Tracking the Effects of Sea Level Rise in Georgia's Coastal Communities

Prepared by Georgia Institute of Technology

School of City & Regional Planning

Dr. Larry Keating, FAICP

Dana Habeeb, PhD Candidate

Fall 2012

Tracking the Effects of Sea Level Rise in Georgia's Coastal Communities

Georgia Institute of Technology
School of City & Regional Planning
245 Fourth St. NW Suite 204
Atlanta, GA 30332-0155
(404) 894-2350
www.planning.gatech.edu
December 14, 2012

Student Contributors:

Gillam Campbell
Marvin Clermont
Kathryn Colberg
Richelle Gosman
Anna Rose Harkness
Amy Moore Hugens
Paul Lorenc
Dzung Nguyen
Jennifer Yun
Joy Zhou

A Studio Project under the Direction of:

Professor Emeritus Larry Keating, FAICP
Dana Habeeb

Acknowledgments:

We would like to express our appreciation to the Georgia Conservancy for drawing attention to the important issues surrounding sea level rise and the necessity of including it in future planning efforts. Special thanks is extended to Katherine Moore, Growth Management/Blueprints Program Manager, Johanna McCrehan, Urban Desigener, and Beth Blalock, General Counsel, for their patient support and guidance.

We would also like to express our gratitude to the other groups and individuals who worked to make this report possible:

Dr. Clark Alexander, Skiddaway Oceanographic Institute

Paul Wolff, Tybee Island City Council

Jeanne Cyriaque, African Americal Program Coordinator, Georgia Department of Natural Resources

Althea Sumpter, Vice Chair, Georgia Gullah-Geechhee Heritage Corridor

Melissa Mailloux, Marketek, Inc.

Geechee Kunda Center & Staff, Riceboro, Georgia

Georgia Department of Natural Resources

Finally, to Dr. Larry Keating and Dana Habeeb, your vision, insight, dedication, and consistent humor were a special addition to this studio. We thank you.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Climate scientists have projected that in approximately 100 years sea level will rise by at least one meter along the Georgia coast. While this prognosis is significant and potentially devastating, the change will be slow and incremental. We are fortunate to have the opportunity to take advantage of these early warnings to investigate the effects that a sea level rise of this extent would have on our population, our natural and built environments, and our economy.

In an effort to confront the challenge of planning for sea level rise (SLR), ten graduate students from the Georgia Institute of Technology's School of City and Regional Planning, under the direction of Dr. Larry Keating, FAICP, and Dana Habeeb, and in partnership with the Georgia Conservancy, have investigated potential impacts and adaptation opportunities for three counties along the Georgia coast: Chatham, Liberty, and McIntosh. This study region spans 1,378 square miles of the Georgia and contains a population of 334,099. Our hope is that residents, decision-makers, and researchers will utilize this report to prepare for a future in which the coast is better equipped for the coming changes.

How Will Sea Level Rise Affect the Physical Landscape?

By the year 2110, our projections indicate that almost one-third (30.45%) of the study area will be inundated by SLR. This inundation represents 418.92 square miles of the Georgia coast.

Wetlands

More than 50% of the land currently classified with a land use of parks/ recreation/conservation in each county is threatened by SLR. Most of these areas are wetlands. Fortunately, the majority of wetlands have a high chance of survival because of their ability to migrate inland. However, land must be conserved to facilitate this migration. Other methods for preserving wetlands include: supplying additional sediment to promote wetland accretion rate; installing "soft" shoreline protection alternatives to allow wetland migration; and building and enhancing barrier islands to create an offshore protection system.

These strategies are supplementary to one another and should be considered inclusively in any adaptation plan for wetlands. Hardscaping shorelines has been a popular method for mitigating damage caused by changing water levels; however, this method causes significant disruption in wetland migration. We recommend that municipalities consider strategically removing some of the hardscaping currently in place to create more area for wetland movement.

In the end, it is important to remember that though SLR is a slow process, local governments must take early action to reduce the costs and difficulties of implementing plans to protect the natural environment.

The Built Environment

McIntosh County has the largest percentage of McIntosh County has the largest percentage of residential land threatened by flooding due to SLR at nearly 20%. Most of this land is concentrated in Darien (where 30% of residential areas are projected to experience inundation), adjacent to the Darien River, along SR-99, and in Crescent.

The more extensively urbanized nature of Chatham County will contribute to a greater loss of buildings due to inundation. Projections indicate that 8,968 buildings in Chatham County will be impacted, compared to 859 buildings lost in Liberty County and 1,243 buildings lost in McIntosh County.

It is important to note that the majority of the historic district in Savannah is not projected to be affected by inundation; however, much of the commercial district adjacent to the Savannah River along River Street is threatened. These buildings form the foundation for the structures above and along Bay Street. Therefore, the implications on the stability of the structures above could be significant.

Tybee Island is expected to experience significant impacts by the year 2110 due to SLR. Nearly 50% of the residential land, 48% of the land used for transportation purposes, and 30% of the commercial land is projected to be inundated. Approximately 40% of the currently existing buildings on Tybee Island are in danger of damage due to sea level rise.

For the environmentally sensitive facilities in the three-county study region, inundation will not be extensive.

However, an impact is important to note due to the services and potential hazards that these facilities present to neighboring areas. Facilities threatened by SLR include:

- Hazardous Materials Sites: 4 out of 46 at risk;
- Landfills: 1 out of 30 at risk;
- Power Plants: 0 out of 7 at risk; and
- Waste Water Treatment Plants: 3 out of 49 at risk for inundation.

Communities should consider taking action now to shape their land use, development, and redevelopment policies to encourage activity in areas that are not expected to be affected by SLR. By proactively identifying land threatened by SLR and discouraging development in those areas, communities can reduce the cost associated with reactionary responses ten, twenty, or fifty years from now.

We recommend that SLR be incorporated as a standard concern in local comprehensive planning processes. Communities should shape their future land use plans to prepare and account for SLR. Zoning, building codes, and the cost of investing in new infrastructure should be considered. While channeling future growth to less threatened areas can limit future damage, present development patterns expose residential, commercial, and recreational land as well as basic wastewater treatment facilities, water intakes, landfills, and hazardous materials sites to inundation. The policy choices here are difficult and contentious: Can these sites be safely and economically adapted or should they retreat to safer ground?

Local communities participate in the National Flood Insurance Program to protect property owners from damage caused by flooding. Areas vulnerable to

Georgia Tech Sea Level Rise Studio Participants (left to right): Kathryn Colberg, Anna Harkness, Marvin Clermont, Gillam Campbell, Richelle Gosman, Joy Zhou, Dzung Nguyen, Amy Moore Hugens, Jen Yun (Paul Lorenc [photographer] not pictured).

flooding include the areas that are threatened by SLR. Local communities should consider adopting policies that encourage residents and business owners to obtain flood insurance. Both the Federal Flood insurance program and Stafford Act funding for repairing damaged infrastructure are on fiscally unsustainable trajectories. Neither program will operate in the future as they do today because demands are already exceeding funding by far. Prudent local governments should both track changes in federal policies and funding and prepare to respond independently.

Finally, we suggest that local communities within the study area consider creating a Transfer of Development Rights program for both undeveloped and developed properties within the SLR impact zone as a mechanism for shifting the focus of development away from endangered areas

Transportation

Roads and railroads threatened by SLR are especially important as these travel routes are crucial to the local economy and the safety of residents in need of evacuation from the coast in the event of hazardous events. Approximately thirteen miles of Interstate 95 and US 80 are threatened by inundation. Flooding of the section of US 80 that is at risk, from the intersection with Johnny Mercer Boulevard in Savannah, to the intersection with Campbell Avenue, on Tybee Island will prevent residents and visitors to Tybee Island from accessing and leaving the island. Although it will be costly, the portions of Interstate 95 and US 80 that will be inundated could be replaced by bridges in order to maintain a safe route away from the coast and access to Tybee Island.

Approximately eleven total miles of the CSX Norfolk Southern rail that links the Port of Savannah are projected to be exposed to inundation. Most of the threatened rail links are on Hutchinson Island and the Liberty Terminals property adjacent to East President Street. This lack of connection with the rail network will create difficulties in the transportation of goods from the Port of Savannah to the rail and highway networks, which will negatively impact the local and State economy. Again, these rail links within the Port of Savannah that are expected to be impacted by SLR will need to be elevated or relocated east, down the Savannah River. This relocation process may prove difficult, because the Conoco Phillips Warehouse and Kemira Water Solutions currently occupy much of the adjacent property.

How Will the Population on the Coast be Impacted?

The population of coastal Georgia is diverse, and the effects of SLR will have very different implications for people depending on their unique circumstances. Though the portions of the study area that will be impacted by SLR tend to be low in population density, 20,079 households and 50,059 people in the three counties are threatened by flooding due to SLR. Most of this population is concentrated in Chatham County, with 17,187 households and 42,623 people anticipated to be affected by inundation (See Table 3.2). Of the people whose homes will be inundated by SLR, 7,428 are over the age of 64. Of this population, 6,377 (85.9%) are in Chatham County. People over the age of 64 are considered more vulnerable because they are likely to be less mobile and may be dependent on others for transportation. (See Table 3.3 for a list of all inundation counts per social variable.)

In the three counties, 15.8% of employed persons (22,957) will be inundated at their residences. Over two-fifths (45.9%) of the population anticipated to be inundated is employed, and over one-half (56.7%) of this group is employed in the service sector. Many of these people will be affected because their jobs depend on the second largest regional employment sector – tourism – which is likely to be substantially impacted because of its orientation to the ocean, marshes and rivers.

While 15.0% of the total population will be inundated, a larger proportion of the white population – 19.7% – will be. Correspondingly, smaller proportions of the non-white and Hispanic population will be directly affected: 10.4% of Hispanics and 9.7% of non-white people. These differentials derive from residential patterns in which wealthier white residents occupy more expensive residences along the marshes on the west side of Tybee Island, interior properties on Tybee, coastal marshes on Wilmington Island and below the bluffs in suburban Savannah. Concentrations

of African American residences anticipated to be inundated are on low-lying land west of Savannah's center where the Savannah River rises with the tides.

Eighty percent (80.0%) of the directly affected families in poverty live in Savannah. The incidence of inundation for impoverished households is 9.0%, which is lower than the overall population because a higher proportion of those with higher incomes have located in the more expensive areas on the coasts, on the marsh islands or along the rivers.

Twice the number of owners (13,845) compared to renters (6,238) will be inundated. The incidence of inundation by tenure is 23.5% for owners and 11.6% for renters. Again, the explanation for the differential is greater access to preferred sites by income, but in this instance local zoning plays a contributing role. While some rental properties have managed to obtain sites along the marshes and rivers, local zoning favors owner-occupied housing in heretofore more desirable areas. Rental properties that will be inundated are more likely to be located in flood prone areas west of central Savannah and along tributaries of both the Savannah and Altamaha Rivers.

A total of 2,634 manufactured homes in the three-county area are projected to be inundated; 1,466 (55.7%) of these homes are located in Chatham County. A large number of these mobile home communities are located in southwest Savannah and central McIntosh County. Nearly 730 mobile homes are located in McIntosh, which is almost two times the amount of Liberty County. The ability of these structures to withstand the water damage associated with sea level rise is diminished by their lower initial construction standards, and the limited incomes of many of the residents will restrict their ability to avoid or react to that damage.

Some of the most vulnerable people, notably 1,238 homeless and 10,724 households without access to a motor vehicle will be threatened by sea level rise. Present data does not permit precise estimates of the proportions of either of these groups who will be directly affected. The absence of data and knowledge of the locations occupied by these populations presents a challenge requiring greater preparedness from local governments that will be responsible for evacuating homeless and transportation-dependent residents as sea level rise extends areas vulnerable to hazardous weather events.

Similarly, there are 33,066 people in the region with various forms of disabilities, some of whom would require assistance ranging from replenishment of medication to relocation under different sea-level-rise-spawned weather events. More complete knowledge of the location of these people and of the particular limitations they face is a prerequisite for effective action.

Single parent households have higher proportions of vulnerability because one person is responsible for income, parenting and organizing a response to external threats or emergencies. There are 2,044 single parent families in areas that will be inundated in the region, 1,752 (or 85.7%) of whom are in Chatham County. Over one-quarter of these families (534 / 26.7%) were impoverished. Some of the larger group had sufficient resources and income to be able to manage external threats without too much difficulty, but many do not and would require assistance. Over 9 in 10 (92.5%) of the impoverished single parent families had a female householder.

The capacity to respond effectively to external threats and contend with the substantially changed circumstances sea level rise will produce is not precisely measurable, but having a high school education (or equivalent) is a plausible proxy. Three thousand five hundred and sixteen adults 25 years old or older lack this level of education and are in the path of inundation. Over two-thirds (72.3%) of these people are in Chatham County. Some of these persons are in households with better equipped adults and therefore have the support they will need to manage forthcoming problems. But many are not so fortunate.

It is also important to recognize that the populations that lack resiliency and the ability to cope with the effects of SLR are concentrated in Savannah, outside of the Historic District and often in more marginal areas. People in these areas who are affected by SLR will need more assistance from local governments in order to adapt than those in other areas.

Our recommendations for mitigating the potential effects of SLR on vulnerable populations include creating a focus on SLR-related education (especially at the school-age level), outreach, and community

discussion. There is clearly a need for the expansion of resources available to vulnerable families and individuals.

The Gullah-Geechee

The Gullah-Geechee are descendants of West African slaves who remained along the southern Atlantic Coast after the Civil War and the demise of cotton, rice and indigo production. Because the Gullah-Geechee are concentrated in areas closer to the coast, including the small communities of Hog Hammock, Sandfly and Pin Point, the homes of a large (but imprecisely measurable) portion of this population are in danger of inundation. Their relocation could cause a disruption in the culture, history, social cohesiveness, and organization of this important cultural group.

Utilizing ArcGIS and population estimates based on block size, an analysis on the effects of SLR on three Gullah Geechee communities has been performed. Barring any change to current infrastructure, SLR will inundate the homes of 95% of the population in Hog Hammock in McIntosh County. In Chatham County many roads leading to the Pin Point community will face inundation, though it will not directly affect any of the homes in this community.

To prevent the history of the Gullah-Geechee culture from falling by the wayside, we recommend strategies that include education on the importance of the culture and the danger that SLR poses. Geechee Kunda in Riceboro, Georgia, may serve as a prime location for education efforts and also as a cultural hub.

An important finding in the analysis of the social consequences of SLR is a lack of accurate, clear, and accessible beyond the Census. The remote location of the Gullah Geechee and the lack of population available data has made it difficult to track these people. To facilitate the creation of thorough, inclusive, and effective plans for the future of the coast, municipalities should consider the characteristics of vulnerable subgroups of their populations. Measurement for presently unidentified or un-measured characteristics of the population, including homeless, those with various types of physical and mental disabilities, geographically isolated people, those with different types of housing needs, those without access to transportation and medically dependent people, should be developed and utilized to create a better understanding of socially vulnerable people.

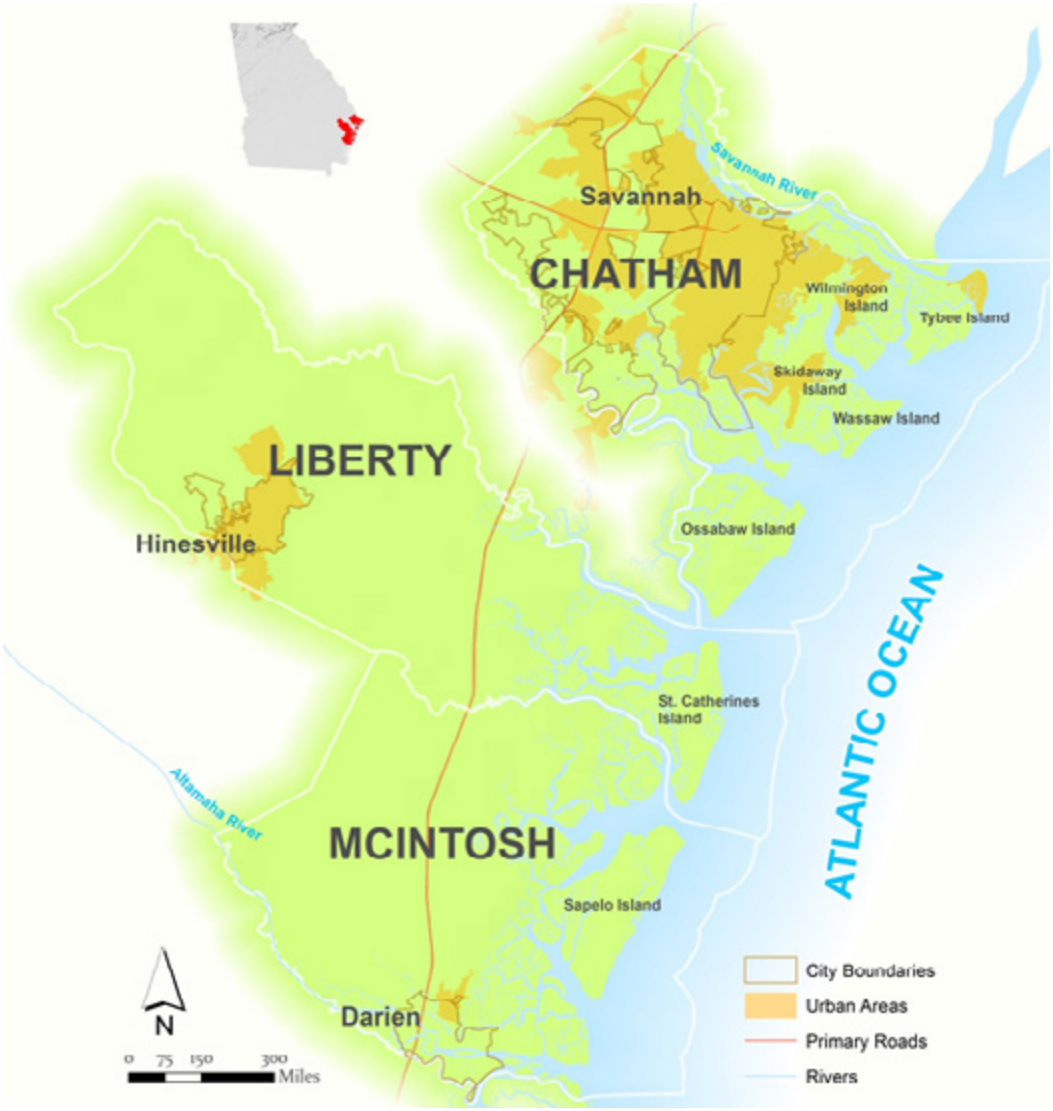
The full report seeks to place sea level rise, a global phenomenon, into context for the Georgia coast, creating a foundation of inquiry from which to launch this long-term planning process.

INTRODUCTION

Over the course of the next century, coastal communities will face the daunting task of preparing for the consequences of sea level rise (SLR). Marine researchers report that ocean levels are rising at a substantial rate (Nicholls, 2011). The National Oceanic and Atmospheric Administration's (NOAA) tide gauge at Georgia's Fort Pulaski, near the mouth of the Savannah River, indicates that sea levels on the Georgia coast have risen between ten and eleven inches since 1935 (NOAA, 2012). Climate scientists estimate that by the year 2110, sea level will be approximately one meter (39.37 inches) above today's level. This increase in sea level rise may have a devastating impact on the Georgia coast. However, by proactively planning for the increase in sea level rise, coastal communities can increase their resilience to future coastal hazards in order to mitigate the impacts of sea level rise.

In this report we focus on the sea level rise impacts and adaptation opportunities for three counties along the Georgia coast: Chatham, Liberty, and McIntosh. We investigate the effects that sea level rise will have on the population, the natural and built environments, and the economy of this three county area. Our goal is to provide residents, decision-makers, and researchers with information that can help them proactively plan for future sea level rise so that the Georgia coast is better equipped for the coming changes. This report is the result of

Figure 1.1- Context Map



a semester-long graduate planning studio led by Dr. Larry Keating and Dana Habeeb at the Georgia Institute of Technology and generously supported by the Georgia Conservancy.

Three County Study Area

Our research examines the impact of sea level rise on three of Georgia's five coastal counties: Chatham, Liberty, and McIntosh Counties (See Figure 1.1 – Context Map) which comprise over a half (56%) of Georgia's coastal area. Of the five counties, Chatham covers the greatest area of Georgia's coast at 27.7 % while Liberty covers the least at 11.8 % (See Table 1.1). The Georgia shoreline is protected by a chain of seventeen major barrier islands. The barrier islands were formed during different geological periods with marsh hammocks in between. The older islands, located closer to the mainland, are from the Pleistocene period and the young islands,

Table 1.1– Study Area Coastline

	Miles	Percentage of Total
Chatham	31.53	28%
Liberty	13.46	12%
McIntosh	18.57	16%
Glynn	27.89	24%
Camden	22.56	20%
Three County Study Region	63.55	56%
Counties Outside Study Region	50.45	44%
TOTAL	114.00	100%

Table 1.2 – Basic Physical, Demographic, & Inundation Characteristics

	Chatham County	Liberty County	McIntosh County	Three County Region Total
Total Land (sq mi)	433	517	428	1,378
% of Total Land	31%	38%	31%	100%
Non-Wetland (sq mi)	289	448	319	1,056
% of County Land	67%	87%	74%	-
% of Total Land	21%	33%	23%	77%
Shoreline (miles)	32	13	19	64
% of Total Shoreline	50%	21%	29%	100%
Wetlands (sq mi)	144	69	109	322
% of County Land	33%	13%	26%	23%
% of Total Land	10%	5%	8%	23%
Area Inundated (sq mi)	194	90	160	444
% Inundated of County Land	45%	17%	37%	-
% Inundated of Total Land	14%	7%	12%	32%
Barrier Islands	6	2	3	11
Population	256,428	63,854	13,817	334,099
White Population	139,303	30,047	8,470	177,820
Nonwhite Population	117,125	33,807	5,347	156,279
Hispanic Population	12,510	6,070	237	18,817
Households	100,450	22,626	5,687	128,763
Median Household Income	$44,298	$42,674	$39,075	$42,016 (average)
Dominant Land Cover	Wetlands (44%)	Forest (56%)	Forest (48%)	Forest (43%)
Dominant Land Use	Parks/Recreation/ Conservation (44%)	Parks/Recreation/ Conservation (37%)	Agiculture/ Forestry (43%)	Parks/Recreation/ Conservation (33%)
Buildings	34,531	21,552	28,071	84,154

located further away, are from the Holocene period. Marsh hammocks are low-lying land masses (small islands) surrounded by marshlands. They are located between the mainland and the barrier islands. The extensiveness of the marsh hammocks along Georgia's coast makes it unique. There are over 17,000 acres of marsh hammocks supporting maritime forests and coastal wooded habitats that are disappearing. These marsh hammocks are habitats and nesting sites for many birds, animals and fish. Our three-county study area contains eleven of the Coast's seventeen barrier islands. From north to south they are: Wilmington Island, Tybee Island, Little Tybee Island, Skidaway Island, Wassaw Island, Ossabaw Island, Colonels Island, St. Catherine's Island, Blackbeard Island, Sapelo Island, and Wolf Island.

