptation Strategies Scenario I proposes to help the natural environment adapt to these impacts through wetland restoration and forest management, in order to promote the health of sustainable ecosystems, create a buffer from flooding and waves, contribute to reduced CO_2 emissions, and provide ecosystem services to the community by improving water quality and supporting resource-based industries.

For wetland restoration, salt-tolerant plants would be the best choice for the coastal area. With limited human and financial resources in rural communities, it is important to set priorities for protection and restoration. For example, the biodiversity of the system could be a criterion in determining the most critical habitats. Additionally, cooperation with conservation organizations such as the Big Bend Seagrasses Aquatic Preserve or The Nature Conservancy will help develop research and monitor changes to coastal habitats, as well as disseminate information and suggestions to the public and decision makers. For forest management, data from the vulnerability analysis shows that about 668 acres of upland forests, including mixed hardwood conifer, tree plantations, pine flatwoods, upland coniferous forest, and longleaf pine habitats would be affected by a 3-foot sea level rise scenario by the year 2100. These forests would shrink significantly or even disappear if no appropriate management were taken. Climate change and sea level rise will increase the uncertainties and challenges in effective management. Rather than resisting the changes and impacts, enabling forests to gradually adapt to the inevitable effects seems more reasonable for preventing catastrophic disaster (Millar et al., 2007). Adaptation options such as planting permeable landscapes, facilitating species migrations, or enhancing diversity with mixed planting should be applicable (Millar et al., 2007). Integrating scientific information to identify key species and prioritize practices with a higher chance of success is also important to effectively build adaptive capacity and enhance the resiliency of forests (Blate et al., 2009). On the other hand, wetland restoration and forest enhancement can help maintain public access to wetlands and water, as well as provide opportunities for recreation.

As coastal wetlands in Yankeetown area would migrate inland in respond to sea level rise, Adaptation Strategies Scenario I recommends facilitating the acquisition of these areas as a natural buffer zone, and gradually relocating existing structures and residents to safer upland areas, so that habitats can migrate inland over the long term. New development in the future should be discouraged in these areas. The acquisition of the vulnerable lands can be achieved through rolling easements, Transfer of Development Rights (TDR), or conservation easements. However, more research and planning are needed to address the policy and legal issues presented by this option. Figure 5-10 shows the areas with specific structures that would need to be removed to less vulnerable uplands in this scenario. These structures are found on private properties, marina facilities, civic properties, and community parks, which currently serve as a community center for residents. Therefore, a more detailed plan for gradually facilitating this relocation process and redesigning a new community center to the upland should be considered. The corridor along CR-40 is one potential location for the new community center. Additionally, identifying vulnerable areas with high adaptation priority and ecological significance will help promote the effectiveness of implementation.

Besides the relocation strategy, Adaptation Strategies Scenario I also recommends combining the accommodation strategies. As the area along the Withlacoochee River is vulnerable to sea level rise but also important for providing community access to the water, accommodation strategies are suggested for areas with less vulnerability. Strategies such as elevating structures, improving infrastructures, and enhancing design standards are applicable. Designing setbacks and expanding buffers with a living shoreline strategy are also recommended for the vulnerable waterfront areas, in order to accommodate both the ecosystem adaptation and public access.

It has been noticed that the community has no stormwater management plan, so designing integrated adaptation strategies for stormwater retention and percolation are critically necessary. Green infrastructure and LID strategies are recommended to all community areas, particularly at vulnerable waterfront locations. Currently, applicable green infrastructure and techniques include different types of eco-roofs, green streets and alleys, green open spaces, and forestry (Foster et al., 2011). These have been recognized as the “best practices” for achieving sustainability and resiliency goals in applying with traditional “grey” infrastructure at a local level. LID techniques share the same principles with green infrastructure approaches and contain bioretention systems, grass swales, vegetated roofs, cisterns, and permeable pavements (EPA, 2000). The benefits of green infrastructure and LID strategies are broadly from improving stormwater management, accommodating natural hazards, storing and conserving water, filtering pollutants and managing water quality, to reducing GHG emissions. Many projects have proved that green infrastructure and LID are more cost-benefit strategies than conventional technologies for climate adaptation (Foster et al., 2011). For Yankeetown and Inglis, several green infrastructure and LID options are available. Permeable paving and driveways are suggested along major roads such as CR-40 and at waterfront public access points to facilitate drainage of stormwater runoff, floods, and storm surges. Rain garden is another option for controlling rainwater and stormwater runoff; this technique involves planting flood-tolerant plants in low points in the landscape. Moreover, bioswales (vegetated drain channels) can be placed along residential streets in low-lying areas to direct flood and rainwater away from development. Figure 5-11 shows an example of waterfront design using these strategies. An added benefit of incorporating these practices into the study area is that they contribute to improving the community with high quality landscapes and aesthetic appeal, which can attract more residents and investments.

Though CR-40 has the capacity to evacuate the residents of Yankeetown and Inglis during natural hazards and disasters (as seen during past hurricanes), the town's emergency evacuation plan needs to be updated to identify the best evacuation routes, reduce evacuation times, and ensure shelters are correctly placed. Because

Yankeetown-Inglis has a large population of elderly people, providing assistance to those with special needs during evacuation should also be considered in the plan.

Outside the vulnerable areas, new infill and redevelopment are suggested for both eastern Yankeetown and northern Inglis. Private properties relocated from the vulnerable areas can be proper infill in existing residential zones. As residential density increases, improvements to the infrastructure such as wastewater treatments should be carefully considered to meet future demands and changes. In addition, the redevelopment of community centers is encouraged to incentive economic development and community revitalization. New infill such as restaurants, retail operations, and other commercial mixed-use businesses can be placed in these community centers, which are adjacent to residential areas. This influx of development will improve the quality of life for residents, diversify land use (reducing vulnerability), and enhance community connectivity. Innovative design elements can be incorporated to enhance the community identity, including new signage at the entrance of each town, a multi-use trail along CR-40A to connect Yankeetown with the natural coast, and street landscape improvement using native plants. Finally, education and outreach to the public should be continued and expanded to increase awareness of sea level rise and the associated effects.

The major strategies for Adaptation Strategies Scenario I can be summarized as follows:

- Facilitate natural environment adaptation with wetland restoration and forest management
- Preserve and expand ecological buffer areas to promote inland migration of habitats and species

- Gradually relocate existing structures from vulnerable areas to safer upland areas
- Incorporate accommodation strategies such as elevating structures and improving infrastructure
- Use living shorelines to protect structures in the vulnerable waterfront areas
- Apply green infrastructure approaches such as permeable pavements, rain gardens, bioswales, and etc.
- Apply LID techniques to control stormwater runoff and protect water quality
- Update evacuation plan for hurricane and emergency events by identifying evacuation routes, reducing evacuation times, and improving shelter locations
- Pursue infill and redevelopment in new town center of Yankeetown and existing town center in Inglis
- Enhance education and outreach for community