Over 300,000 people reside in the study area inhabiting a total of 128,763 households. Chatham County is by far the most populated county with over 265,000 residents and over 127,000 jobs (See Table 1.2). The port city of Savannah is located in Chatham County and is the largest economic engine in the region. Tybee Island, also in Chatham County, is the most developed barrier island in the three counties and is a major source of tourism during the summer months. Of note, Sapelo Island, located in McIntosh County, is the home to one of the longest lasting communities of the Gullah-Geechee, an African-American ethnic group with strong cultural ties to West Africa. The majority of the population in the three county study area is white (53%). African Americans comprise the majority of the remaining 47% of the nonwhite population. The most extensive land cover for the three counties is forest (44%), and the most extensive land use is parks/recreation/conservation (33%). Twenty-three percent of the land cover in the study area is mixed salt water and fresh water wetlands that are intermixed with the eleven barrier islands.

Sea Level Rise Data

In order to investigate the future impact of sea level rise on the Georgia coast, we utilized the Skidaway Institute of Oceanography's hydro digital elevation bathtub model, which describes the extent of inundation that a one-meter rise in sea level will cause. An SLR bathtub model is a rudimentary assessment of sea level rise that uses elevation data to project the extent of land submersion that results from rising coastal waters. The SLR bathtub model calculates sea level change as a one-meter rise in the average water line at the highest daily tide (the mean higher high water – MHHW) from the year the digital elevation model (DEM) was constructed (2010). The bathtub model is an additive model that does not account for responsive land cover changes (i.e., wetlands migration). By not taking into account land cover change dynamics, the bathtub model inherently overestimates wetland losses.

Study Approach

For our analysis we estimate the impact of SLR on the Georgia coast over the next 100 years, assuming a sea level rise of one meter. The base year for our analysis is 2010 since the SLR data was created using a 2010 DEM. In our analysis we do not project how coastal counties will change over time and therefore assume current conditions for 2110. In essence we are analyzing the impact of what would happen if the average high tide was to instantaneously rise today by 1 meter. As such, we have assumed constant population and development conditions, based on the most recent available data. Since all three counties have had steady increase in both their populations and economies, we implicitly assume that our impact analysis is quite conservative for the year 2110.

One hundred years is a long time for communities to plan for change. Realizing it is important for communities to plan both for the near term and the distant future, we conducted a temporal analysis that examines the impact of sea level rise over small time intervals. Using the same high-resolution digital elevation model discussed above and sea level projection rates from the literature, we estimate sea level rise at approximately twenty-year intervals. Estimating more immediate impacts allows communities to prioritize adaptation responses.

To quantify the impact of SLR we analyze both the social and physical geographies of the three-counties through a geospatial analysis in ArcGIS. Physical

Table 1.3 – Overview of Physical Vulnerability Studies and Indicators

		Herberger et al. 2009	Concannon et al. 2010	Flynn et al. 1984	Mao & Welfang 2011	Georgia Tech SLR Studio 2012
LAND COVER						*
HABITATS						*
WETLANDS		*				*
LAND USE			*			*
HAZUS DATA		*				*
BUILDINGS	Total Number	*				*
	Replacement Value	*				*
TRANSPORTATION	Rail	*			*	*
	Evacuation Routes		*		*	*
	Roads		*		*	*
FACILITIES	Hazardous Materials	*		*		*
	Wastewater Treatement Plants	*	*			*
	Water Systems	*				*
	Landfills			*		*
	Power Plants	*				*
	Airports	*				*
	Governemental		*			*
	Medical					*
	Schools	*				*
	Shelters					*
	Churches and Cemeteries					*
HISTORIC SITES			*			*

geography consists of natural and manmade physical components such as habitats, land cover, land use, facilities and transportation. Social geography is comprised of demographic and economic variables with a strong focus on vulnerable communities. Through an extensive literature review we identify physical variables that cause a community to become vulnerable to the effects of SLR. We also identify the variables that characterize vulnerable populations and groups. When conducting the social geography analysis we pay particular attention to the impact of SLR on the Gullah Geechee community.

What is Vulnerability?

Brooks (2003) states that "vulnerability" has two components: social vulnerability and biophysical vulnerability." Natural scientists use biophysical vulnerability, or physical vulnerability, when referring to the likelihood of occurrences and impacts of disaster events (Nicholls, Hoozemans, & Marchand, 1999). Social scientists define the concept of vulnerability as a social groups' ability to cope with disastrous events (Allen, 2003).

Cutter et al. (2004) use the concepts of "biophysical vulnerability" and "social vulnerability" to refer to landscapes and social groups poised to experience harm caused by disaster events. In other studies, researchers include human systems such as commercial and industrial development, residential property, infrastructure and lifelines, etc. as "social vulnerability concepts" (Cutter, Boruff, & Shirley, 2003; Heinz Center for Science, Economics, and the

Table 1.4 – Overview of Social Vulnerability Studies and Indicators

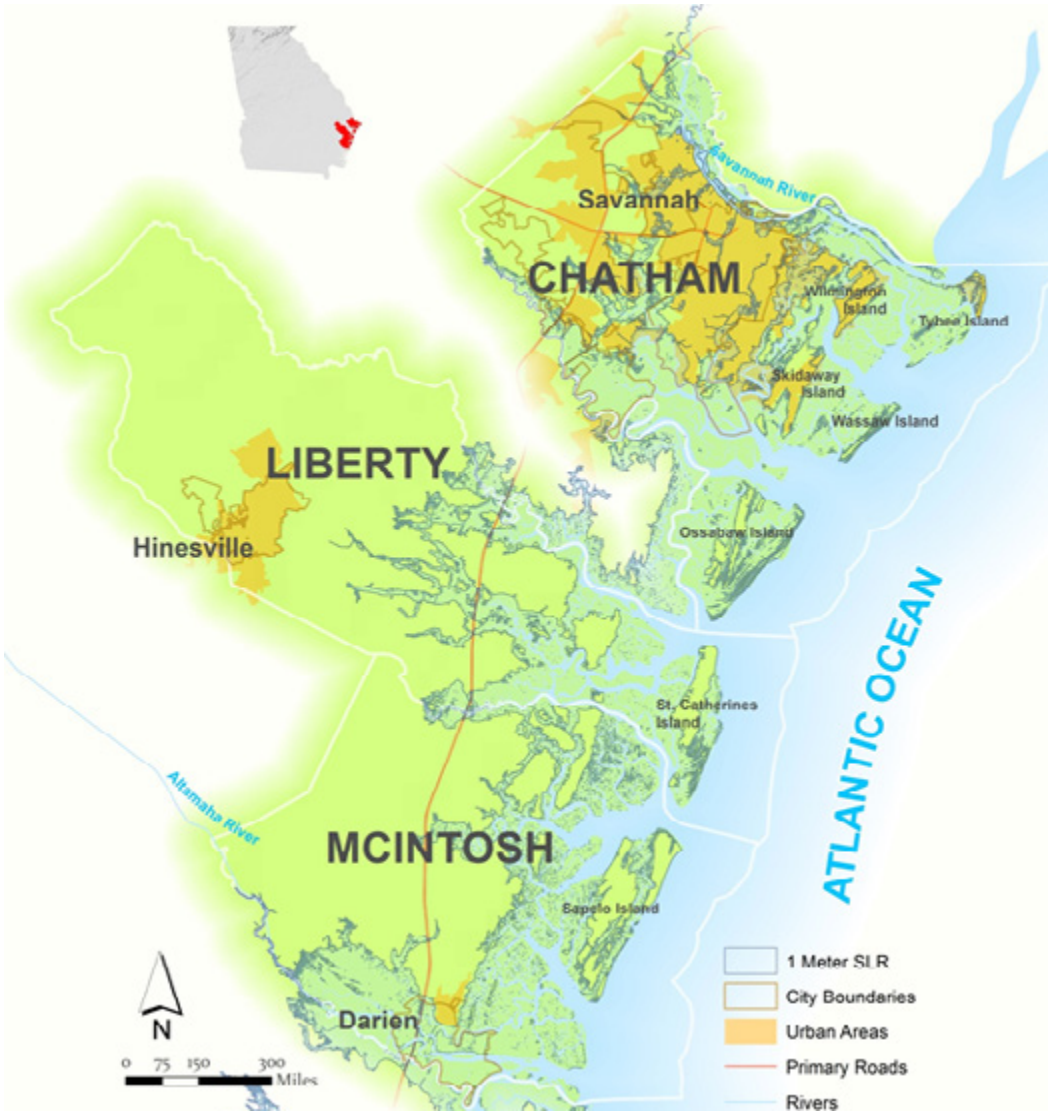
	Schmidtlein et al 2008	de Olivera Mendes 2009	Clark et al. 1998	Shepard et al. 2011	Florida Special Needs Shelter 2012	Georgia Tech SLR Studio 2012
Population and Household Density	*	*		*		*
Age	*	*	*	*	*	*
Race and Ethnicity	*		*	*	*	*
Gender and Family Status	*	*	*	*		*
Education	*	*	*	*		*
Occupation and Employment	*	*	*	*		*
Income and Poverty	*	*	*	*	*	*
Housing and Built Environment	*	*	*	*		*
Manufactured Housing		*				*
Mode of Transportation			*	*		*
Disability	*	*		*	*	*
Social Capital	*	*	*	*	*	*

Environment, 2000; Webb, Tierney, & Dahlhamer, 2000). They then use property value, housing, manufacturing and commercial building densities as variables to measure "social vulnerability." These studies illustrate that while it is acceptable to use physical or biophysical vulnerability terms to refer to the potential risk of the natural and built environment, a uniform distinction between physical vulnerability and social vulnerability does not exist in the literature.

For the purpose of this report, physical vulnerability is defined as the exposure and sensitivity of infrastructure and the natural environment to hazardous events and inundation caused by sea level rise. Exposure refers to the extent to which these systems are at risk of inundation due to sea level rise. Sensitivity conveys the extent to which exposure could harm those communities (adapted from San Francisco Bay Conservation and Development Commission, 2012). The measurement of physical vulnerability conducted here describes both the exposure and sensitivity of those systems to sea level rise. We seek to understand what percentage of existing infrastructure, facilities and natural environment will be inundated due to sea level rise and the relative scale of that impact.

Of course, an analysis of the potential impact of sea level rise must delve deeper than physical features. We must understand the people that inhabit the affected areas and investigate how changes to the physical landscape will influence their lives. This study defines social vulnerability as the opposite of resilience such that it is the exposure of families and communities to the effects of sea level rise and their ability to cope and/or adapt to these disruptions of the physical environment. Table 1.3 and Table 1.4 lists the variables included in our analysis for both physical and social geography and identifies previous literature, which include these variables in their analyses.

Figure 1.2 - Context Map with One Meter Sea Level Rise Inundation



Extent of Inundation

Figure 1.2 shows the area of land in the study area that will be inundated due to a 1-meter rise of sea level. As presented in Table 1.2, 32 % of the region is at risk of inundation, significantly impacting both the physical elements and the population of the Chatham, Liberty, and McIntosh Counties.

With an understanding of the baseline conditions in the study area and a sense of the likely inundation due to sea level rise, we now turn to the specific consequences of change. We hope that identifying existing vulnerable facilities, infrastructure, habitats and populations, will extend the conversation regarding adapting to the changes that are coming.

PHYSICAL IMPACT

For the physical vulnerability analysis, we have identified several physical variables that allow us to describe and quantify the impact that sea level rise will have on both the built and natural environments. These variables include land cover, land use, buildings, transportation infrastructure, service and cultural facilities. We used a variety of methods to quantify the impact of sea level rise on these physical variables depending on whether the data was continuous or discrete. Continuous data, such as land cover and land use, were summarized on a countywide level. Conversely, point-based, discrete data such as service and cultural facilities were analyzed on a per site basis.

The physical variables we investigated span a wide range of environmental and structural attributes. We have organized the variables from the general to the specific. The contextual variables, land cover and land use, were analyzed first. We then proceeded to a facility and site level analysis. When reading the report it is important to remember that many of these variables are not mutually exclusive. For example, a discrete hazardous site may be zoned as an industrial land use, which is then further generalized as "developed" within the land cover classification system. For methodology used in this section, see Appendices I.1-I.3.

Land Cover and Existing Habitats

We begin with the most general perspective: scope and components of land cover that characterize the Georgia Coast. The analysis examines two broad factors: 1) land cover itself, and 2) threatened ecosystems (see Figure 2.1). For information regarding the source of this data and methodology, please see Appendix B.

Broadly speaking, the land cover of an area is classified by the material that most generally characterizes the uppermost surface of that location. Land cover classes range from natural landscapes, such as water or trees, to manmade features like pavement or rooftops. Land cover differs from land use in that it does not account for the use of human interventions

Figure 2.1- Land Cover in Chatham, Liberty, and McIntosh Counties

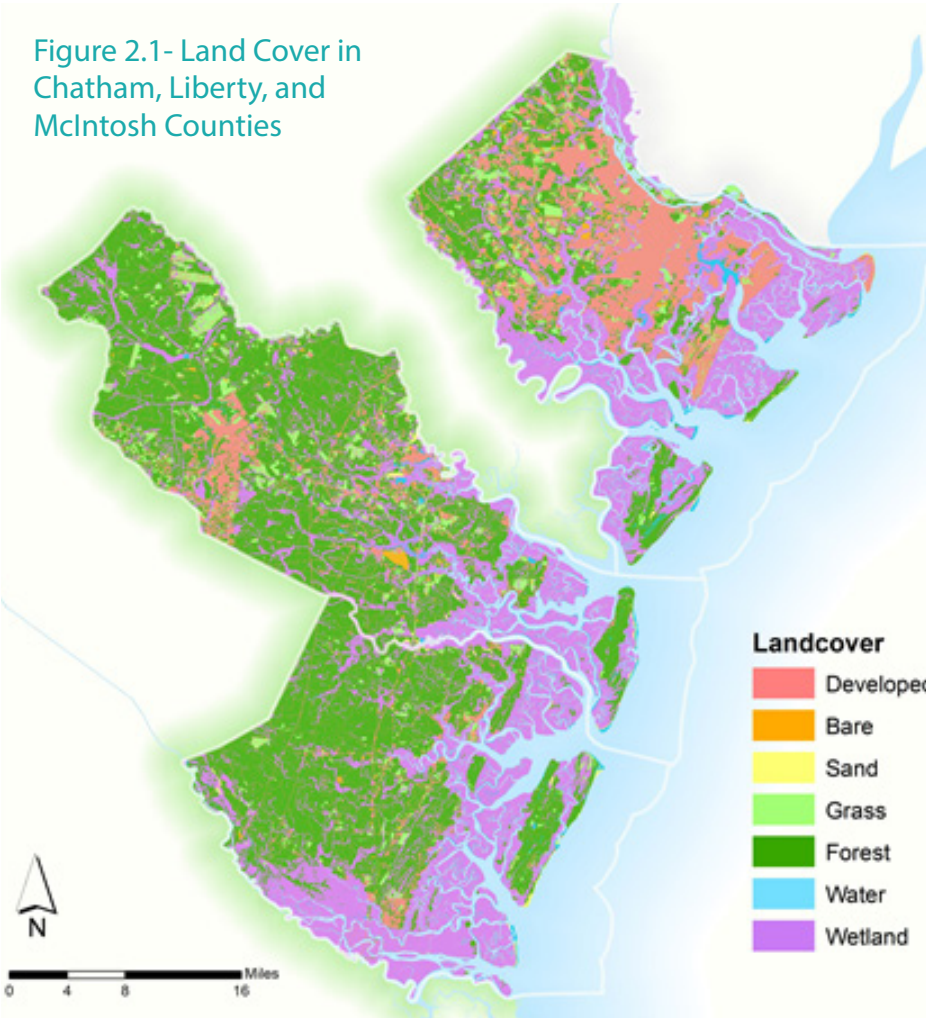


Table 2.1- Overview of Physical Characteristics of Chatham, Liberty, and McIntosh Counties, 2009

		Chatham	Liberty	McIntosh	Three County Totals
Land Cover (Acres)	Bare	4,599	2,960	727	8,286
	Developed	71,813	32,175	15,651	119,639
	Grass	15,589	20,666	6,263	42,518
	Forest	61,429	183,493	132,294	377,216
	Sand	1,841	1,557	1,708	5,106
	Wetland	121,650	87,672	116,739	326,061
Habitats (Acres)	G1 Critically Imperiled	1,773	3,337	62	5,172
	G2 Imperiled	16,168	20,552	20,457	57,176
	G2/G3 Mix	516	74	267	857
	G3 Vulnerable	13,113	16,773	21,957	51,843
Land Use (Acres)	Agriculture/Forestry	25,824	108,169	115,938	249,931
	Commercial	5,262	1,618	570	7,450
	Industrial	8,433	7,262	23	15,718
	Parks/Recreation/ Conservation	123,000	51,292	113,326	287,618
	Public/Institutional	13,250	121,060	9,248	143,738
	Residential	34,571	30,429	28,471	93,521
	Transportation/ Communication/Utilities	23,055	5,549	4,397	33,001
	Undeveloped/Vacant	47,509	5,038	431	53,978
Buildings	Total Number	94,531	51,552	28,071	144,154
	Average Building Replacement Value (X $1,000)	$26,810,340	$4,599,078	$855,212	-
Transportation	Rail	180	43	19	242
	Evacuation Routes	122	80	67	268
	Roads (High Volume)	205	136	83	424
Facilities	Hazardous Materials	42	3	1	46
	Wastewater Treatment Plants	38	7	4	49
	Landfills	22	6	2	30
	Power Plants	6	1	0	7
	Airports	3	3	16	22
	Governmental	66	24	13	103
	Medical	678	61	9	748
	Shelters	0	0	0	0
	Churches	327	80	50	457
	Cemeteries	29	21	31	81
Historic Sites	General	52	11	9	72
	Gullah-Geechee	53	18	38	109

Sources: FEMA, Hazards-United States (HAZUS), 2010; Georgia Department of Natural Resources, 2009; U.S. Census, 2010

to the environment. For example, a land use analysis would classify houses as fulfilling a residential use (of varying density), while a land cover analysis would categorize these areas simply as 'developed.' While a land cover analysis will not encompass the wide range of human activities present in any region occupied by people, it does allow for one to determine the general character of the environment. When we consider the wealth of natural resources present on the coasts, it is especially important to inventory land cover to gauge the impact of sea level rise.

We begin with a broad overview of the land cover classes that compose Chatham, Liberty, and McIntosh counties. The characteristics of the study area's environment are summarized in Table 2.1.

The data shows that the 1,376 square miles of land area covered by the three counties are predominantly characterized by vegetation, namely by forests (42.89%) and wetlands (37.13%). Developed land

Table 2.2 - Overview of Land Cover Inundation in Chatham, Liberty, and McIntosh Counties, 2009

	Area (sq. miles)	% of Total Land Area
Bare	12.98	0.94%
Developed	187.39	13.62%
Grass	66.58	4.84%
Forest	589.92	42.89%
Sand	8.00	0.58%
Wetland	510.70	37.13%
Total Land	1375.57	100.00%

Source: Georgia Department of Natural Resources, 2009

encompasses the third-largest portion of the study area's land (13.62%), though most of this is located within one county, Chatham.

When the 2009 ranges of land cover classes are compared with the scope of area inundated, an overall illustration of the sea level rise impacts emerges. This data is summarized in Table 2.2 and illustrated in Figure 2.2.

Between one-quarter and one-third of land in the region will be inundated (30.45% / 418.92 square miles) The class of land cover that would be affected the most from one-meter of sea level rise is wetland, with 365.53 estimated square miles impacted by inundation. In addition to being the land cover class influenced most significantly by inundation, (87.26% of all inundation would occur where wetlands currently exist), the wetlands of the study area will shrink to over 70% of their original extent. While sand would also become inundated to a significant extent as well (41.75%), its range is significantly less (only 8 square miles circa 2009), and, therefore, makes up a small percentage of the total land inundated (0.80%). Nevertheless, lands classified as sand (including dunes and beaches) are both critical habitats and primary attractions for recreation and tourism, so this loss would be damaging to the coastal ecosystem and tourism.

While forests are not forecast to have a large portion inundated (6.51%), they make up another 9% of

Figure 2.2 - Land Cover in Chatham, Liberty, and McIntosh Counties: Range of Inundation

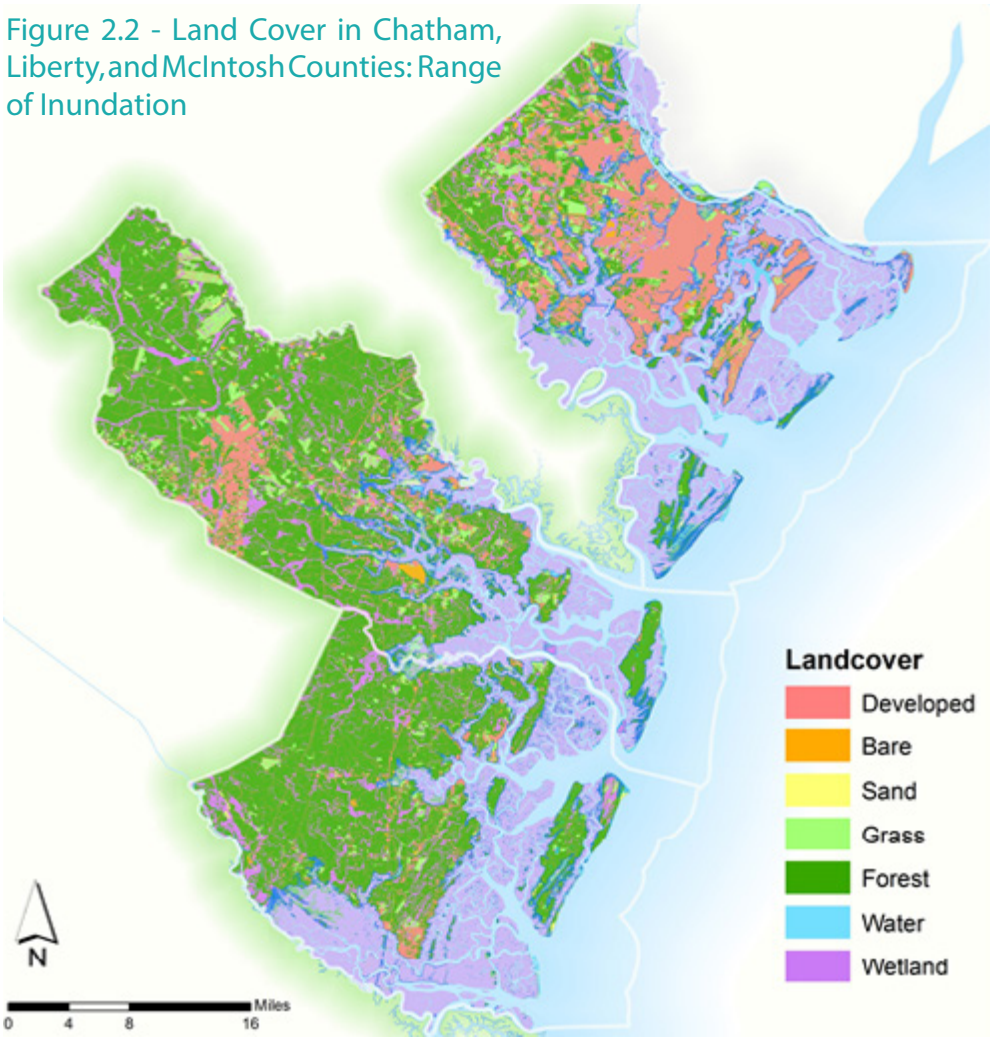


Table 2.3 - Overview of Change in Extent of Land Cover Due to Inundation in Chatham, Liberty, and McIntosh Counties, 2009-2109

	Area (sq. miles)	Area Inundated (sq. miles)	% of Area Inundated	% of Overall Inundation
Bare	12.98	0.95	7.29%	0.23%
Developed	187.39	7.02	3.75%	1.68%
Grass	66.58	3.69	5.55%	0.88%
Forest	589.92	38.39	6.51%	9.16%
Sand	8.00	3.34	41.75%	0.80%
Wetland	510.70	365.53	71.57%	87.26%
Total Land	1375.57	418.92	30.45%	100.00%

Source: Georgia Department of Natural Resources, 2009

the total inundated lands; as a whole, wetlands and forests comprise over 95% of all submerged lands. Developed lands are projected to neither have a large portion of their current extent inundated by one-meter of sea rise (7.29%), nor do they make up a substantial percentage of lands inundated (1.68%), yet exceptional attention must be given to them, as impacts to these lands pose the greatest direct threat to the region's population. Table 2.3 illustrates the area and percent inundation for six land cover categories in our analysis.

Additionally, we investigated the impact of sea level rise on rare and endangered ecosystems and habitats. The threatened ecosystems in the study area were cataloged according to NatureServe's global (G) conservation status ranks (NatureServe, 2012).

In order to better inform conservation efforts, the impact that rare habitats face with the advance of sea levels was also assessed; this is accomplished through an analysis of (G)-Rankings (Table 2.5).

As shown by the description of global conservation status ranks (Table 2.5), G1-G3 range from G1-Critically Imperiled (very high risk of extinction) through G2-Imperiled (high risk of extinction/ elimination) to G3--Vulnerable (moderate risk of extinction/elimination. The final two rankings (G4-

Figure 2.3: Threatened Global Conversation Status-Ranked Habitats: Chatham, Liberty, and McIntosh Counties

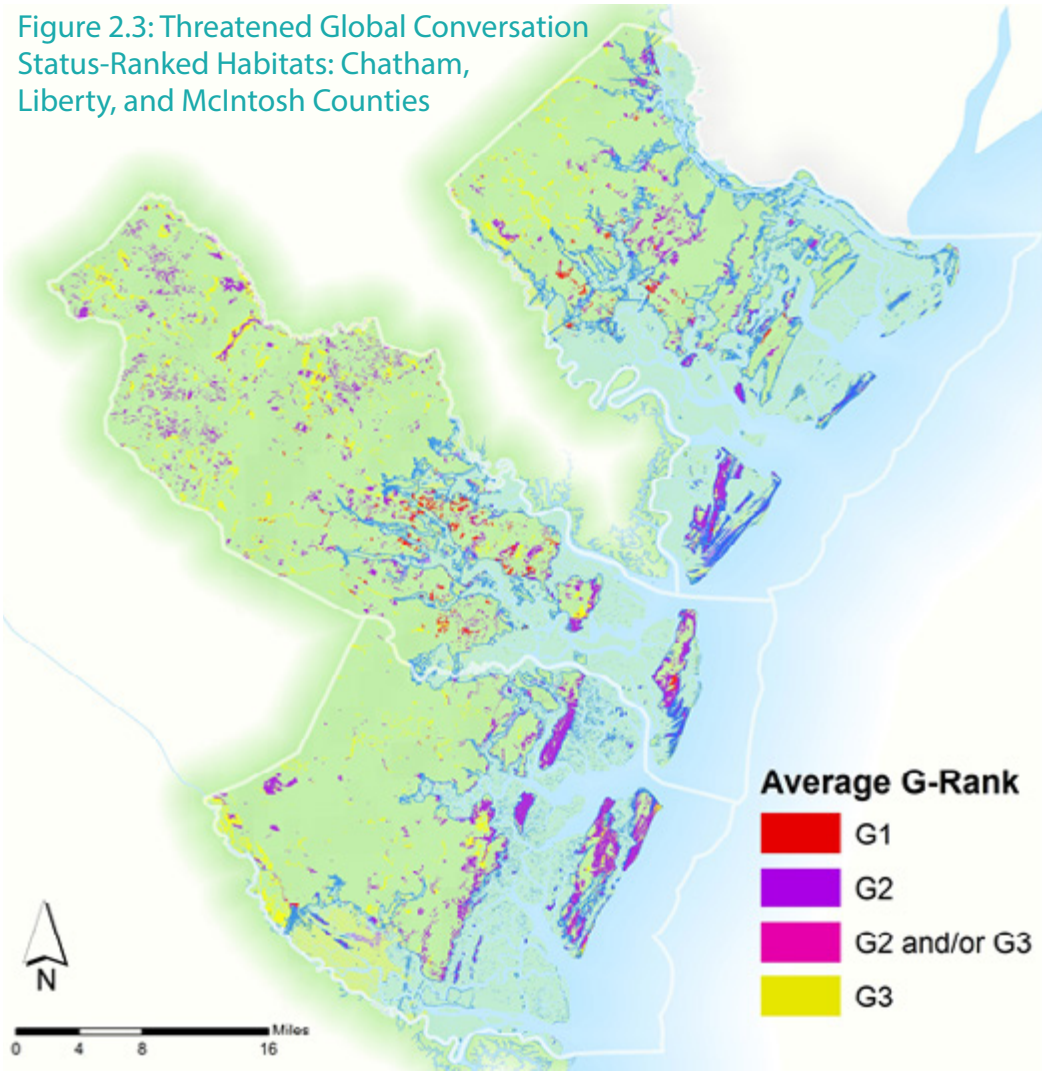


Table 2.4 - Overview of (G)-Rankings –Three Counties

	Area (sq. miles)	% of Total Land Area	2109 Area (sq. miles)	% of 2109 Land Area	Δ % of Total Land Area
Bare	12.98	0.94%	12.03	1.26%	0.31%
Developed	187.39	13.62%	180.37	18.85%	5.23%
Grass	66.58	4.84%	62.89	6.57%	1.73%
Forest	589.92	42.89%	551.53	57.65%	14.77%
Sand	8.00	0.58%	4.66	0.49%	-0.09%
Wetland	510.70	37.13%	145.18	15.18%	-21.95%
Total Land	1375.57	100.00%	956.65	100.00%	0.00%

Source: Georgia Department of Natural Resources, 2009

Apparently Secure and G5-Secure) are of lesser immediate concern. To sufficiently inform future conservation efforts, it is important to first locate both vulnerable and imperiled habitats (G1-G3) and then determine whether they are further threatened due to the projected rise in sea levels. The distribution and extent of these habitats in our study area are illustrated in Figure 2.3.

Table 2.5 - Overview of Global Conversation Status Ranked Habitats in Chatham, Liberty, and McIntosh Counties, 2009

RANK	DEFINITION
G1	**Critically Imperiled:** At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.
G2	**Imperiled:** At high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors.
G3	**Vulnerable:** At moderate risk of extinction or elimination due to a restricted range, relatively few populations, recent and widespread declines, or other factors.
G4	**Apparently Secure:** Uncommon but not rare; some cause for long-term concern due to declines or other factors.
G5	**Secure:** Common; widespread and abundant.

Source: Georgia Department of Natural Resources, 2009

Table 2.6 summarizes the threatened Global Conversation Status ranked habitats for the three counties as a whole. Slightly more than 95% of vulnerable habitats are between G2 (Imperiled) and G3 (Vulnerable) ranks, while G1 (Critically Imperiled) habitats comprise the last 5%. Though G1-ranked habitats make up the smallest portion of the total, they are the most rare and at risk. Therefore, these areas should be given special attention. G2 ecosystems, conversely, comprise almost one-half of threatened habitats and, because they are imperiled, they should be considered a priority over G3 habitats.

The land cover class of each individual (G) habitat was also calculated, with each falling into one of the four naturally occurring land cover classes: 1) forest, 2) grass, 3) sand, and 4) wetland. As Table 2.6 shows, all G1 habitats in the study areas are forests, while G2 and G3 habitats encompasses the entire breadth of natural vegetation. In general, G2 ecosystems are predominantly characterized by tree cover. G2 forests make up the highest percentage of total (G) area (39.42%), with G3 wetlands making up a large share of the remainder (36.11%). What can be gleaned through this stratification of the data is the extent to which G1- and G2- ranked forests are made up by forests, and G3 ecosystems by wetland. The less extensive land cover classes of sand and grass also make up a portion of G2 and G3 places, yet their overall coverage is miniscule. Since the widespread inundation of wetlands has already been projected, it can be expected that G3 habitats will experience most of the impacts due to sea level rise.

As with the land cover analysis, the area of each Global Conversation Status ranked habitat was calculated for all three counties and overlaid with one meter of sea level rise. As Table 2.6 displays, the original extent of (G)-Ranked ecosystems is compared with the area of each that is due to be inundated.

Overall, nearly one-third (54.91 square miles) of all Global Conversation Status ranked Ranked habitats will be impacted by the projected rise in sea level. The majority (70.01%) of this inundation is of G3-ranked habitats, which are expected to lose nearly 50% of their extent. As alluded to previously, a large factor contributing to the loss of G3 ecosystems is due to the fact that they are comprised mostly of

Table 2.6 - Overview of Global Conversation Status Ranked Habitat Inundation in Chatham, Liberty, and McIntosh Counties, 2009

	Area (sq. miles)	% of Total (G) Area
G1	8.10	4.52%
Forest	8.10	4.52%
G2	89.55	49.95%
Forest	70.68	39.42%
Grass	0.45	0.25%
Sand	0.88	0.49%
Wetland	17.54	9.79%
G2/G3	1.34	0.75%
Forest	0.41	0.23%
Grass	0.93	0.52%
G3	80.29	44.78%
Forest	0.01	0.00%
Grass	9.43	5.26%
Sand	6.11	3.41%
Wetland	64.74	36.11%
Total G1-G3	179.28	100.00%

Source: Georgia Department of Natural Resources, 2009

wetland; indeed, wetlands makes up most (63.64%) of the total loss in G-ranked areas. Nearly all (99.98%) of forests ranked as G3 are expected to be inundated. In addition, nearly half (49.33%) of vulnerable sand habitats will be impacted.

The "imperiled habitats" (G2) comprise much of the remainder of this loss (27.53%), which is composed of an inundation of 15.2 square miles (17.01% of the existing area). Most of this consists of forests (19.86%) and wetlands (7.06%), though neither will lose more than one-quarter of their original scope. G2-ranked grasslands, conversely, will be nearly two thirds (64.92%) underwater in this scenario.

While loss attributed to "critically imperiled" (G1) ecosystems is only 1.85% of the G1-G3 total, its reduced scope means that the inundation of slightly more than one square mile (1.07) is 13.28% of its total extent. All of G1-ranked land is considered forestland, the geographic pattern of which likely protects this extremely vulnerable land from some impacts of sea level rise (as compared to wetlands).

Data Limitations

Our biggest limitation for the land cover analysis is the fact that we are using the bathtub model instead of a more sophisticated sea level rise projection model such as the SLAMM data (Sea Level Affecting Marshes Model). In bathtub model, areas of inundation are projected based only on the elevation of the land. The SLAMM data simulates the dominant processes involved in wetland conversions and shoreline modifications and incorporates them into the sea level rise projection (Warren Pinnacle Consulting, Inc. 2012). Because the SLAMM data incorporates an estimation of the real way that marshes and wetlands will respond to sea level rise, it produces a much more accurate projection of inundated areas than the bathtub model. We highly recommend that future analyses of sea level rise on the Georgia coast utilize the SLAMM data.

Land Use

After analyzing the impacts of sea level rise on the natural environment through the broad lens of land cover and habitat data, the next most informative way to investigate impacts is through the analysis of land use.

Data

In our land use analysis we used ArcGIS shapefiles obtained from the Coastal Regional Commission for Liberty and McIntosh Counties and from the Georiga Planning website for Chatham County. Both land use data sets divide the land uses into eight broad categories:agriculture/forestry,commercial,industrial, park/ recreation/ conservation, public/ institutional, residential, transportation/ communication/ utilities, and undeveloped/ vacant. It is important to note that in this data set much of the land that is classified as forest is disturbed by human activity as seen by the agriculture/forestry designation. This is an important distinction from the forest category described in the land cover analysis. However, the land use data set categorizes the majority of the wetland areas as park/ recreation/ conservation, which confirms their status as natural land. A map showing the existing land uses in the study area is shown in Figure 2.4 below and a map showing an overlay of sea level rise inundation is shown in Figure 2.5 below.

Analysis

For the land use data analysis, we overlaid the land use data with the sea level rise data to identify the

percentage of each land use within each census block that will become inundated. For this analysis we used GIS tools to quantify the total acreage of each land use within each census block and to quantify the total inundated acreage of each land use within each census block. We were then able to calculate the inundated percentage of each land use in each census block. The inundated land use percentages were then aggregated to the county level to portray overall trends. The methodology is more completely described in the appendix.

Results

The county level results of this analysis are summarized in Table 2.7 below. The county level results indicate that a high percentage of parks and recreation lands in the three counties will become inundated. Based on the results of the land cover analysis in the previous section and the visual observation that these parks and recreation lands are located adjacent to the coast, we know that these lands are mostly wetlands. Additionally, not all of the land in this category is natural land as some of the forests are actually commercial pine farms. This highlights the importance of integrating multiple datasets when analyzing the impacts of sea level rise. If we had used only land use data we would have thought the study area was projected to lose a significant amount of parks, but what they are really losing is wetlands. A similar problem would have occurred if we had only used the land cover data because it does not capture all impervious paving, transportation/communications/utilities in the land use data.

Chatham County is projected to receive the largest proportional impact in all of the land use categories except for residential and industrial, which will be located in McIntosh and Liberty Counties, respectively. It is important to highlight that even though Chatham County is predicted to lose the largest percentage of developed land from the land cover analysis, the largest percentage of residential land projected to be lost is in McIntosh County and is 19.34%. This loss in residential land is mainly in Darien adjacent to the Darien River as well as along GA-99 and in Crescent, Georgia.

Figure 2.6 below shows the inundation of residential land use. The blue areas of the map show the degree to which the residential land uses in those census blocks will become inundated and the yellow areas of the map show the residential areas that will not become inundated. From this map it is important to note that much of the inundation is not going to

Figure 2.4 - Existing Land Uses

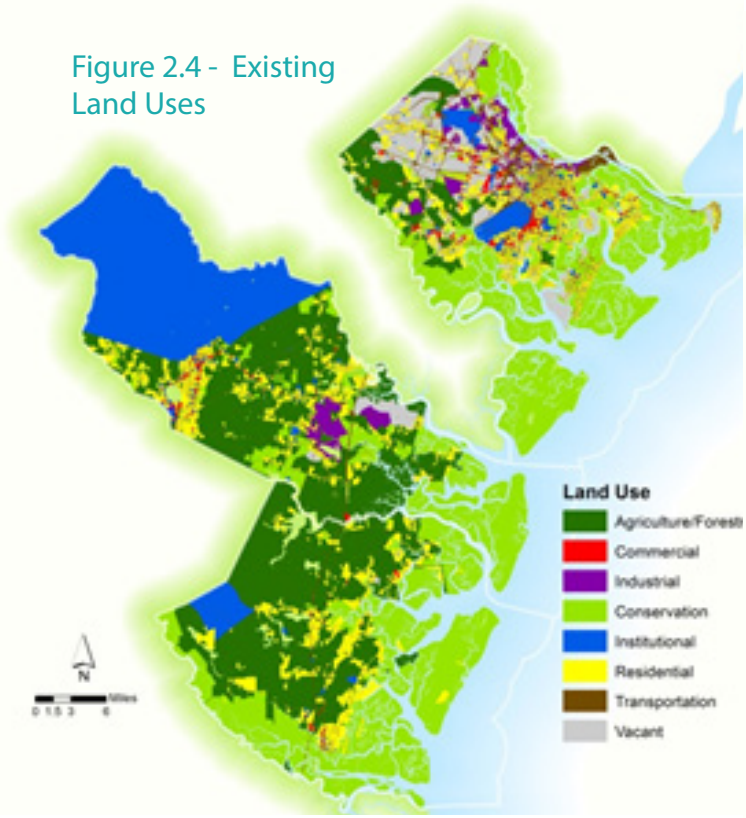


Figure 2.5 - Existing Land Uses and Sea Level Rise

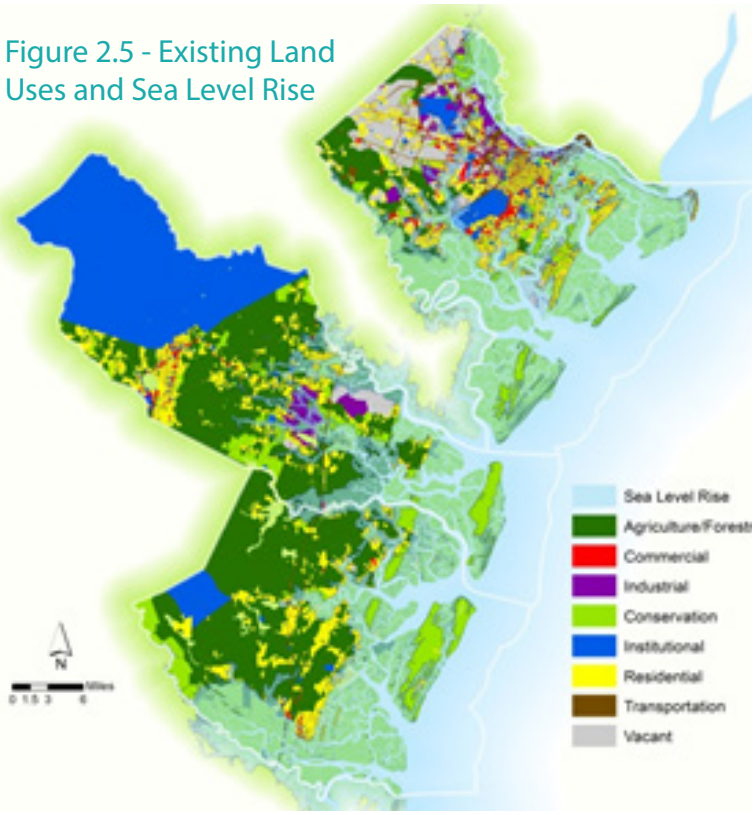


Table 2.7 – Land Use: Total Acreage and Percent Inundation by County

	Chatham		Liberty		McIntosh	
	Total Acreage	% Inundated	Total Acreage	% Inundated	Total Acreage	% Inundated
Agricultural/Forestry	25,824	15.36%	108,169	20.25%	115,938	10.02%
Commercial	5,262	4.20%	1,618	7.23%	570	6.32%
Industrial	8,433	9.34%	7,262	31.95%	23	1.30%
Parks/Recreation/ Conservation	123,000	78.16%	51,292	54.88%	113,326	71.86%
Public/Institutional	13,250	12.19%	121,060	0.11%	9,428	0.06%
Residential	34,571	12.18%	30,479	7.42%	28,471	19.34%
Transportation/Communication /Utilities	23,055	10.99%	5,549	4.09%	4,397	2.68%
Undeveloped/Vacant	47,509	20%	5,038	10%	431	6%
TOTAL	280,904	42.31%	330,467	16.83%	272,584	36.23%

Source: Calculations based on Skidaway Institute, Coastal Regional Commission of Georgia, and Georgia Planning data

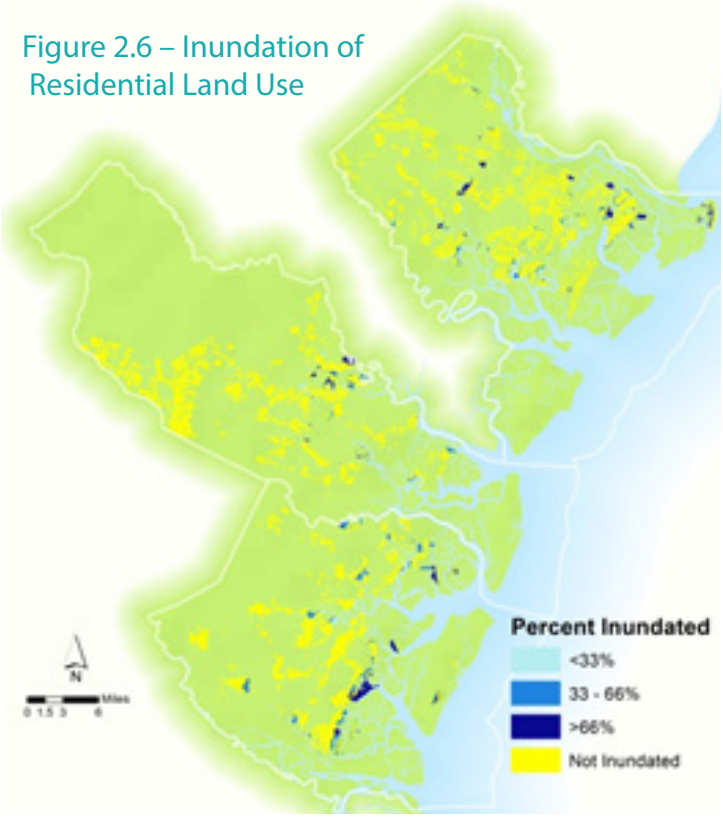
occur in the major populated areas, although certain blocks near the coast will see impacts. The impact of sea level rise on residential buildings will be explored further in a later section of this report. Additional maps separately showing inundation of the other six land use categories can be found in the appendix.