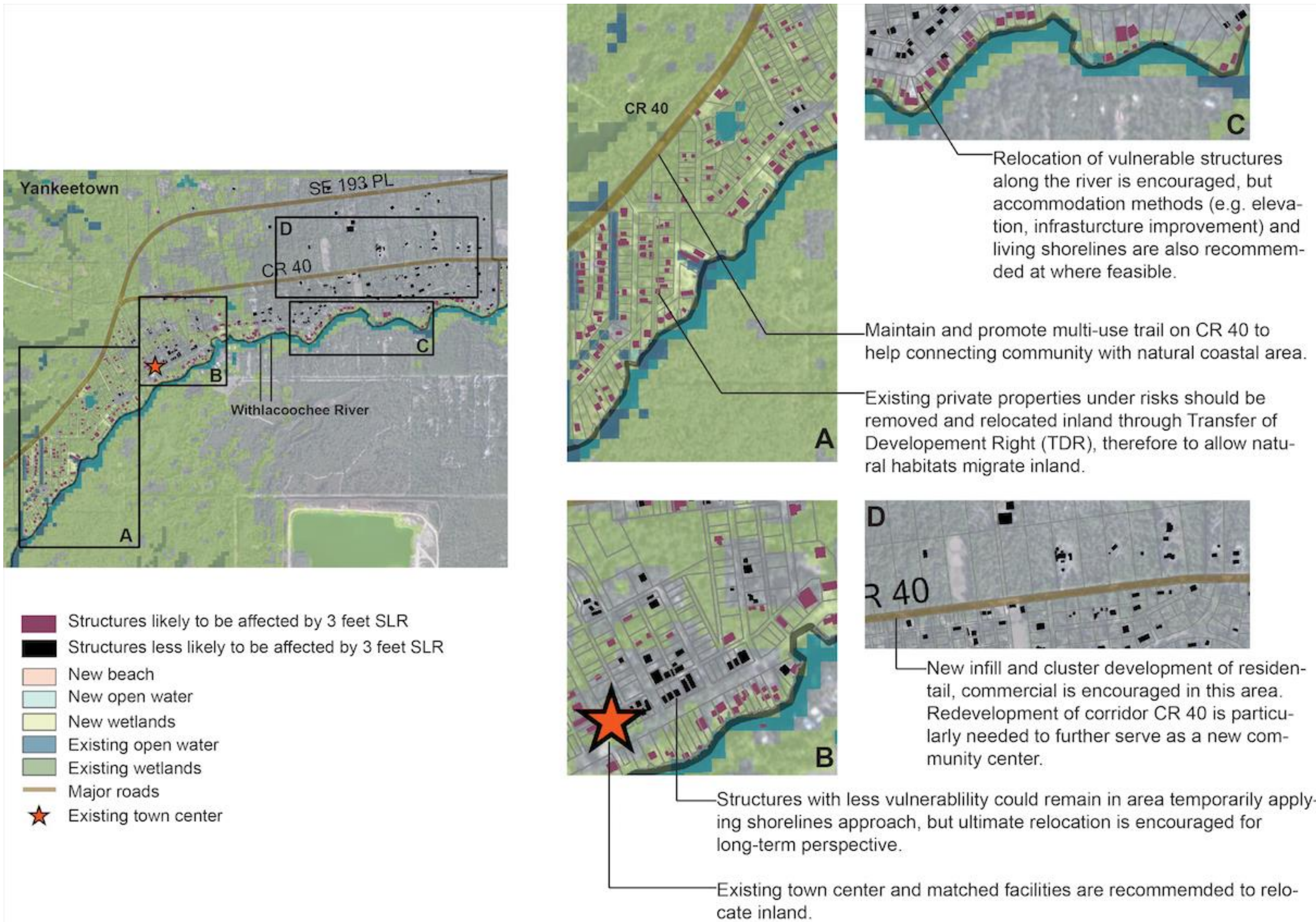


Figure 5-10. Adaptation Strategies Scenario I—adaptation strategies for the vulnerable areas.