Building Number and Replacement Value Data

HAZUS

Land use and inundation data does not address the potential impact to the physical structures on the

Figure 2.6 – Inundation of Residential Land Use



land. The dataset only indicates the extent to which land that is legally designated for a particular use will be impacted. For example, a rural parcel of residential land of 5 acres may become 50% inundated but the house on the parcel may not be impacted. In order to address this problem, we use HAZUS data to quantify the number and types of buildings that will be impacted by sea level rise. The HAZUS data set developed by FEMA's Mitigation Division by the National Institute of Building Sciences provides information on the number of existing buildings and an estimate of their replacement values. The most recent HAZUS data from year 2000 was used in the analysis of the land use variable as a supplement to the land use data sets and as a tool to look more specifically at buildings. The HAZUS data set divides buildings into seven broad categories: residential, commercial, industrial, agricultural, religious, education, and government. Within each category, the data set provides the number of existing buildings and an estimation of their replacement value. The HAZUS data is available at the census block level for each of the three counties in the study area. A map of the total number of buildings in each census block is shown in Figure 2.7 below and a map of the total building replacement value in each census block is shown in Figure 2.8 below (neither map has been normalized by area).

The California Climate Center's report on the impacts of sea level rise on the California Coast influenced our decision to include both land use and HAZUS data and influenced our methodology. Their analysis involved overlaying inundation maps with census block data and assuming that if 50% of an area is affected, then 50% of its assets are at risk (Heberger 2009). For this analysis, we used a similar approach which is described in more detail below.

Analysis

The goal of the HAZUS data analysis was to quantify the number and type of buildings that will be affected by sea level rise as well as quantify the replacement value associated with those buildings. Additionally, this information can also be used to estimate the potential loss in the tax base in specific areas.

Using the HAZUS data set and the sea level rise data, a GIS analysis was performed to estimate the number of buildings that will be affected by sea level rise and the approximate replacement value of those buildings. The first step in the analysis was to use ArcGIS tools to find the percentage of each

Figure 2.7 – Total Buildings by Census Block

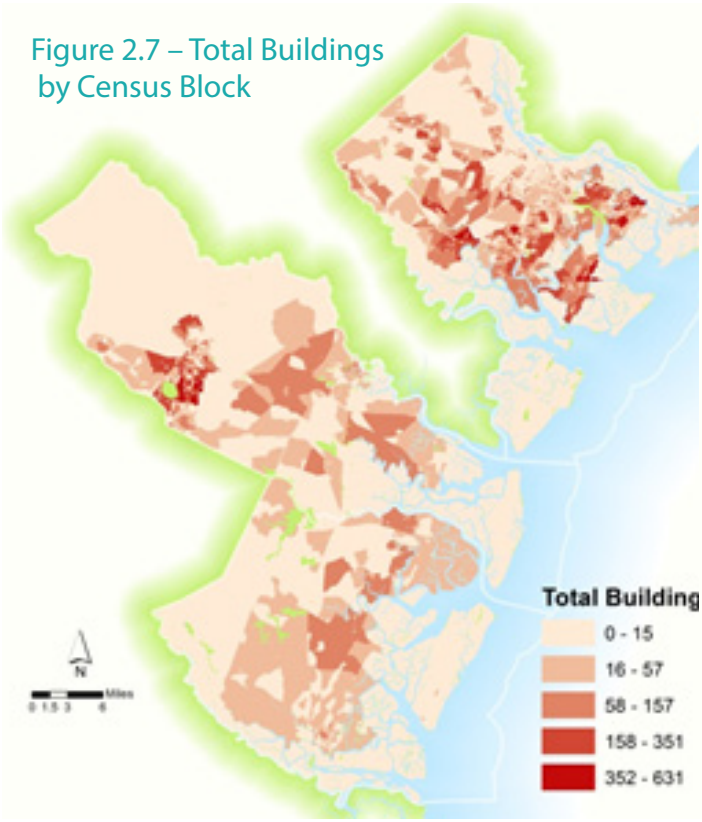
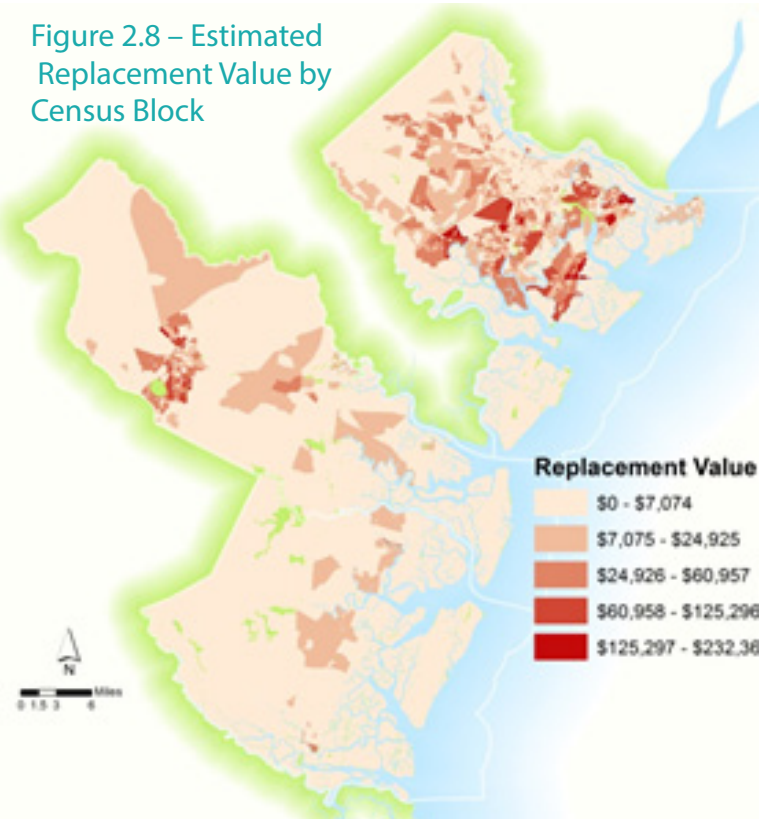


Figure 2.8 – Estimated Replacement Value by Census Block



census block inundated by sea level rise. Next, this percentage for each census block was multiplied by the corresponding HAZUS data for each census block. This step of the analysis assumed that the buildings were evenly distributed across each of the census blocks. The results of this analysis were aggregated to the county level to investigate overall trends. The methodology is more fully described in the appendix.

The census block level analysis of buildings affected by sea level rise was again aggregated up to a higher level – the census block group level. This step was necessary so that the land use variable could be compared with other important variables that did not have data available at as fine a grain as the census block level. A complicating factor in this census block group aggregation was that the census block HAZUS data was only available from year 2000, but the other variables were compiled by the more recent 2010 census block groups. The year 2000 census blocks do not fit neatly inside the year 2010 census block groups because there was a significant change in the number and shape of the census blocks between the two time periods. To overcome this issue, a GIS tool was used to assign the year 2000 census blocks to the 2010 census block group containing their centroid and then aggregate the 2000 census block data to the 2010 block group level. The methodology is described in the appendix.

It is important to point out the limitations associated with the HAZUS data and with the methods used to process the data. There are inherent limitations in the replacement value portion of the HAZUS data that come from the way the data is produced. Replacement value is based on national-average construction costs. The difference between the replacement value and market value can be large due to the added values associated with land value, neighborhood, and several other factors (Heberger 2009). For these reasons, it is important to note that the HAZUS derivative replacement value often underestimates the actual costs associated with replacing those buildings.

Another important limitation associated with the processing of the HAZUS data is that we assumed in our analysis that the buildings were evenly distributed throughout census blocks. This is a substantial assumption and significantly increases the variability in our results for the number of inundated buildings and their associated replacement values. In a later section entitled "Suggestions for Further

Figure 2.9 - Inundated Buildings Total

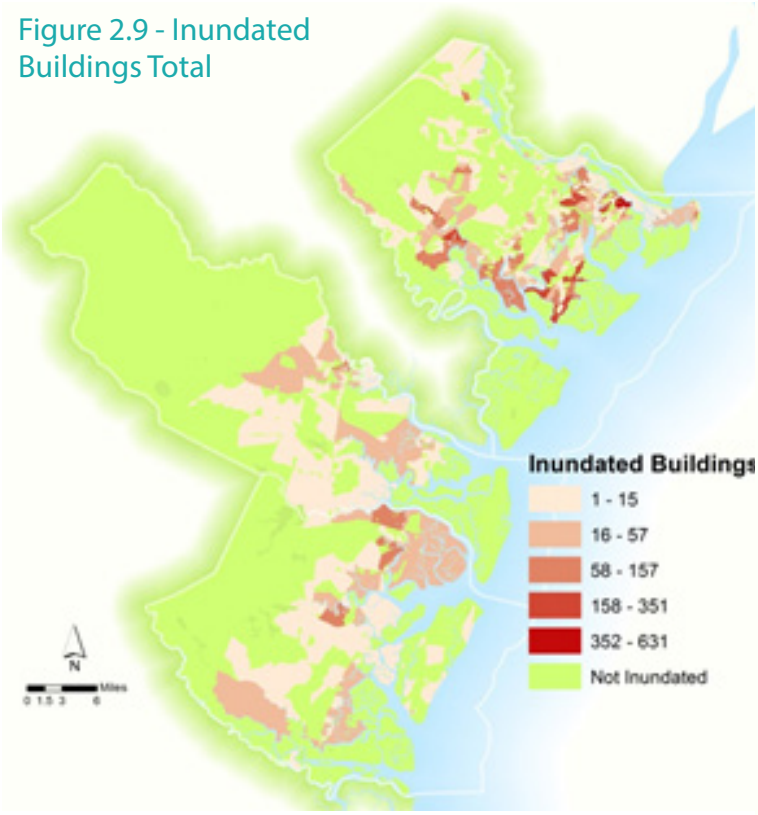


Figure 2.10 - Inundated Buildings' Replacement Value (Note: Building replacement values are X $1000)

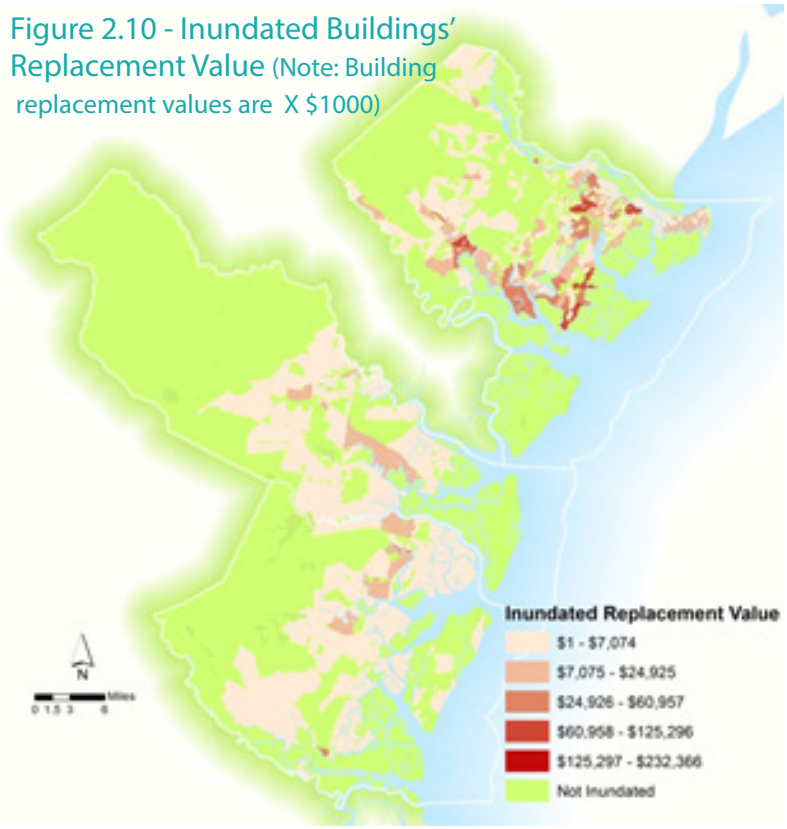


Table 2.8 – HAZUS: Number of Inundated Buildings and Replacement Value (Note: Replacement values are X1000)

	Chatham		Liberty		McIntosh		Three County Study Region	
	Inundated Buildings	Replacement Value	Inundated Buildings	Replacement Value	Inundated Buildings	Replacement Value	Inundated Buildings	Replacement Value
Residential	8,348	$2,032,065	808	$111,793	1,181	$134,537	10,337	$146,055
Commercial	419	$380,764	13	$13,568	39	$53,809	471	$54,319
Industrial	117	$81,171	31	$18,198	12	$7,352	160	$7,524
Agricultural	26	$8,038	3	$697	3	$902	32	$937
Religion	40	$39,118	2	$1,670	5	$10,751	47	$10,803
Government	7	$6,708	1	$1,172	3	$1,473	11	$1,487
Education	11	$21,739	1	$166	0	$0	12	$12
TOTAL	8,968	$2,569,603	859	$147,264	1,243	$208,824	11,070	$221,137

Source: Calculations based on Skidaway Institute and 2000 HAZUS data

Land Use Analysis" we suggest a method to improve the results by combining the land use data and the HAZUS data to avoid assuming an even distribution of buildings throughout census blocks.

Results

The results of the analysis of the HAZUS data are shown in the maps in Figure 2.9 and Figure 2.10 on page 20. In these maps, the green portions of the map represent the census blocks that are projected to not have any inundated buildings. The red graduated colors indicate the degree to which building inundation will occur and the estimated replacement value of those buildings.

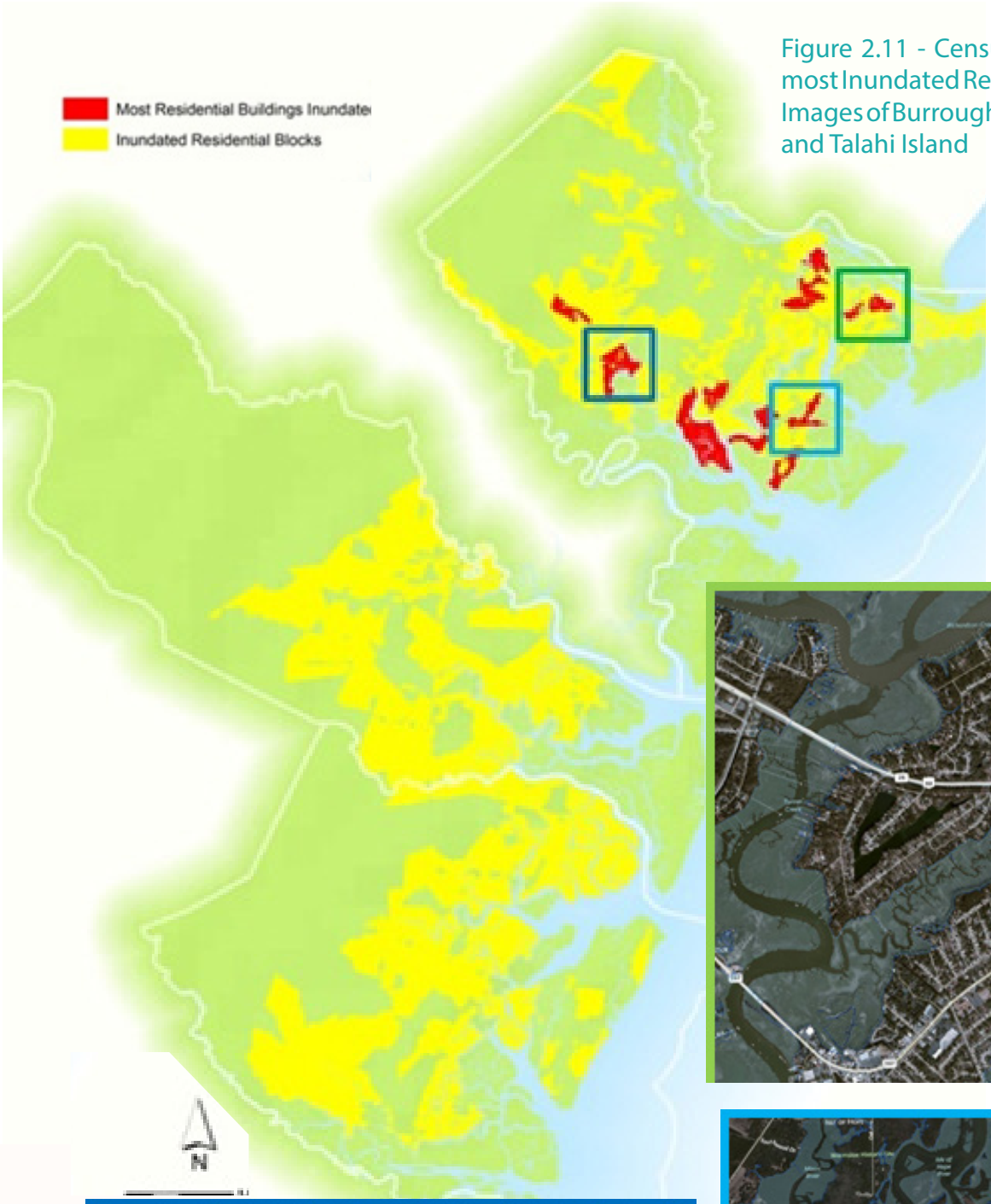
The data used to make the above two maps is shown in Table 2.8 and is summarized at the county level. The percentage of the total buildings and replacement values that these inundated buildings represent are shown in Table 2.9 below. From county level data, it is evident that Chatham County will experience a much greater level of building loss to inundation than the other two counties as is to be expected due to the highly urbanized nature of this county. This data also confirms the finding of the land use data analysis that McIntosh County will experience the greatest percentage of inundation of residential buildings at 19%. McIntosh County will also experience the greatest percentage loss of commercial, industrial, agriculture, religious, and government buildings as compared with the other two counties. This is important because although McIntosh County is the least populated and developed county of the three,

Table 2.9 – Percentage of Inundated Buildings and Replacement Value (Note: Replacement values are X $1000)

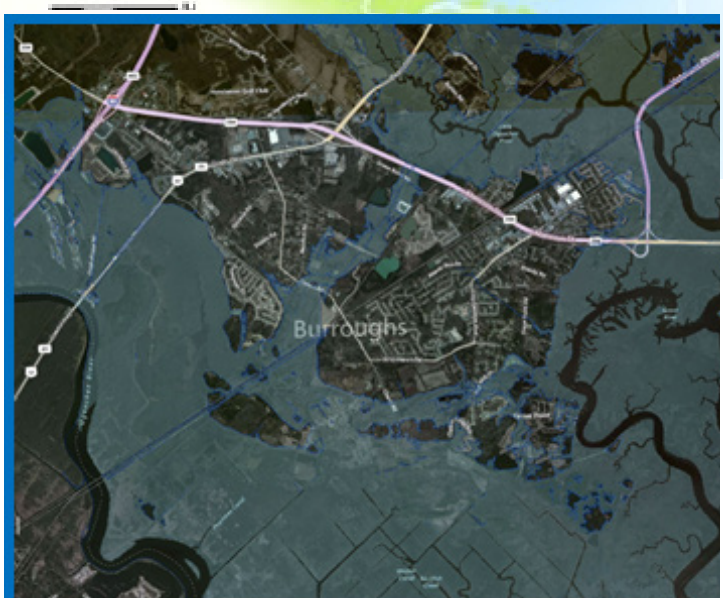
	Chatham		Liberty		McIntosh		Three County Study Region	
	Inundated Buildings	Replacement Value	Inundated Buildings	Replacement Value	Inundated Buildings	Replacement Value	Inundated Buildings	Replacement Value
Residential	9.7%	11.7%	4.0%	3.1%	18.8%	20.9%	9.2%	10.5%
Commercial	7.1%	6.1%	1.7%	2.2%	26.9%	37.8%	6.9%	6.4%
Industrial	8.2%	5.8%	17.6%	10.8%	37.5%	45.7%	9.7%	6.7%
Agricultural	10.9%	13.5%	8.6%	8.2%	37.5%	46.5%	11.3%	13.7%
Religion	5.4%	4.2%	2.2%	2.0%	23.8%	47.6%	5.5%	5.0%
Government	4.8%	3.4%	2.1%	2.2%	16.7%	6.9%	5.2%	3.5%
Education	6.0%	4.2%	2.6%	0.3%	0.0%	0.0%	5.2%	3.8%
TOTAL	9.5%	9.6%	4.0%	3.2%	19.1%	24.4%	9.0%	9.1%

Source: Calculations based on Skidaway Institute and 2000 HAZUS data

Figure 2.11 - Census Blocks with the most Inundated Residential Buildings, Images of Burroughs, Skidaway Island, and Talahi Island