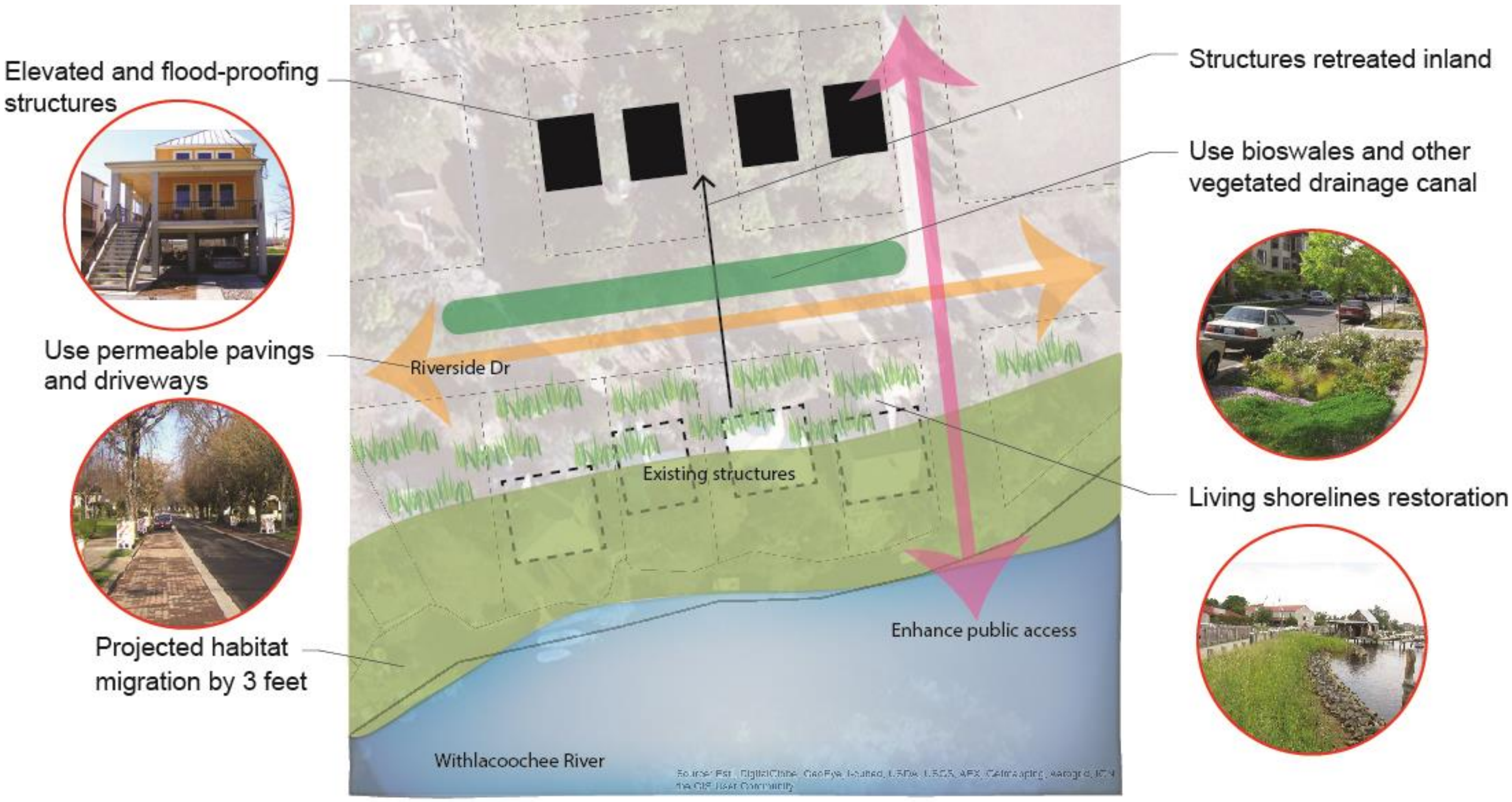


Figure 5-11. Adaptation Strategies Scenario I—waterfront design. Source of images: FloodProBE, n.d.; City of Berkeley Department of Public Works, n.d.; Eye On Annapolis, 2011.

Adaptation Strategies Scenario II

Adaptation Strategies Scenario II is more concentrated on adaptation for the built environment to protect people and property from the negative impacts of climate change and sea level rise. More traditional and existing adaptation strategies derived from the literature review and case studies will be used for this scenario.

Goals and objectives

The following goals and objectives are provided to support the development of Adaptation Strategies Scenario II to help the built environment adapt to sea level rise impacts. Although Adaptation Strategies Scenario I and II share some goals and objectives, they are different in terms of the approaches they propose to achieve them.

1. Adapt for the built environment to protect public health and safety
2. Protect infrastructures, public and private properties from the negative impacts of sea level rise
3. Protect water quality and water supply
4. Adapt to emergency events including flooding and storm surges
5. Provide opportunities for economic development to promote long-term growth
6. Maintain rural community character and enhance cohesion and resiliency

Strategies and recommendations

Unlike Adaptation Strategies Scenario I, Adaptation Strategies Scenario II aims to protect existing development from sea level rise impacts, but on the other hand, it recommends direct future development away from the high-risk area. Thus, for the most vulnerable areas in western Yankeetown and along the Withlacoochee River, Adaptation Strategies Scenario II suggests the community use protection measures to prevent residents and their properties from flooding and inundation impacts. Recommended hard protection methods include seawalls, dikes, floodgates, and bulkheads. These structures tend to maximize the protection of existing land uses including private properties, civic buildings, marina facilities, and critical infrastructures. The design standards for the protective structure should be carefully considered to account for future sea level rise and related impacts. Soft protection methods such as living shorelines are also recommended at certain locations to mitigate the negative impacts on the natural environment. Figure 5-12 shows how hard and soft protection methods can be used together in the study area.

If necessary, accommodation approaches can also be applied to strengthen the ability of structures to resist flooding and inundation. Available options include revising the building codes, enhancing design standards for existing and new structures, and improving infrastructures. Capital Improvement Programs (CIPs) could be a useful tool for Yankeetown and Inglis to acquire investments in their public facilities in order to accommodate future growth and mitigate sea level rise impacts. Additionally, rezoning is suggested to restrict new development in the vulnerable areas, and it is also recommended that higher standards for flood-proofing features should be incorporated into building codes. To prepare for hurricanes and other natural events, it is needed to identify the best evaluation routes, reduce evacuation times, and improve shelter placements.

Furthermore, sea level rise can potentially provide an opportunity for redevelopment and revitalization in the community. It is suggested to redevelop the centers of Yankeetown and Inglis, as well as the areas along the Withlacoochee River. The centers can be revitalized with new infill and mixed-use of land, such as new residential and commercial areas. The concepts of cluster development and smart growth should be incorporated in designing these centers. Additionally, existing major roads and sidewalks need to be improved. For example, SE 193rd Place is the main road leading to Yankeetown and extending to the Gulf of Mexico. This roadway could be improved with the creation of a multi-use trail for both bicycles and pedestrians. The portion extending to the western natural coast could be elevated to withstand future inundation by increased sea levels. Tree planting and landscaping with native vegetation are recommended to other major roads and sidewalks. Public access to the river can be increased in the less vulnerable areas in waterfront Yankeetown-Inglis to provide recreational opportunities and enhance community character.

As a result, the strategies for Adaptation Strategies Scenario II can be summarized as follows:

- Use hard protection techniques to protect people and properties from inundation and flooding
- Use soft protection measures such as living shorelines where feasible
- Use accommodation methods such as building code revision and design standard improvement
- Apply Capital Improvement Programs (CIPs) to invest in infrastructure improvement to accommodate future growth and sea level rise impacts
- Use zoning to restrict new development and require higher standards for flood-proofing design in the vulnerable area
- Update evacuation plan for hurricane and emergency events by identifying evacuation routes, reducing evacuation times, and improving shelter locations
- Redevelop the towns’ centers using cluster development and smart growth to revitalize community and maintain its character
- Create opportunities for outdoor recreation and activities to facilitate social communications