Images Source: Bing Maps



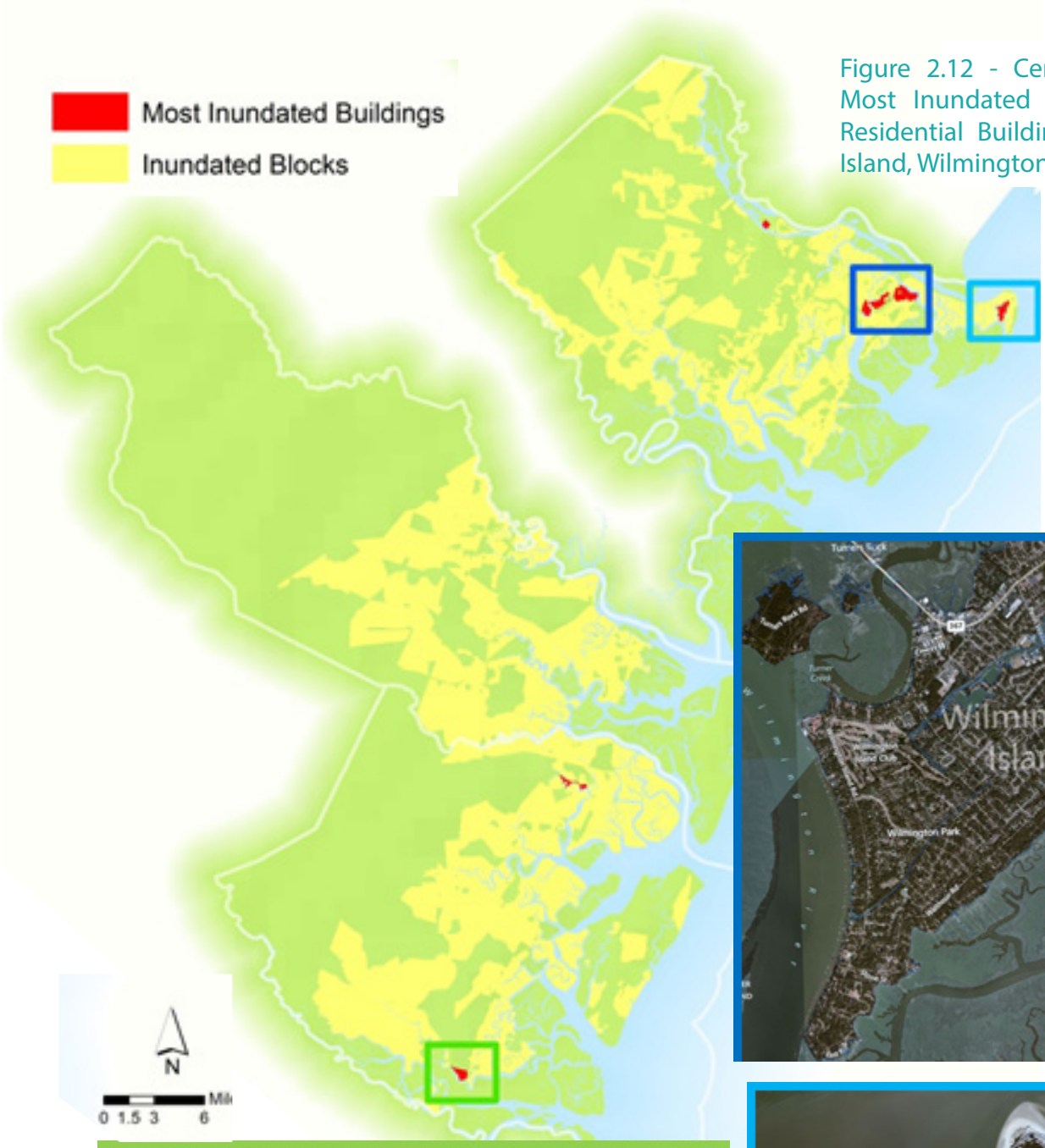


Figure 2.12 - Census Blocks with the Most Inundated Buildings other than Residential Buildings, Images of Tybee Island, Wilmington Island, and Darien

Source: Bing Maps

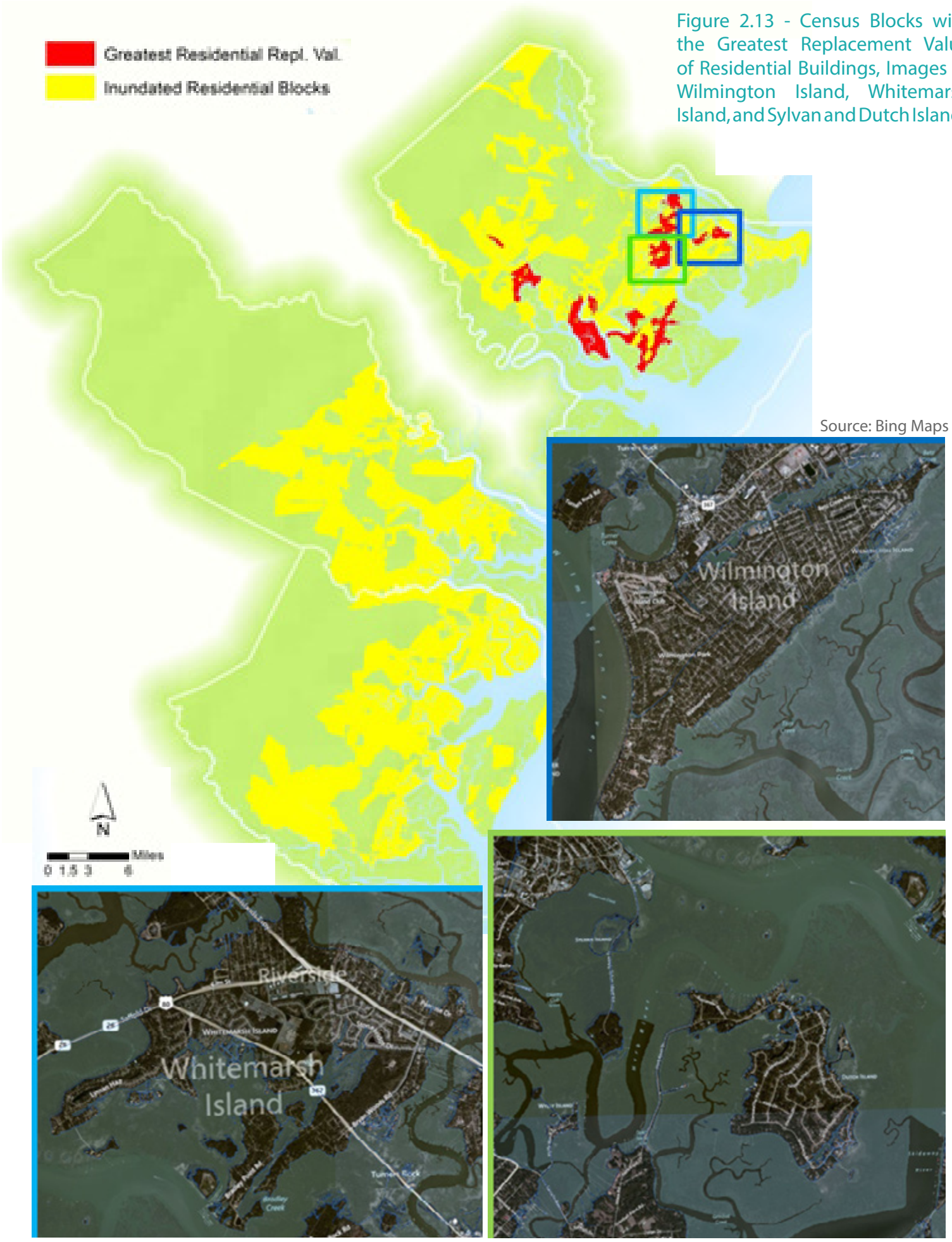


Figure 2.13 - Census Blocks with the Greatest Replacement Value of Residential Buildings, Images of Wilmington Island, Whitemarsh Island, and Sylvan and Dutch Islands

Source: Bing Maps

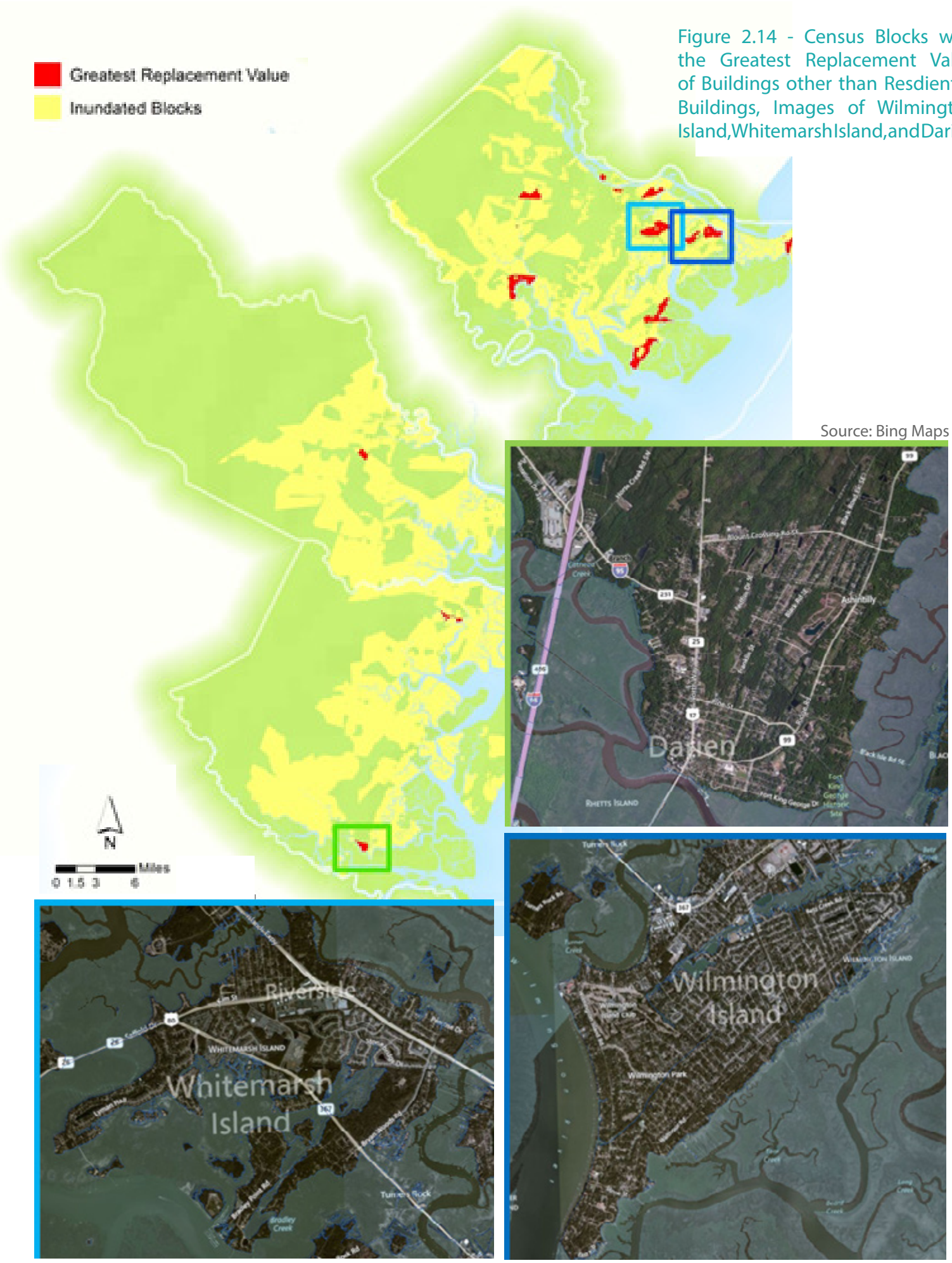


Figure 2.14 - Census Blocks with the Greatest Replacement Value of Buildings other than Resdiential Buildings, Images of Wilmington Island,WhitemarshIsland,andDarien

Source: Bing Maps

it is projected to lose a greater proportion of its development compared with the other two counties. Overall, McIntosh County is projected to lose 19% of its total buildings.

The HAZUS data was also analyzed to investigate the census blocks and areas with the greatest number of residential buildings affected by sea level rise, the greatest number of all other buildings affected by sea level rise, the largest replacement value of residential buildings affected by sea level rise, and the largest replacement value of all other buildings affected by sea level rise. The results are shown in Figure 2.11 – Figure 2.14 with images from Bing Maps showing the inundation of specific areas of impact. The areas with the greatest number of inundated residential buildings are all in Chatham County with some of the most inundated residential buildings located in Burroughs, Skidaway Island, and Talahi Island. The areas with the most inundated buildings other than residential buildings are located in parts of Chatham County and McIntosh County and include areas such as Tybee Island, Wilmington Island, and Darien. The areas with the most expensive inundated residential buildings are all located in Chatham County and are many of the same locations with the greatest overall inundated residential buildings. Some of the areas with the most expensive inundated residential buildings include Wilmington Island, Whitemarsh Island, and Sylvan and Dutch Islands. The areas with the greatest replacement value of inundated buildings other than residential buildings include many areas in Chatham County as well as a few areas in Liberty and McIntosh County with some of the affected areas including Wilmington Island and Whitemarsh Island in Chatham County and Darien in McIntosh County.

Suggestions for Further Land Use Analysis

Combining the Two Data Sources

We suggest that an additional analysis of the land use variable be performed that combines a land use data set with the HAZUS data set in order to refine and improve the estimation of the number of buildings that will be inundated by sea level rise. For example, instead of assuming that all residential buildings are evenly distributed throughout an entire census block as we did in our analysis, we suggest using a land use data set to gain a more accurate understanding of where the residential buildings are located within each census block. This will allow a better estimate to be made of how many of those residential buildings will actually be inundated by sea level rise.

Combined Analysis

We were not able to conduct this combined analysis using either of the land use data sets that we had available. We found that neither of our land use data sets matched up well with the HAZUS data set. The data sets do not classify land uses in a consistent manner and there is a discrepancy between the locations where the two data sets display various land uses. In order to overcome this issue we recommend that either a new land use data source be obtained that is more consistent with the land uses presented in the 2000 HAZUS data set or a new updated HAZUS data set be obtained that aligns better with the land use data set. The methodology to accomplish this combined analysis is described in the appendix.

Additional Analyses

Additional analyses of the land use and HAZUS data were conducted at the city level for Savannah and Tybee Island in Chatham County and for Darien in McIntosh County. For each city, the same land use data sets described in the overall land use analysis section were clipped in ArcGIS to the municipal boundary of the city and a land use analysis similar to the overall land use analysis was performed. The resulting land use maps show the existing land uses with the city limits and the locations within the city that are projected to become inundated by sea level rise. Additionally, the same HAZUS data sets described in the overall HAZUS data analysis section were clipped in ArcGIS to the municipal boundary of each city and a HAZUS data analysis similar to the overall HAZUS data analysis was performed. The resulting HAZUS data maps show the inundated buildings within the city limits at the census block level and the associated replacement values of the those buildings.

Savannah, Chatham County

Figure 2.15 and Figure 2.16 below show that the majority of the inundation within the city limits of Savannah is not projected to occur within the

historic district. The inundation that is projected to occur within the historic district is discussed in a subsequent section of this report. The results of the Savannah land use analysis are summarized in Table 2.10. Approximately one-third of the land area within the city limits of Savannah is projected to become inundated with a vast majority of the land being parks/ recreation/ conservation lands. Relatively few agricultural/ forestry, commercial, industrial, public/ institutional, residential, and transportation/ communication/ utilities areas will be affected as approximately ten percent or less of each of those land use areas are projected to become inundated.

Figure 2.17 and Figure 2.18 show that a significant portion of the City of Savannah is not projected to be affected by a one meter rise in sea level. The results of the Savannah HAZUS data analysis are summarized in Table 2.11 below. The results of the HAZUS data analysis indicate that a small percentage (about 3%) of the existing buildings within the city limits of Savannah are projected to become inundated by sea-level rise. However, 3% of the buildings in Savannah is equivalent to about 2,000 buildings, which is still significant and accounts for about 20% of the total inundated buildings in the study area. The results also show that these inundated buildings have approximately the average replacement value for the area as the inundated replacement value is also about 3% of the total replacement value.

Table 2.10 - Land Use: Total Acreage and Percent Inundation in Savannah

	Total Acreage	% Inundated
Agricultural/Forestry	17,522	11.19%
Commercial	3654	2.74%
Industrial	4818	10.63%
Parks/Recreation/ Conservation	37,617	83.95%
Public/Institutional	11,634	10.84%
Residential	14,511	10.09%
Transportation/ Communication/ Utilities	11,231	7.12%
Undeveloped/Vacant	16,736	14%
TOTAL	117,723	34.04%

Savannah Historic District

Figure 2.15 - Existing Land Uses in Savannah

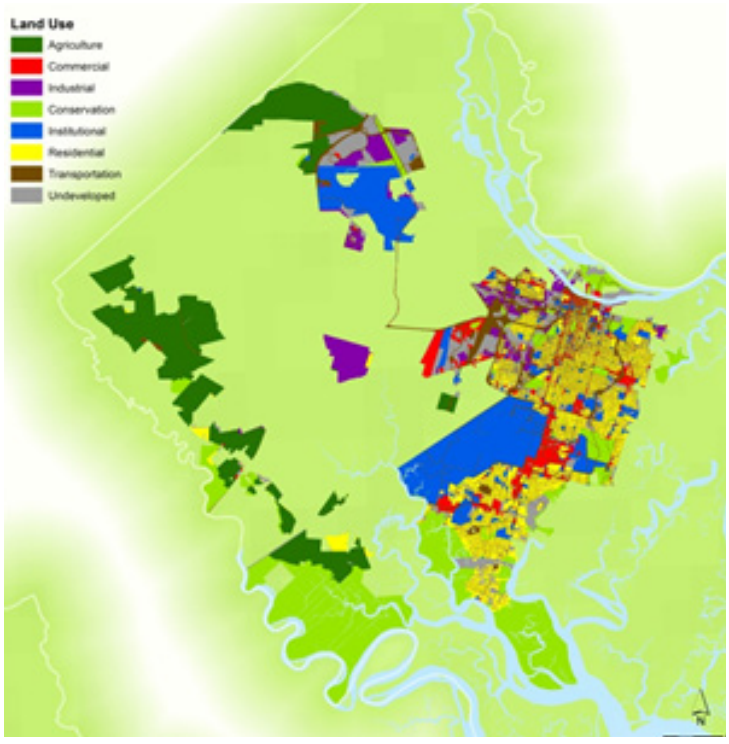
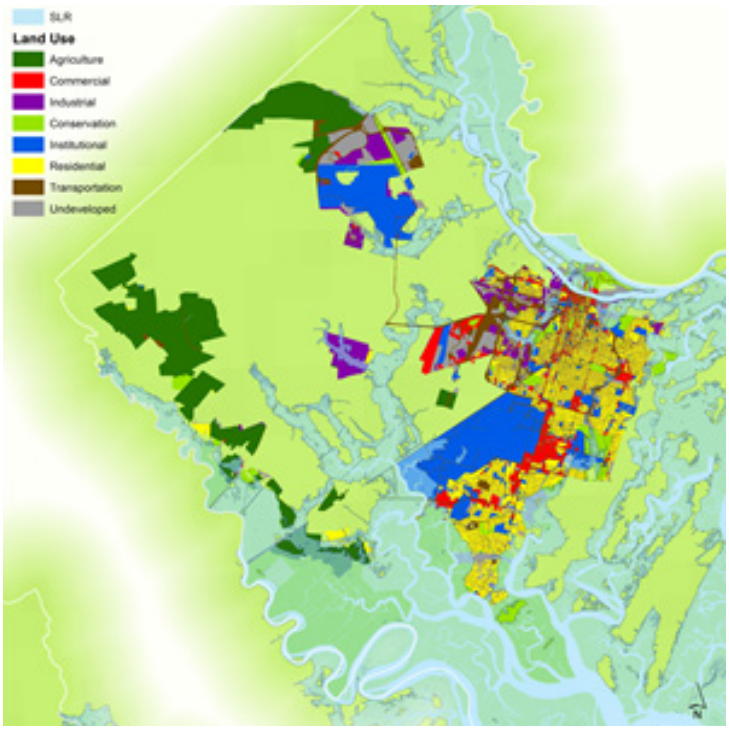


Figure 2.16 - Existing Land Uses in Savannah and Sea Level Rise



Source: Calculations based on Skidaway Institute, Coastal Regional Commision of Georgia, and Georgia Planning data

Table 2.11- HAZUS: Number of Inundated Buildings and their Replacement Value in Savannah (Note: Replacement values are X $1000)

	Total Buildings	Inundated Buildings	% Inundated	Total Building Replacement Value	Inundated Building Replacement Value	% Inundated Value
Residential	50975	1976	3.88%	$9,586,948	$424,111	4.42%
Commercial	4087	135	3.30%	$4,654,020	$144,768	3.11%
Industrial	884	31	3.51%	$890,213	$33,056	3.71%
Agricultural	127	5	3.94%	$31,366	$2,060	6.57%
Religion	565	15	2.65%	$723,002	$17,815	2.46%
Government	114	2	1.75%	$165,498	$2,390	1.44%
Education	130	4	3.08%	$402,493	$8,459	2.10%
TOTAL	56882	2168	3.81%	$16,453,540	$632,659	3.85%

Source: Calculations based on Skidaway Institute and 2000 HAZUS data

As shown in Figure 2.19 below, the majority of the historic section of the City of Savannah is not projected to become inundated. However, as shown in Figure 2.20 below, the commercial district along River Street that is directly adjacent to the Savannah River is projected to experience a significant level of inundation. The inundation of this area has the potential to have substantial impacts on the economy of the area as this district is mainly composed of retail stores and restaurants that are frequented by both residents and tourists of Savannah. Additionally, as shown in Figure 2.21

Figure 2.17- Total Number of Buildings in Savannah by Census Block (not normalized by area)