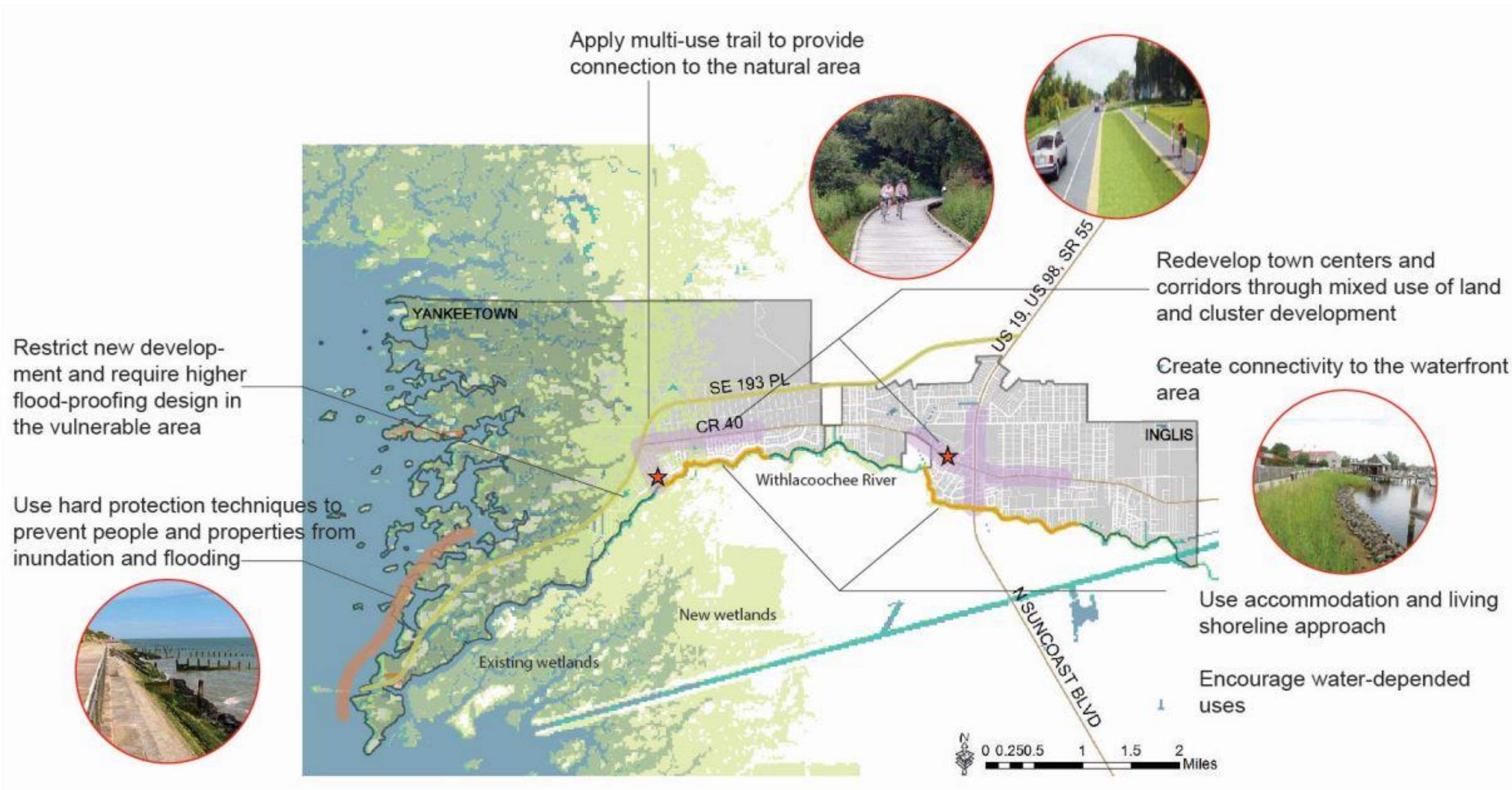


Figure 5-12. Adaptation Strategies Scenario II—adaptation strategies. Source of images: Essex Walks, n.d.; Macdonald, n.d.; Wisconsin Department of Transportation, 2011; Eye On Annapolis, 2011.

Comparison and Summary

Although Adaptation Strategies Scenario I and II share some goals and objectives, different adaptation strategies are employed by each adaptation scenario to achieve its aims. The evaluation framework outlined in the Case Studies Analysis Chapter is also helpful for assessing the sustainability of different strategies when comparing them.

Table 5-4 shows the result of comparison of two adaptation strategies scenarios through determining which one is a more sustainable solution to sea level rise adaptation for Yankeetown-Inglis. The strategies were evaluated based on two components: ecosystem and livelihood. This study did not evaluate the process component of each adaptation strategies scenario because it is more suitable for local governments and decision makers when selecting adaptation strategies for their communities. Essential elements, which include diverse stakeholders' involvement, communications for consensus, and social learning, should be taken into account to facilitate successful selection of adaptation strategies based on community needs and character.

When comparing the two adaptation strategies scenarios, Adaptation Strategies Scenario I seems to be a more sustainable alternative than Adaptation Strategies Scenario II as the average value of its strategies is much greater than Adaptation Strategies Scenario II. The primary reason for this is that Adaptation Strategies Scenario I uses more integrated adaptation strategies that take into account the effects of both social and ecological systems. The significant difference between the two adaptation scenarios is their strategy preferences for the most vulnerable areas in Yankeetown and Inglis. Adaptation Strategies Scenario I suggests to use a relocation strategy in the vulnerable developed areas for preventing the community from flooding and storm surges, in the meanwhile, allowing for habitats migrating inland. However, Adaptation Strategies Scenario II prefers to take hard protection measures to protect existing development and public safety. Although the relocation of existing development and structures is costly and will increase GHG emissions in the short term with redevelopment, using hard protection measures will cause cumulative negative impacts to the natural environment and increase shoreline erosion. Additionally, Adaptation Strategies Scenario I advocates for assisting coastal ecosystems adaptation to sea level rise with wetland restoration and forest management, which will not only help protect ecological buffer zones for hazards but also enhance climate mitigation goals by increasing carbon storage. The other integrated strategies in Adaptation Strategies Scenario I are green infrastructure approaches and LID techniques. These tactics use ecological components to control stormwater drainage problems that could be caused by rising water tables. The economic benefits of these practices usually outweigh their costs, unlike traditional measures, in many cases (Foster et al., 2011). However, a more detailed cost–benefit analysis of LID and green development is needed for the study area before a final adaptation strategies scenario is adopted.

According to Adaptation Strategies Scenario II, soft protection measures seem to be more sustainable than hard protection structures in many ways, so strategies such as living shorelines can be used with hard protection methods where feasible in order to mitigate the negative impacts on the natural environment. Adaptation Strategies Scenario II promotes a couple of feasible strategies for better adapting the built environment to sea level rise impacts, such as restricting new development by rezoning the vulnerable areas and promoting cluster development in safer uplands. These strategies could help to protect new development from sea level rise impacts over the long term and revitalize both the social and economic character of the existing community.

In conclusion, integrated strategies from Adaptation Strategies Scenario I contribute to the sustainable goal and enhance the resiliency of both the natural and built environments. Given the fact that the community depends on its rich natural resources for economic health, the application of integrated strategies would better maintain and enhance the community's identity, thereby improving the overall quality of life for residents.

Furthermore, in order to select feasible strategies and guarantee their successful implementation with the limited financial and public resources in the rural communities, it is important for local governments and decision makers to prioritize strategies based on their community needs and character, as well as the perceived short-term and long-term benefits. On the other hand, the projection of sea level rise impacts still contains a lot of uncertainties. It is possible that sea level rise might be more severe or swifter than currently projected, so more flexibility should be considered into adaptation strategies. An adaptive management approach could be integrated into adaptation planning by taking into account new developments in climate change impact prediction as they emerge.

Table 5-4. Adaptation strategy evaluation of Adaptation Strategies Scenario I and II

	Adaptation Strategy	Evaluation Indicator																	
		Ecosystem				Livelihood									Process				
		Ecological components	Relationships and functions	Diversity	Memory and continuity	Econ/Social well-being	Decrease vulnerability	Public health and safety	Increase food security	Sustainable resource use	Reduce GHG emissions	Flexibility	Public access	Community character	Diverse stakeholders	Communication and negotiation	Transactive decision making	Social learning	Value
Adaptation Strategies Scenario I																			
1	Facilitate natural environment adaptation with wetland restoration and forest management	++	++	++	++	+	+	+	0	0	+	+	0	+					14
2	Preserve and expand ecological buffer areas to promote inland migration of habitats and species	++	++	++	++	+	+	+	+	0	+	+	+	+					16
3	Gradually relocate existing structures from vulnerable areas to safer upland areas	+	+	+	+	0	++	++	0	0	-	0	+	0					8
4	Incorporate accommodation strategies such as elevating structures and improving infrastructure	0	0	0	0	+	+	+	0	0	0	+	0	+					5
5	Use living shorelines to protect structures in the vulnerable waterfront areas	+	+	+	+	+	+	+	+	0	+	+	+	0					11
6	Apply green infrastructure approaches such as permeable pavings, rain gardens, bioswales, and etc.	+	+	+	+	+	+	+	+	+	+	+	+	+					13
7	Apply LID techniques to control stormwater runoff and protect water quality	+	+	+	+	+	+	++	++	+	+	+	0	0					13
8	Update evacuation plan for hurricane and emergency events by identifying evacuation routes, reducing evacuation times, and improving shelter locations	0	0	0	0	+	++	++	0	0	0	0	0	0					5
9	Pursue infill and redevelopment in new town center of Yankeetown and existing town center in Inglis	0	0	0	0	++	0	0	0	0	-	+	0	++					4
10	Enhance education and outreach for community	0	0	0	0	+	+	+	0	0	0	0	0	+					4
																	Total: 93		Average: 9.3
Adaptation Strategies Scenario II																			
1	Use hard protection techniques to protect people and properties from inundation and flooding	-	-	-	-	0	++	++	0	0	-	0	-	0					-2
2	Use soft protection measures such as living shorelines where feasible	+	+	+	+	+	+	+	+	+	+	+	+	0					12
3	Use accommodation methods such as building code revision and design standard improvement	0	0	0	0	+	+	+	0	0	0	+	0	+					5
4	Apply Capital Improvement Programs (CIPs) to invest in infrastructure improvement to accommodate future growth and sea level rise impacts	0	0	0	0	+	+	+	0	0	0	+	0	+					5
5	Use zoning to restrict new development and require higher standards for flood-proof design in the vulnerable area	0	0	0	0	+	+	+	0	0	0	+	0	+					5
6	Update evacuation plan for hurricane and emergency events by identifying evacuation routes, reducing evacuation times, and improving shelter locations	0	0	0	0	+	++	++	0	0	0	0	0	0					5
7	Redevelop the towns' centers using cluster development and smart growth to revitalize community and maintain its character	0	0	0	0	++	0	0	0	+	+	+	0	++					7
8	Create opportunities for outdoor recreation and activities to facilitate social communications	0	0	0	0	++	0	0	0	0	0	+	++	++					7
																	Total: 44		Average: 6.3

CHAPTER 6
CONCLUSIONS AND FURTHER STUDIES

Conclusions

This thesis identified a variety of adaptation strategies for sea level rise from a review of existing literatures on adaptation strategies and an analysis of five cases in different scales. These strategies were then classified and assessed through an evaluation framework with a series of indicators derived from the principles of adaptive co-management from Plummer and Armitage (2007), sustainable rural livelihoods from Scoones (1998), and San Diego Bay Adaptation Strategy from Hirschfeld (2012). Previous studies and a vulnerability analysis of sea level rise impacts support the development of two adaptation strategies scenarios for the thesis study area Yankeetown-Inglis. A comparison of the two adaptation strategies scenarios demonstrates that the integrated strategy that addresses both the natural and built environments provides a more sustainable approach to help build resiliency for the social–ecological systems of Yankeetown-Inglis.