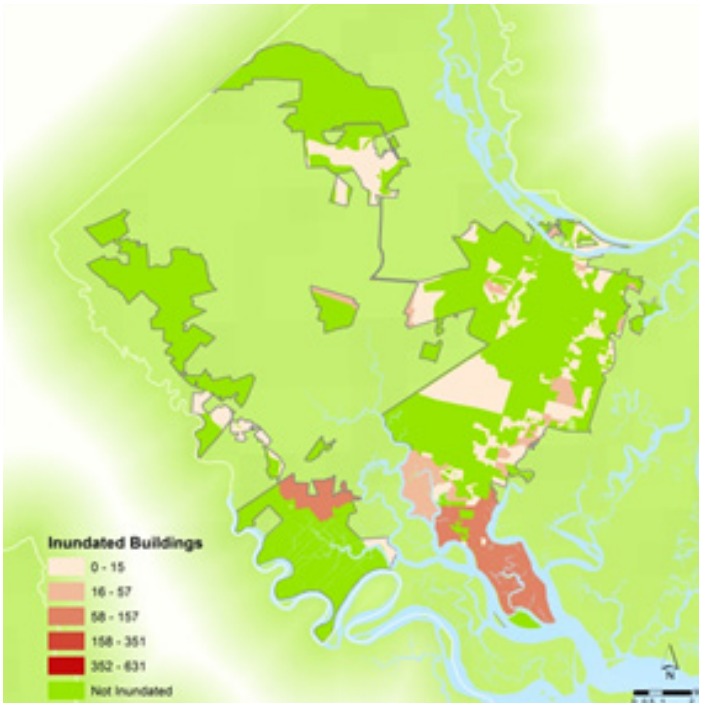
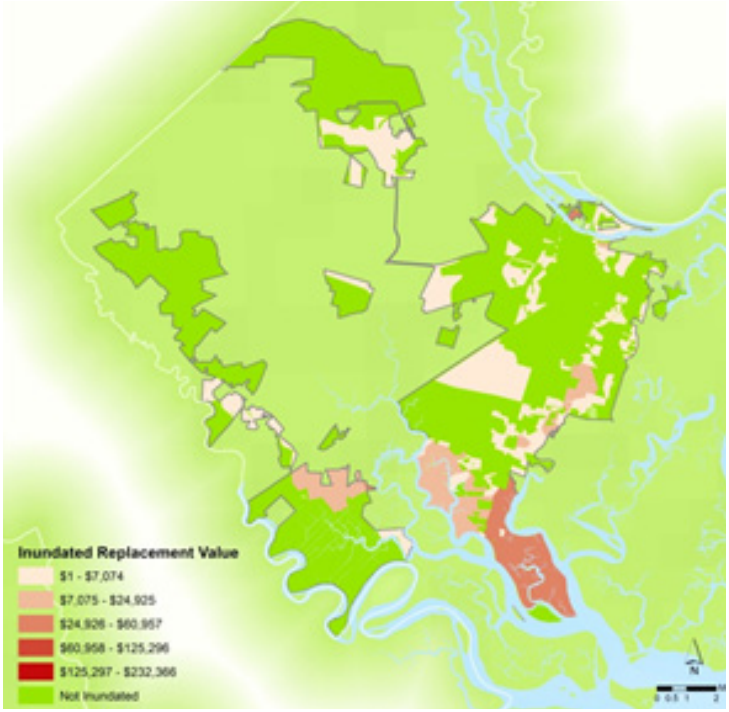


Figure 2.18 - Total Number of Buildings' Estimated Replacement Value in Savannah by Census Block (not normalized by area)



below, the area directly to the east of the Savannah historic district is projected to experience extensive inundation as this area is of significantly lower elevation than the area within the historic district boundaries. From this analysis we can see that portions of the Savannah Marriott Riverfront are projected to experience inundation and that the redevelopment area adjacent to the hotel is not projected to become inundated, but could become isolated due to projected inundation on all sides of the area.

Tybee Island, Chatham County

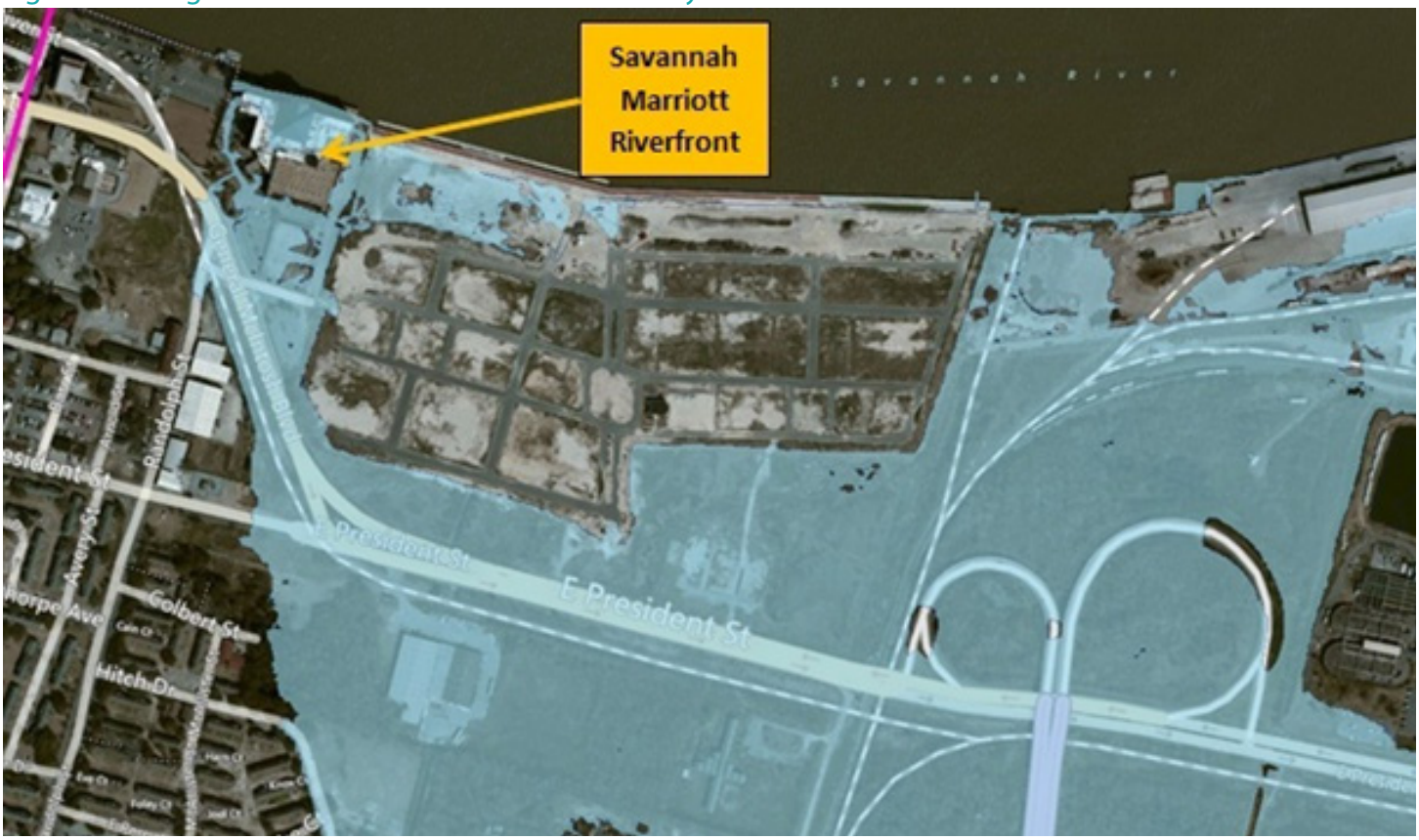
From Figure 2.22 and Figure 2.23 it is clear that a majority of the land on Tybee Island is projected to become inundated within the next 100 years. The results of the Tybee Island land use analysis are summarized in Table 2.12. These results show that almost three-quarters of the land area on Tybee Island is projected to become inundated. A significant portion of this inundated land area is parks/recreation/ conservation lands and undeveloped/ vacant lands at 85% and 81% inundation of their respective land areas. However there are also substantial impacts on the residential, transportation/ communication/ utilities, and commercial land uses at 50%, 48%, and 30% inundation of their respective land areas.

Figure 2.24 and Figure 2.25 show that a significant amount of Tybee Island is projected to be affected by a one meter rise in sea level. The results of the Tybee Island HAZUS data analysis are summarized in Table 2.13. The results of the HAZUS data analysis indicate

Figure 2.19-The pink outline shows the limits of the Savannah historic district overlaid on a hybrid aerial map. The green and orange boxes outline two areas projected to experience significant inundation, which are described in more detail in Figures 2.20 and 2.21.

Figure 2.20- Inundation of the River Street district

Figure 2.21- Significant inundation of the area directly east of the historic district.



that about 40% of the buildings on Tybee Island are projected to become inundated as much of the major commercial and residential areas on the island are within the projected inundated area. It is important to keep in mind that there are significant limitations to the HAZUS data analysis due to the assumption that the buildings are evenly distributed throughout the census blocks that they are located in. Additionally, it is important to note that the total replacement value of the 1,019 residential buildings is only $572 million, which highlights the fact that the HAZUS data does not represent the market value of buildings and their land lots.

Darien, McIntosh County

Figure 2.26 and Figure 2.27 indicate that over one-quarter (29.09%) of the land within the city limits of Darien is projected to be affected by sea level rise. The results of the Darien land use analysis are summarized in Table 2.14. These results indicate that about 30% of the land within the city limits of Darien is projected to become inundated by sea level rise. A significant amount of the inundated land will be parks/ recreation/ conservation as 87.63% of that land use will become inundated. Most of this is wetlands. The results also indicate that there will still be about a 20% inundation of residential land use primarily adjacent to the Darien River.

Table 2.12 - Land Use: Total Acreage and Percent Inundation in Tybee Island

	Total Acreage	% Inundated
Agricultural/ Forestry	0	N/A
Commercial	67.04	30.34%
Industrial	0.90	23.33%
Parks/ Recreation/ Conservation	1,748	85.61%
Public/ Institutional	28.83	1.32%
Residential	659	50.30%
Transportation/ Communication/ Utilities	322	48.38%
Undeveloped/ Vacant	595	81.21%
TOTAL	3,420	72.73%

Figure 2.22 - Existing Land Uses in Tybee Island

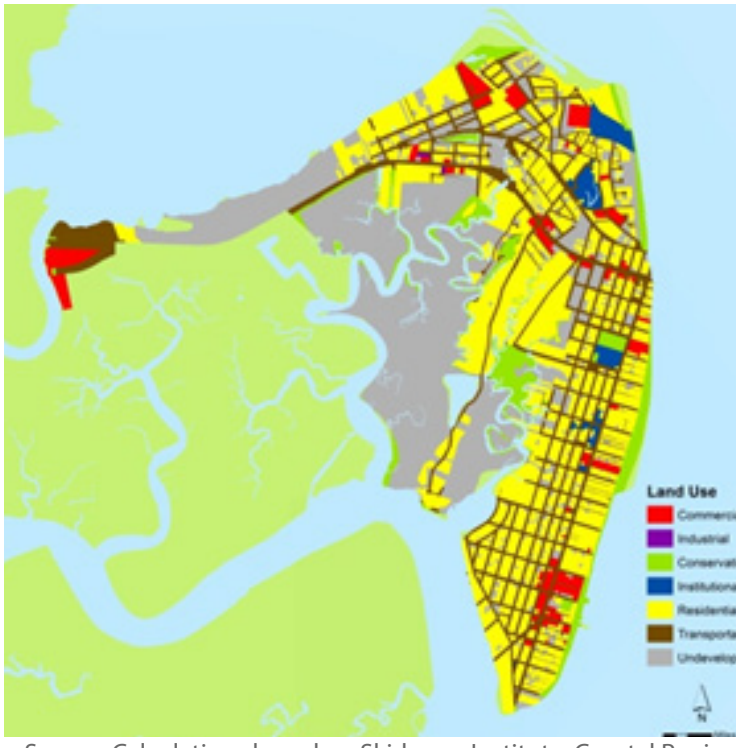
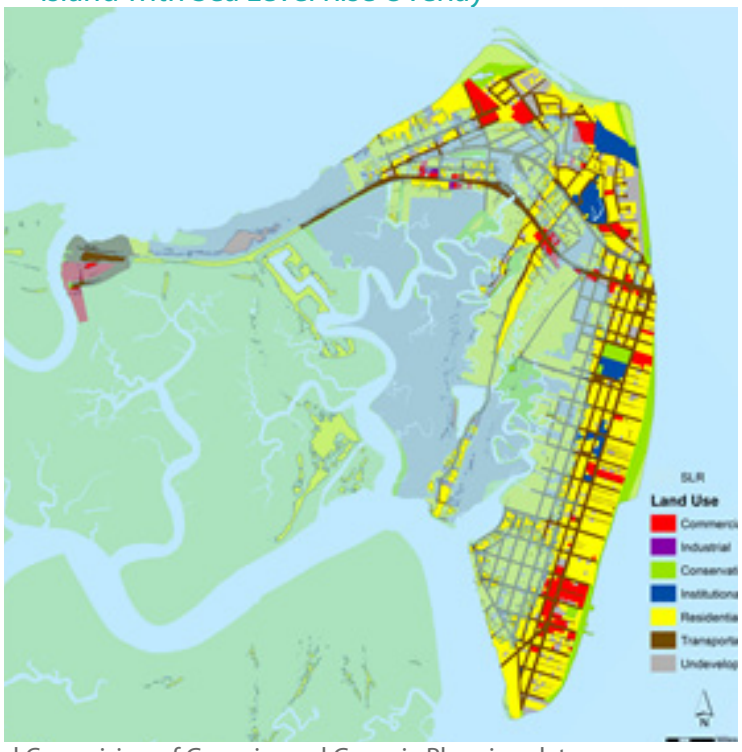


Figure 2.23 - Existing Land Uses in Tybee Island with Sea Level Rise Overlay



Source: Calculations based on Skidaway Institute, Coastal Regional Commision of Georgia, and Georgia Planning data

Table 2.13- HAZUS: Number of Inundated Buildings and their Replacement Value in Tybee Island
(Note: Replacement values are X1000)

	Total Buildings	Inundated Buildings	% Inundated	Total Building Replacement Value	Inundated Building Replacement Value	% Inundated Value
Residential	2,592	1,019	39.3%	$572,027	$217,979	38.11%
Commercial	113	46	40.6%	$75,985	$29,912	39.37%
Industrial	20	11	52.5%	$5,041	$2,902	57.57%
Agricultural	4	3	72.5%	$730	$554	75.89%
Religion	13	6	45.4%	$10,636	$3,925	36.90%
Government	3	2	80.0%	$846	$714	84.40%
Education	4	2	42.5%	$13,373	$8,731	65.29%
TOTAL	2,749	1,088	39.6%	$678,638	$264,717	39.01%

Source: Calculations based on Skidaway Institute and 2000 HAZUS data

Figure 2.28 and Figure 2.29 show that a significant amount of Darien is not projected to be affected by a one meter rise in sea level. The results of the Darien HAZUS data analysis are summarized in Table 2.15 below. The results of the HAZUS data analysis indicate that less than 10% of the buildings within the city limits of Darien are projected to be affected by sea

Figure 2.24- Total Number of Buildings in Tybee Island by Census Block (not normalized by area)

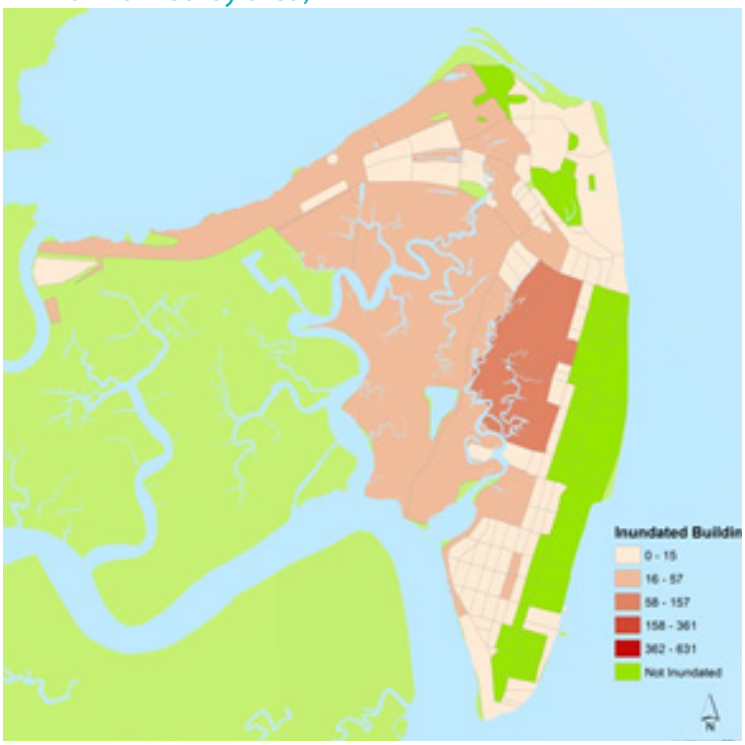


Figure 2.25-Total Number of Buildings' Estimated Replacement Value in Tybee Island by Census Block (not normalized by area)

level rise. Over 1,000 residential buildings in McIntosh County are projected to become inundated but only 75 residential buildings within Darien are projected to be impacted, which also reflects that the majority of inundated residential buildings in McIntosh County are located outside of Darien. The results of the replacement value analysis indicate that the impacted buildings within Darien are, on average, of significantly higher value than the buildings that are not projected to be impacted. This is indicated by the fact that the inundated replacement value is about 21% of the total replacement value while the inundated buildings are only about 7% of the total buildings. See Appendix III for Data Source and Methodology.

Physical Variables

This next section discusses the final three physical variables we considered in our vulnerability impact assessment. These variables are also included in Table 2.1.

Transportation

After exploring the potential impacts of sea level rise from the broad perspectives of land cover and land use, we investigated the transportation systems in the study area. Our examination of the transportation system networks within the three counties was essential for further understanding the overall impacts of the projected one-meter rise in sea level. The transportation systems within the study area provide the means by which coastal Georgia residents can connect with other locations,

Table 2.14- Land Use: Total Acreage and Percent Inundation in Darien

	Total Acreage	% Inundated
Agricultural/ Forestry	61.62	0.49%
Commercial	79.17	6.43%
Industrial	5.29	0.00%
Parks/ Recreation/ Conservation	313.15	87.63%
Public/ Institutional	45.83	0.00%
Residential	871.60	20.37%
Transportation/ Communication/ Utilities	221.95	0.50%
Undeveloped/ Vacant	128.53	4%
TOTAL	1,727	29.09%

Figure 2.26- Existing Land Uses in Darien

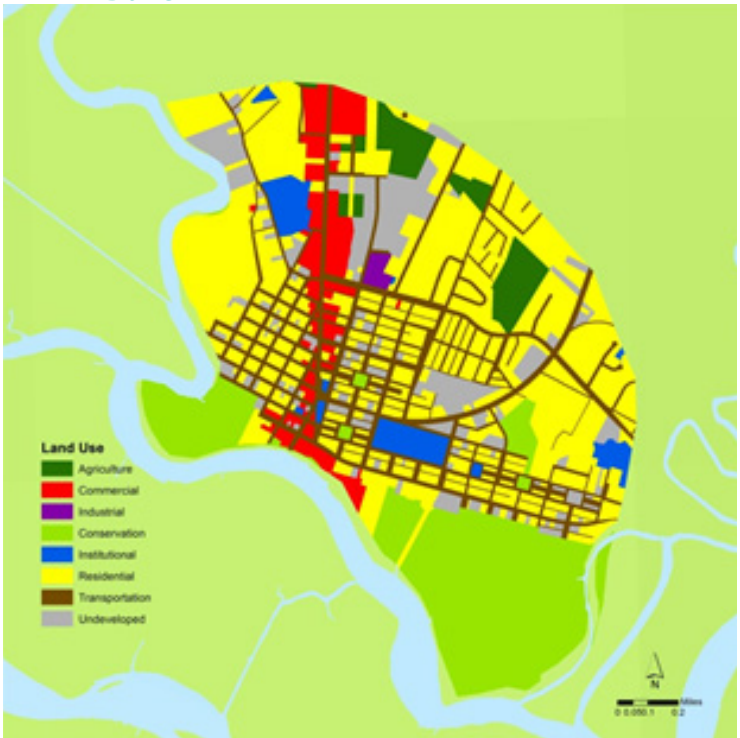
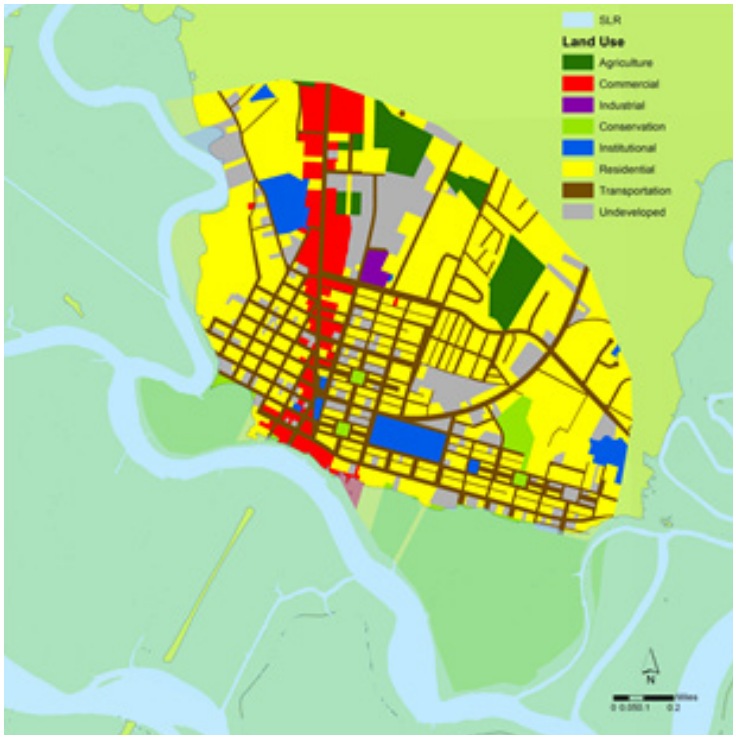


Figure 2.27- Existing Land Uses in Darien and Sea Level Rise



Source: Calculations based on Skidaway Institute, Coastal Regional Commision of Georgia, and Georgia Planning data

Table 2.15 - HAZUS: Number of Inundated Buildings and Replacement Value in Darien
(Note: Replacement Values are X $1000)

	Total Buildings	Inundated Buildings	% Inundated	Total Building Replacement Value	Inundated Building Replacement Value	% Inundated Value
Residential	1,141	75	6.57%	$101,599	$10,003	9.85%
Commercial	55	4	7.09%	$65,190	$21,448	32.90%
Industrial	12	4	32.42%	$7,508	$2,983	39.73%
Agricultural	4	1	35.00%	$1,032	$408	39.53%
Religion	8	2	21.25%	$10,502	$5,253	50.02%
Government	8	2	23.75%	$5,578	$906	16.24%
Education	4	0	0.00%	$4,342	$0	0.00%
TOTAL	1,232	88	7.13%	$195,751	$41,001	20.95%

Source: Calculations based on Skidaway Institute and 2000 HAZUS data

maintain safe and efficient access to evacuation routes, and operate and maintain a thriving local economy, which feeds into the overall economy within the State of Georgia. The transportation systems included in our study were: rail lines, US, State and Interstate highways, and local roads. We

Figure 2.28- Total Number of Buildings in Darien by Census Block (not normalized by area)

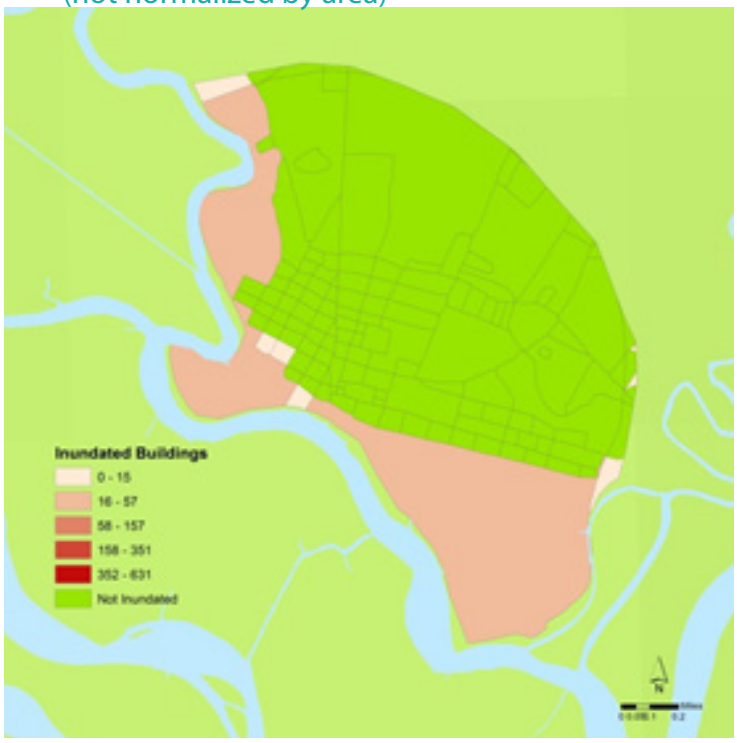


Figure 2.29- Estimated Replacement Value in Darien by Census Block (not normalized by area)

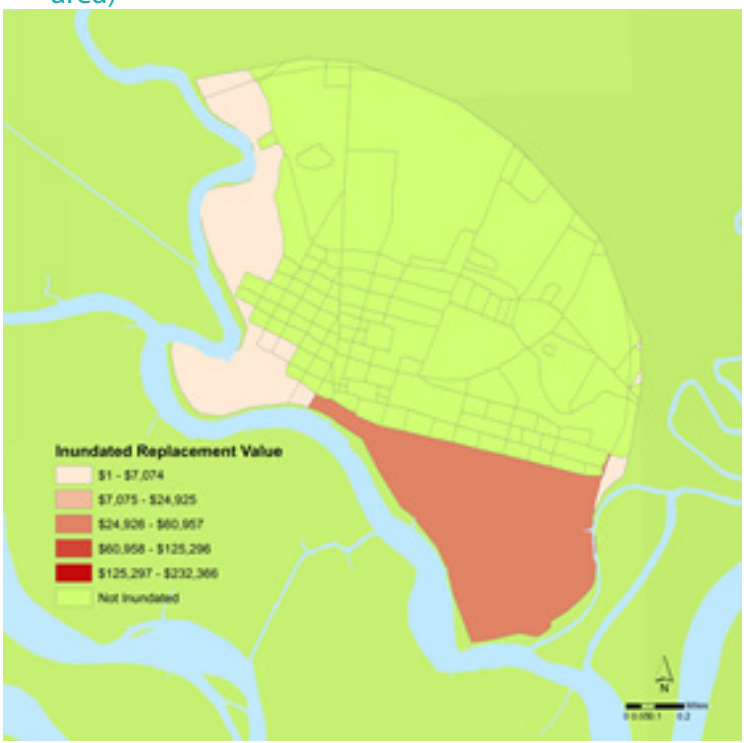


Table 2.16 - Total Existing and Inundated Miles of Rail, Evacuation Routes, and High Volume Roads in Study

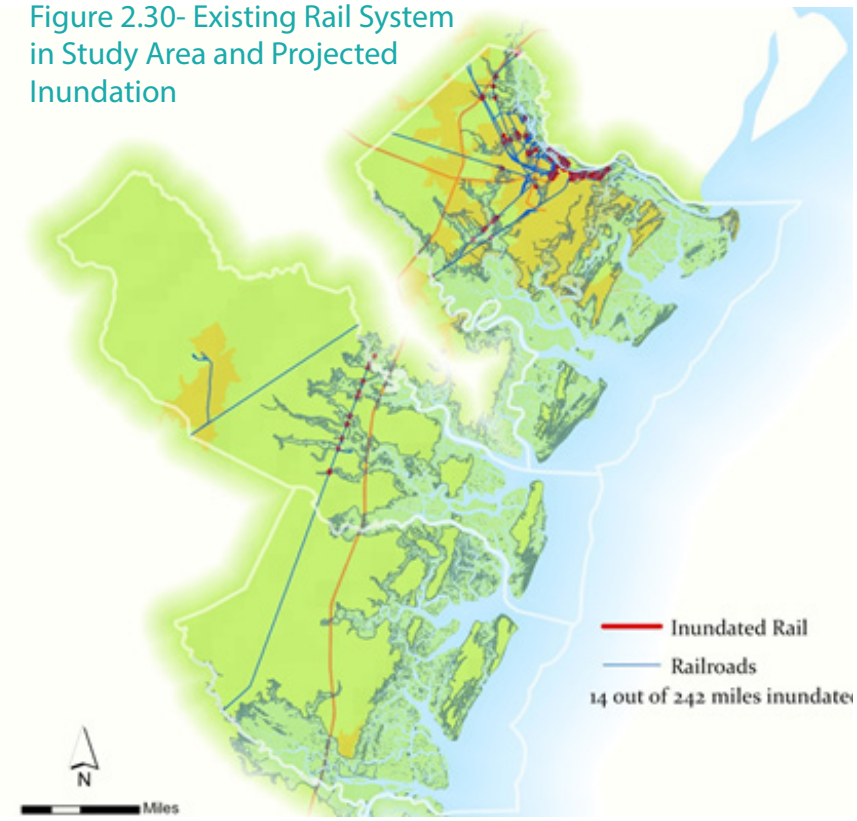
	Rail			Evacuation Routes			Roads (high volume)		
	Impacted	Total	% Impacted	Impacted	Total	% Impacted	Impacted	Total	% Impacted
Chatham	14	180	8%	9	122	7%	17	185	9%
Liberty	0.2	43	1%	0.7	80	1%	0.4	33	1%
McIntosh	0	19	0%	3.4	67	5%	1	21	5%
Three County Study Region	14	242	9%	13	269	13%	19	239	15%

also examined the Georgia Emergency Management Agency's (GEMA) designated evacuation routes and high traffic volume roads, as defined by Average Annual Daily Traffic (AADT) Count data from the Georgia Department of Transportation (GDOT). Determining how and where these transportation systems will be negatively affected by the projected sea level rise, and determining who and what will be affected by these negative impacts is fundamental to undertstanding impacts of sea level rise. A summary of the existing and inundated miles of rail and roadway is shown in Table 2.16.

Rail

The map in Figure 2.30 below shows the existing rail system in the study area and the locations where the rail system is projected to become inundated. There are a total of 242 miles of rail within Chatham, Liberty, and McIntosh Counties. CSX, Norfolk Southern, and Georgia Central own portions of these lines. Amtrak also has a station located west of Historic Savannah. According to our analysis, a total of 14.2 miles of rail within the three-county area will be inundated by sea level rise. Some of the inundated rail lies within the Port of Savannah. The Port contains a multi-modal terminal linking the Savannah River with the State's rail and highway networks. Terminal transfer links owned by CSX and Norfolk Southern within the Port of Savannah are at-risk of becoming inundated. If these links become inundated, it will be extremely difficult for the shipment and transferring of goods to take place within the Port. Economies within the region and the state rely on the port for the shipment and transferring of goods. The connection with the port and the highway and rail networks must be maintained in order to ensure a successful local and State economy.

Figure 2.30- Existing Rail System in Study Area and Projected Inundation



Evacuation Routes

The map in Figure 2.31 below shows the existing evacuation route system in the study area and the locations where the evacuation routes are projected to become inundated. There are 269 miles of Interstate, US, State and local highways that the Georgia Emergency Management Agency considers to be evacuation routes for Chatham, Liberty, and McIntosh Counties. These routes are basic for ensuring the safety of residents and visitors to the area. According to our analysis, 13.1 miles of these evacuation routes will be inundated by sea level rise including segments of Interstate 95, US 80, and State Route 204. Interstate 95 is a major Interstate highway

that is used to connect coastal residents with Interstate 16 and points to he north and south in the event of a hurricane or other hazardous event. US 80 is currently the only road connecting Tybee Island with the mainland of Chatham County. SR 204, also known as the Abercorn Expressway, is a major thoroughfare that Savannah residents and visitors use to access Interstate 95. It is important that the segments of these highways that are at-risk of becoming inundated by sea level rise be maintained to ensure the safety and livelihood of residents living within the three-county area.

Roads (High Volume)

The map in Figure 2.32 below shows the existing high volume roads within the study area and indicates the locations where these roads are projected to become inundated. The Georgia Department of Transportation conducts AADT (Average Annual Daily Traffic) counts at stations throughout the state. An analysis was conducted using the AADT counts from stations located in Chatham, Liberty, and McIntosh Counties to determine which highways have high traffic volumes compared with other highways throughout the three-county area. For the analysis, the top 25% of highways in the three-county area were selected. According to the analysis, a total of 239 miles of road were considered to have high traffic volumes. Among these roads, 18.4 miles are expected to become inundated by sea level rise. The roads within the three-county area that contain high traffic volumes are roads in which residents and visitors frequent in order to access Interstates 95 and 16, jobs, or recreation. These roads are typically four lane highways or freeways. Among these roads are US 80 and SR 204. Because these roads are major connectors with the Interstate highways in the area, and are necessary for ensuring the efficient evacuation of residents, these roads should be maintained.

Facilities

We continue to move from the overall physical vulnerability to more specific variables by looking at environmentally sensitive facilities. Environmentally sensitive facilities within the study area are of particular interest because they are sites that already pose a risk to the well-being of the environment and the populations that surround them. These risks will increase as sea level rise changes the areas surrounding these facilities and inundates some of these facilities. The environmentally sensitive facilities we investigated in our analysis include the following: hazardous material sites, wastewater treatments plants, landfills, and power plants (Figure 2.36).

Environmentally Sensitive Facilities

Figure 2.31- Existing Evacuation Route System in the Study Area and Projected Inundation

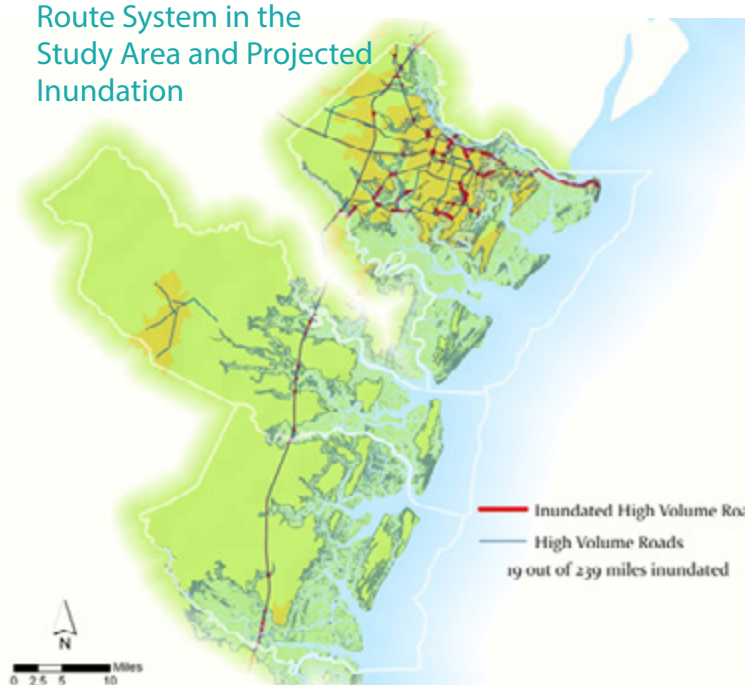
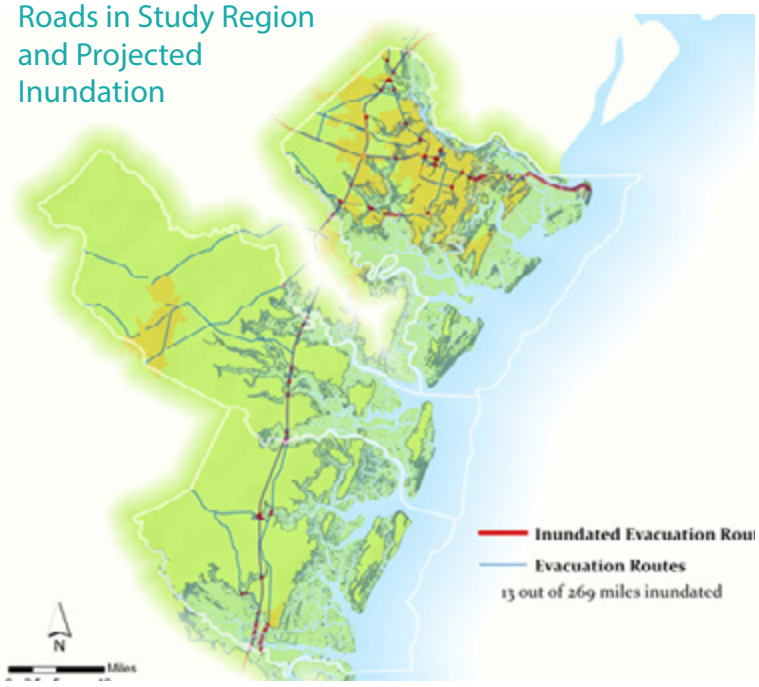


Figure2.32-ExistingHighVolume Roads in Study Region and Projected Inundation



Hazardous Materials

Hazardous materials sites were examined because their environmental impacts will be exacerbated by sea level rise (Table 2.17). In addition, studies often find a disproportionate number of low-income and no-vehicle households living near those sites, which will exacerbate these groups' vulnerability to natural disasters (Heberger, Cooley, Herrera, Gleick, & Moore, 2009; Flynn, Walesh, Titus, & Barth, 1984). Current national legislation such as The Resource Conservation and Recovery Act (RCRA) discourage the location of hazardous waste surface impoundments, wastes, piles, land treatment units, and landfills in a 100-year floodplain. Facilities located in a 100-year floodplain must be managed to prevent washout of any hazardous waste by the flooding events (CFR, 1982, Federal Register, vol. 47(143): 32290-32291).

Table 2.17 – Environmentally Sensitive Facilities

		Chatham	Liberty	McIntosh	Three County Study Region
Hazardous Materials	Inundated	4	0	0	4
	Total	42	3	1	46
	% Inundated	10%	0%	0%	9%
Wastewater Treatment Plants	Inundated	3	0	0	3
	Total	38	7	4	49
	% Inundated	8%	0%	0%	6%
Landfills	Inundated	1	0	0	1
	Total	22	6	2	30
	% Inundated	5%	0%	0%	3%
Power Plants	Inundated	0	0	0	0
	Total	6	1	0	7
	% Inundated	0%	0%	-	0%

performed "in compliance with a corrective plan approved by the Director, which will bring the site into compliance with the risk reduction standards" (EPD 2012, p.iv-v). In the three counties, there are four hazardous sites exposed to inundation caused by sea level rise – two sites are class V and two are class II. They are all located in Chatham County, where most of the industrial and logistics activities take place. These sites' names, hazardous classifications and release substances and status are listed in Table 2.18.

Sea level rise will not just cause flooding for areas below the one-meter elevation; it will also expand the boundary of current the 100-year floodplain since higher sea levels will decrease the drainage capacity of current hydraulic and ecological systems.

Using the hazardous site inventory data provided by the Environmental Protection Division of Georgia Department of Natural Resources, there are four hazardous sites listed for Chatham, Liberty, and McIntosh. These sites are ranked into five classes: Class I to class V. Class I, the most dangerous level, is defined as being known for "human exposure to regulated substances that have sources of continuing releases, or that are causing serious environmental problems" (EPD 2012, p.iv). Class V, the least serious level, is defined as having known releases from a list that requires corrective action and that is being

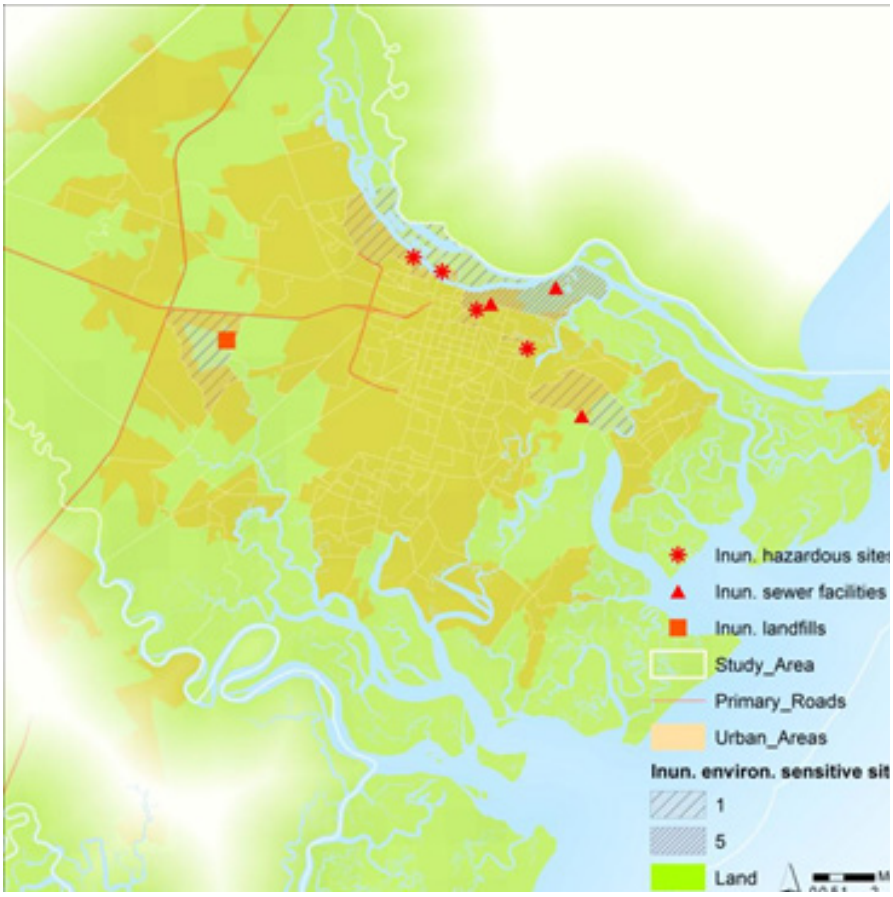
The impacts of sea level rise on hazardous material sites can be classified into three areas: increased storm damage, shoreline retreat, and changes in water level. An important impact is the potential of increased storm damage, which brings previously safe sites into the floodplain and brings more severe floods to the sites already in the floodplains. There is also an additional risk from the increase in storm waves from the deeper water, allowing waves to penetrate further inland (Flynn et al., 1984).

Wastewater Treatment Plants

Table 2.18– Hazardous Sites

Site	Class	Substances	Status
Central of GA RR/Bemuth-Lenoboke Site	II	This site has a known release of Naphthalene in groundwater at levels exceeding the reportable quantity. No human exposure via drinking water is suspected from this release. The nearest drinking water well is less than 0.5 miles from the area affected by the release. This site has a known release of Benzo (b) fluoranthene in soil at levels exceeding the reportable quantity. This site has limited access. The nearest resident individual is less than 300 feet from the area affected by the release.	Cleanup activities are being conducted for source materials, soil, and groundwater.
CSX Transportation – Powell Duffryn	V	This site has a known release of Lead in groundwater at levels exceeding the reportable quantity. No human exposure via drinking water is suspected from this release. The nearest drinking water well is between 1 and 2 miles from the area affected by the release. This site has a known release of Lead in soil at levels exceeding the reportable quantity. This site has limited access. The nearest resident individual is between 1001 and 3000 feet from the area affected by the release.	Cleanup activities are being conducted for source materials, soil, and groundwater.
Truman Parkway Phase II	II	This site has a known release of Lead in groundwater at levels exceeding the reportable quantity. No human exposure via drinking water is suspected from this release. The nearest drinking water well is between 0.5 and 1 mile from the area affected by the release. This site has a known release of Lead in soil at levels exceeding the reportable quantity. This site has unlimited access. The nearest resident individual is between 301 and 1000 feet from the area affected by the release.	Investigations are being conducted to determine how much cleanup is necessary for source materials and groundwater.
Aramark Uniform Services	V	This site has a known release of Tetrachloroethene in groundwater at levels exceeding the reportable quantity. No human exposure via drinking water is suspected from this release. The nearest drinking water well is between 0.5 and 1.0 mile from the area affected by the release.	Cleanup activities are being conducted for source materials, soil, and groundwater.