The final results of the two adaptation strategies scenarios represent a traditional planning approach and a new way of thinking. Traditionally, urban planning serves people by focusing on the built environment in order to improve the quality of life and overall well-being of residents. However, increasingly planners are paying more attention to the relationship between the natural and built environments. Coastal communities, especially rural communities, usually have unique and intrinsic connections with the water and other local ecosystems that provide numerous benefits. In adaptation planning for sea level rise, the strategies of protection, accommodation, and retreat for the built environment alone are unlikely to meet the needs of sustainable development. Thus, applying a more integrated approach to build resiliency for both the social and ecological systems becomes critical. The Yankeetown-Inglis case proved the importance of balancing concerns in the natural and built environments to maintain and enhance the character of rural coastal communities in adaptation planning. The added benefits of this approach are that natural resources and green features in the living environment help enhance community identity and quality of life, in turn attracting more people and investment to the community.

This thesis made attempt to examine the existing and potential role of integrated strategies in promoting sustainable adaptation to sea level rise. Although the analysis of five cases indicates an increasing trend of considering natural adaptation in strategy development, the overall awareness of the concept of integrated planning still needs to be enhanced. The Adaptation Strategies Scenario I for Yankeetown-Inglis presents the concept of integrated adaptation. Though limitations remain, this could be a starting point for decision makers in Yankeetown-Inglis and other similar coastal communities to incorporate the integrated approach into their future adaptation planning. Higher land values in urban areas may result in different adaptation priorities, but an integrated approach could also help decision makers in these areas to balance the tradeoffs among social, economic, and environmental concerns when planning for climate change and sea level rise. By further researching the costs and benefits of different strategies, as well as weighing the short- and long-term goals and needs of the community, Yankeetown and Inglis have the capacity to alleviate the threats sea level rise poses to their communities—or even to turn those threats into opportunities for community revitalization.

Further Studies

Adaptation to sea level rise is an ongoing process requiring continuous learning and exploring. “Learning by doing” can best describe this process of making decisions based on diverse uncertainties and immature knowledge (Ahern, 2011). In order to successfully accomplish sustainability in adaptation planning, it is critically important to integrate the most up-to-date science, innovations, and technology, as well as collaboration and social engagement. For Yankeetown and Inglis, and for other similar coastal rural communities, this thesis provides some ideas for further research and studies.

First, Yankeetown and Inglis should initiate a detailed infrastructure vulnerability to sea level rise, especially for their water supply and wastewater treatment facilities. Since infrastructure and facilities are associated with land use patterns and will affect the future infill and relocation process, there is a need to assess where existing facilities have the capacity to support new development or where new central systems and technologies would be needed. Additionally, it is very necessary to establish a Stormwater Management Plan to accommodate more intensive flooding and inundation by rising sea levels, and to better maintain the quality of water supply.

Second, further studies can concentrate on how to integrate climate change and sea level rise into the policy context, including the local comprehensive plan, zoning ordinances, and land development regulations. For example, a conservation ordinance can be created to identify the priorities for protection and relocation areas. Furthermore, it is important for local governments and decision makers to prioritize strategies based on community needs and character, as well as short- and long-term benefits. Setting a timeframe could help ensure future implementation.

Finally, research is needed regarding how to better engage the public and facilitate social learning in the policy and decision making process. Communication about climate change is critical to help the public understand the changes needed to mitigate its effects and gain their buy-in for related public policy decisions. Research on how to better change people's ideas and behaviors for building resiliency to climate change problems is of vital importance.

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BIOGRAPHICAL SKETCH

Rong Zeng grew up in the historic town of Suzhou, China, and has experienced rapid urbanization and resource exploitation in her hometown. With an initial interest in improving the living environment of her hometown, Rong received a Bachelor of Engineering in Urban Planning and Design at Nanjing Forestry University. Rong pursued a Master of Arts in Urban and Regional Planning at the University of Florida to further explore planning that seeks to better balance the natural and built environments, concentrating on environmental planning and adaptation to sea level rise. She continues to develop her knowledge of and skills related to sustainable development to address climate change challenges with the aim of becoming a professional planner.