Figure 2.33 - Chatham County Hazardous Sites



An inundation of water into wastewater treatment plants could damage pumps and lead to leaching of untreated sewage discharge, causing environmental and health risks to communities (Heberger et al., 2009).

For Georgia, the Environmental Protection Agency's ECHO program provides information from the Integrated Compliance Information System - National Pollutant Discharge Elimination System on sewage discharge permits. Geospatial data from this source allow us to map these permits' locations on the three-county map. There are a total of 49 permits in Chatham, Liberty, and McIntosh. The total number of facilities is most likely less than 49 since one facility may carry multiple discharge permits at once.

A one-meter rise of the sea level will cause inundation of three facilities, which are all located within the Savannah metropolitan area. These affected facilities are listed in Table 2.19

Table 2.19 – Inundated Wastewater Treatment Plants

Facility	Location	Ownership	Permitted Discharge	Peak capacity
President Street Water Quality Control Facility	Savannah	City of Savannah	27 million gal/day	75 million gal/day
Savannah Acid Plant	Savannah	Greenfield Environmental Savannah Trust LLC	Not available	Not available
Savannah Yacht Club	White Marsh Island, Savannah	Savannah Yacht Club	Not available	Not available

and illustrated in Figure 2.34.

The inundation of the President Street Facility would have a major impact on the wastewater treatment system for the city of Savannah in particular and Chatham County in general. The facility treats an average 18 million gallons of sewage per day (City of Savannah, 2012). The President Street Facility accounts for 77% of the city's system and 65% of county's system in terms of treatment capacity (calculation based on data provided by (Commission, 2006)). Furthermore, three other municipal treatment plants in Savannah, Winsor, Georgetown, and Travis Field, discharge through the President Street location. This means the inundation of this facility would disrupt wastewater treatment for the entire city, causing major health and environmental impacts (Figure 2.35). It is important to note that our assignment was to measure the extend of sea level rise relative to existing facilities and not to examine the level of preparation or shielding those facilities might have made or might be planning to make.

Landfills

Landfills are a third environmentally sensitive facility. As with other hazardous materials sites, the environmental impacts of these sites could be exacerbated by sea level rise, especially with the potential release of untreated waste. As Flynn et al. (1998) states, "[w]astes could dissolve or be suspended in the nearby soil and physical erosion caused by coastal wave action might result in a total washout or removal of the soil layer and the incorporated wastes." Flood proofing is necessary to not only protect surrounding communities and employees but to also have uninterrupted daily functions.

There are 22 landfills in Chatham County, six in Liberty County, and two in McIntosh County. One landfill will be inundated by the one-meter sea level rise, Chatham County's Dean Forest Road Municipal Solid

Figure 2.34-Inundated Discharge Facilities

Figure 2.35- President Street Facility

Waste Reclamation and Disposal Facility. The Dean Forest Road Facility is one of two municipal landfills in Savannah, serving 140,000 residents (2011 estimate). The inundation of Dean Forest landfill could cause a major disruption of waste disposal in the city.

Power plants

Power generation facilities produce and deliver energy to maintain a high quality of living and a vital economy. Inundation of power facilities will not only disrupt people's daily activities, but also diminish a local communities' ability to re-build after disaster events (Cutter, Boruff, & Shirley, 2003).

In addition, power plants need fresh, cool water to cool generators. An increase in sea level rise brings with it saltwater intrusion and warmer waters, which makes it difficult for the power facilities to function properly. The saltwater intrusion could also further hamper the lifecycle of the generator since salt is a corrosive agent.

Through our investigation, we found that no power facilities will become inundated by sea level rise. The impact of sea level rise on the power plants in terms of available fresh water resources for cooling will need further data and analysis.

Historic sites

Coastal Georgia is the oldest continuously settled colonial region of the state. The historic places along the Georgia coast are significant both nationally and statewide, and are also economically important to tourism. These historic places also tie local communities to their heritage. Sea level rise is a major threat to these places since they cannot be relocated or compensated for, and the alteration and modification of building materials may make these sites ineligible for the National Register of Historic Places.

We found numerous historic sites along the coast that are susceptible to inundation caused by sea level

Figure 2.36 - Environmentally Sensitive Facilities (ESF)

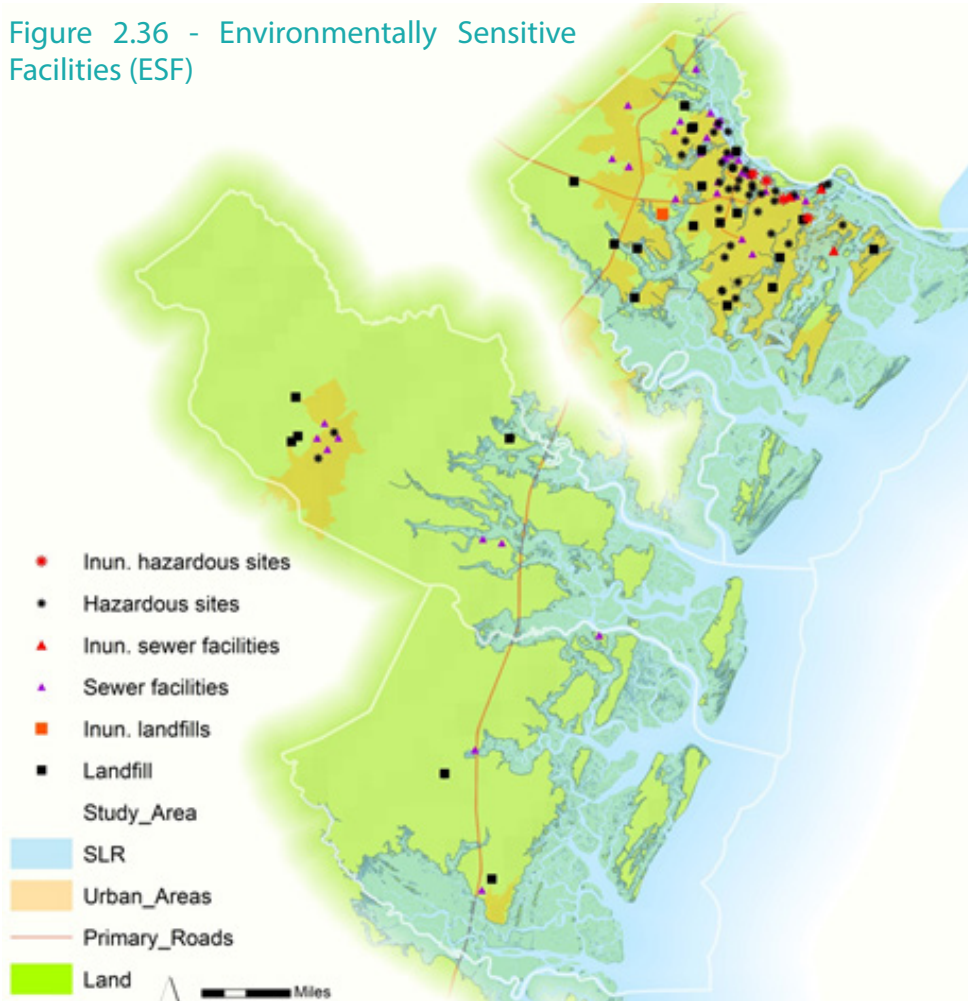
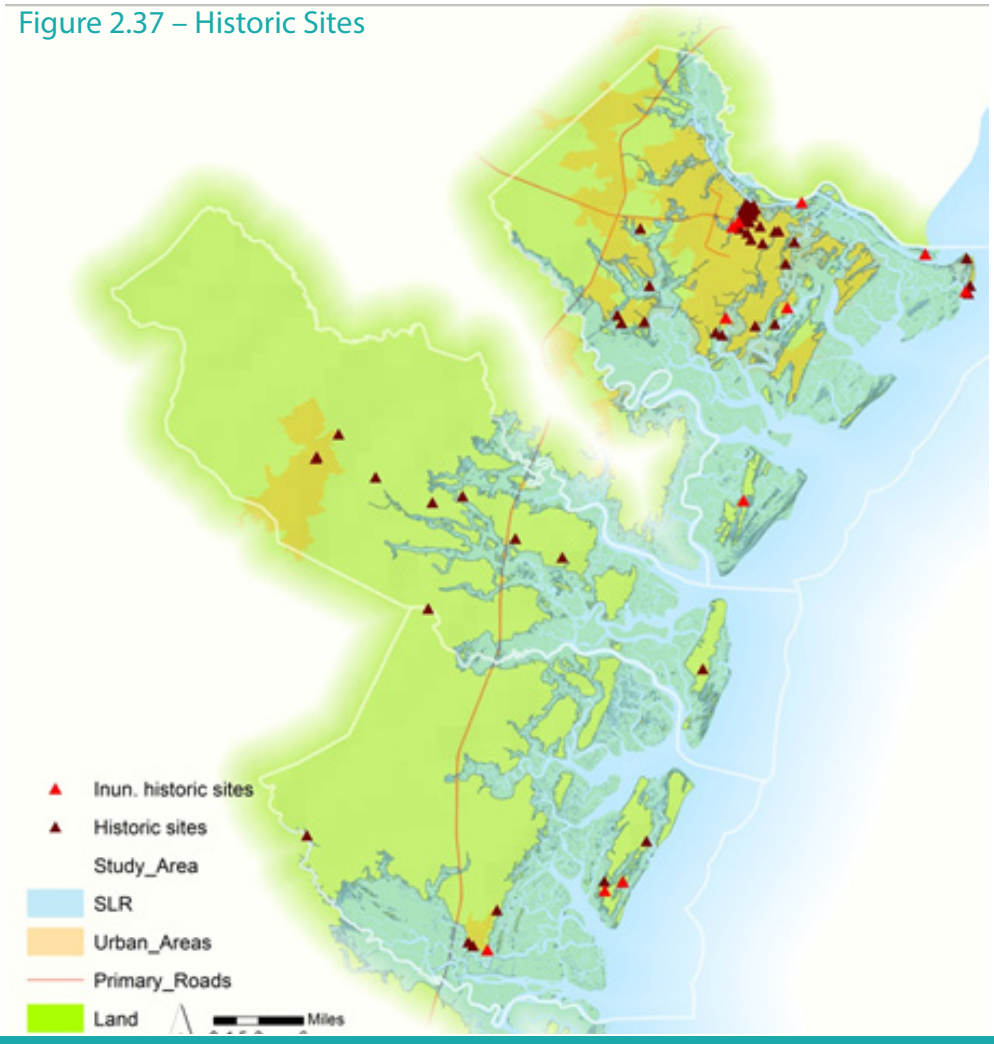


Table 2.20- Inundated Historic Sites

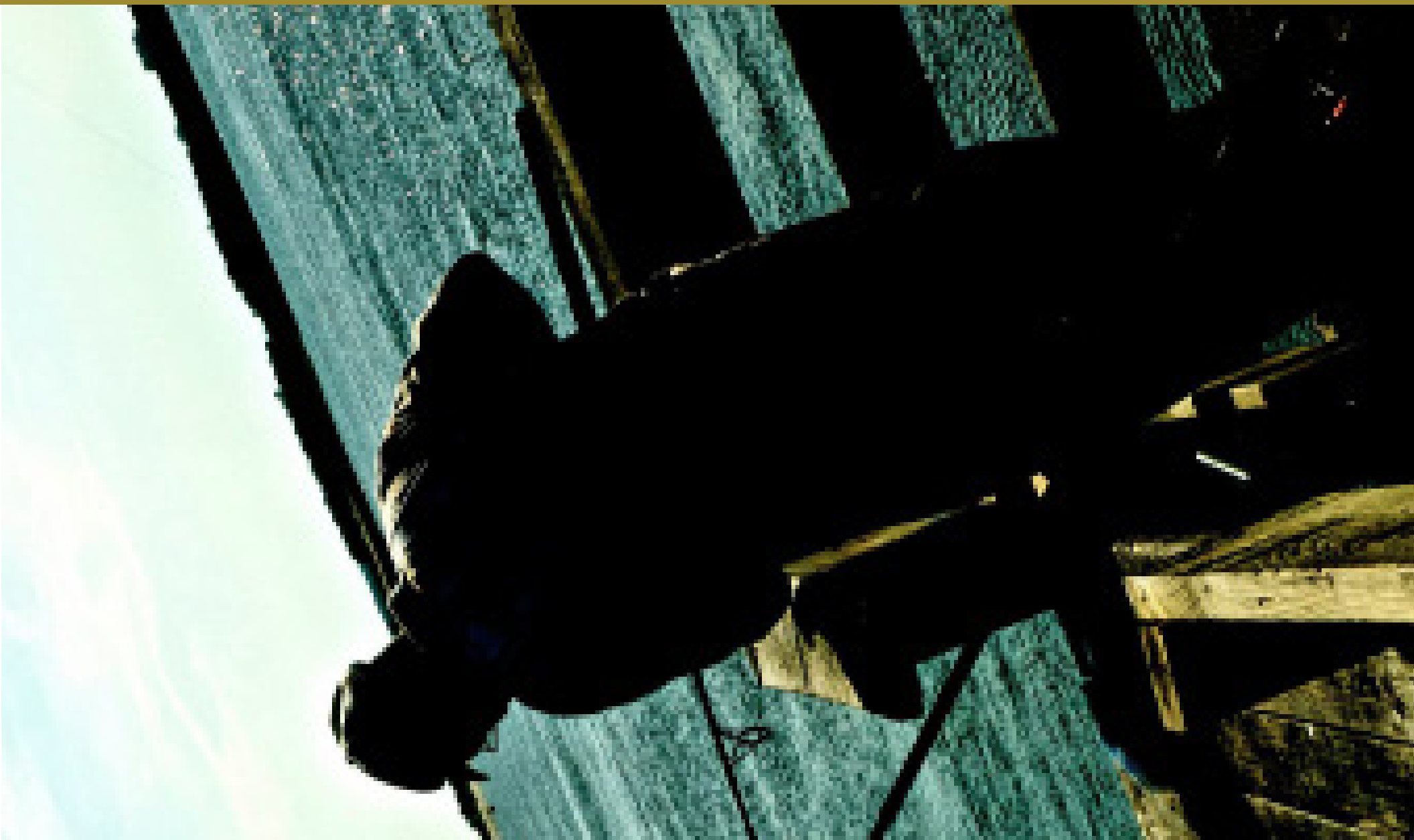
	Place	County	Level of Recognition	Historic significance
1	Fort King George	McIntosh	National	Event, Information potential
2	Hog Mammock Hiistoric District	McIntosh	National	Event, Architecture/Engineering
3	Vernonburg Historic District	Chatham	National	Information potential, Event, Architecture/Engineering
4	Isle of Hope Historic District	Chatham	National	Event, Architecture/Engineering
5	Fort Pulaski National Monument	Chatham	National	Event, Architecture/Engineering
6	Fort James Jackson	Chatham	National	Event, Architecture/Engineering
7	Sapelo Island Lighthouse	McIntosh	State	Event, Architecture/Engineering
8	Ossabaw Island	Chatham	National	Event, Architecture/Engineering, Information Potential
9	Tybee Island Back River Historic District	Chatham	National	Event
10	Laurel Grove – North Cemetery	Chatham	National	Event, Architecture/Engineering
11	Laurel Grove – South Cemetery	Chatham	National	Event

rise (Routhier, Curran, Mulukutla, Jenerson, & Hall, 2011), and have attempted to quantify the impact of sea level rise on these historic assets in terms of the number of inundated places. However, the effect of these losses on the coastal communities is not easily measured. Thorp (Thorp, 2006) argues that the loss of a beloved heritage may exacerbate the pain of a disaster event while the survival of that asset may encourage hope for the community. This argument is supported by FEMA, which suggests "the sudden loss of historic properties and cultural resources can negatively impact a community's character and economy, and can affect the overall ability of the community to recover from a disaster event" (FEMA, 2005 in Thorp, 2006, p.9). Furthermore, historic structures and districts can be more difficult to replace due to their cultural significance.

Figure 2.37 – Historic Sites



SOCIAL IMPACTS



We now review the population of the region and attempt to assess their vulnerability to the consequences of sea level rise.

Table 3.1 lists the social characteristics included in our social vulnerability analysis as well as particular groups deemed potentially vulnerable.

Table 3.2 outlines the population and households threatened by the consequences of a one-meter rise in sea levels. The analysis indicates that 15.0% of the population and 15.6% of the existing households (20,083 households) are subject to inundation.

Table 3.3 describes the characteristics of these people in greater detail.

Table 3.1- Socially Vulnerable Populations: Characteristics Included in Social Vulnerability Analysis

		Chatham	Liberty	McIntosh	Three County Study Region
POPULATION AND HOUSEHOLD DENSITY	Population	256,428	63,854	13,817	334,099
	Households	100,450	22,626	5,687	128,763
AGE	Under 5 Years	18,045	6,386	792	25,223
	5-14 years	30,934	10,146	1,717	42,797
	Above 64 Years	31,618	3,794	2,184	37,596
RACE AND ETHNICITY	Nonwhite	117,125	33,807	5,347	156,279
	Hispanic	12,510	6,070	237	18,817
GENDER AND FAMILY STATUS	Female Population	133,203	32,286	7,112	172,601
	Families	62,377	16,679	3,825	82,881
	Single Parent Families	14,083	4,033	738	18,854
EDUCATION	Over 25 Years with less than High School Education or Equivalent	20,796	3,937	2,306	27,039
OCCUPATION AND EMPLOYMENT	Employed Population	115,743	23,155	6,230	145,128
	Service-Sector Employees	67,060	13,349	3,287	83,696
INCOME AND POVERTY	Median Income	$44,298	$42,674	$39,075	-
	Families in Poverty	7,229	2,508	427	10,164
	Single Parent Families in Poverty	4,554	1,895	286	6,735
	Single Mother families in Poverty	4,236	1,810	276	6,322
HOMELESS	Sheltered	590	50	0	640
	Unsheltered	467	90	41	598
	Total	1,057	140	41	1,238
HOUSING AND THE BUILT ENVIRONMENT	All Housing Units	116,632	25,894	8,586	151,112
	Owner-Occupied Housing Units	58,989	11,498	4,247	74,734
	Renter-Occupied Housing Units	41,461	11,128	1,440	54,029
	Vacant Housing Units	16,182	3,268	2,899	22,349
	Median Home Value	$177,100	$120,300	$39,075	-
	Median Monthly Rent	$697	$627	$406	-
	Manufactured Housing	5,576	5,341	2,515	13,432
MODE OF TRANSPORTATION	Households with No Vehicle Access: Home Owners	1,949	147	228	2,324
	Households with No Vehicle Access; Renters	6,677	1,195	78	7,950
	Total of Households with No Vehicle Access	8,626	1,342	306	10,274
DISABILITY		This variable is not measured.			
SOCIAL CAPITAL		This variable is difficult measure quantitatively.			

Source: American Community Survey, 2010

Table 3.2 - Population & Households: Exposure to Inundation

		Chatham	Liberty	McIntosh	Three County Study Region
POPULATION	Inundated Population	42,623	3,377	4,059	50,059
	% of Inundated Population (to Study Region)	12.76%	1.01%	1.21%	14.98%
HOUSEHOLDS	Inundated Households	17,187	1,311	1,581	20,079
	% of Inundated Households (to Study Region)	13.35%	1.02%	1.23%	15.59%

Source: American Community Survey, 2010

Methodology

The variables were analyzed using U.S. Census American Community Survey data by block group. To estimate the area of each block group that would be affected by sea level rise, the total area of each block group was calculated; then, the area of the intersection was calculated. Finally the SLR intersection was divided by block group area, which produced the portion of each block that would be inundated. To assess the effect of sea level rise on the local population, the value for each variable was multiplied by the proportion of the block group that will be inundated to estimate the number of people, households or housing units that will be inundated. The resulting number was rounded to a whole number. The impacted number for each variable was grouped by all block groups in a county and then summed to create a county-level estimate of the number of people, households, and housing units that will be impacted by sea level rise..

Population Density and Households

TTotal population, population density, and total households provide a picture of the distribution of human exposure to sea-level rise within the study area (Shepard, et. al. 2012). Both the overall number of people exposed as well as the density of the population exposed play a role in determining vulnerability. Understanding these factors is crucial in determining the need for evacuation and disaster preparedness procedures, as well as the magnitude of risk of displacement. In areas with greater levels of population exposed to sea level rise, it is necessary to devote more resources to ensuring that disaster preparation and evacuation measures are in place. In areas of high population density which are exposed to SLR, special consideration must be made for ensuring that evacuation routes can support the transport of proportionally greater numbers of people relative to the area being evacuated than in lower-density areas. De Olivera Mendes (2009) notes that population density is also inversely correlated with wealth, which is also a marker of an area's resilience in the face of hazards (see Affluence factor grouping). Finally, Shepard et al. (2012) assert that total households and household density can help determine the risk of displacement and the magnitude of need for evacuation support and provision of temporary shelters.

The portions of the study area that will be inundated by sea-level rise tend to be low density (Figure 3.1). This is particularly true in Liberty and McIntosh Counties, where all block groups exposed to SLR risk are in the lowest quintile of density for the study area. In Chatham County, more densely populated areas are exposed to SLR, including several block groups in the highest quintile of density. Many of the highest total population block groups in Liberty and McIntosh Counties have higher SLR risk (Figure 3.2).

Age

Populations considered vulnerable due to their age are people under the age of 15 and above the age of 64. The younger subset is more vulnerable because they have a greater inability to provide financially and intellectually for themselves. Those above the age of 64 are vulnerable because people in this group have higher incidence of physical and mental disabilities, as they are more susceptible to illness and, for many, their physical capacities have begun to deteriorate. These two age groups are generally less able to work; physical labor can be difficult for younger, less developed people and for older, less mobile persons. Younger people also have a disadvantage for jobs that require an education because they have not had the opportunity to obtain sufficient education. Figure 3.3 and Figure 3.4 show the

Table 3.3- Socially Vulnerable Populations: Exposure to Sea Level Rise

		VULNERABLE POPULATION TOTALS				% OF COUNTY TOTAL			
		Chatham	Liberty	McIntosh	Three County Study Region	Chatham	Liberty	McIntosh	Three County Study Region
POPULAND AND HOUSEHOLD DENSITY	Population	42,623	3,377	4,059	50,059	17%	5%	29%	15%
	Households	17,187	1,311	1,581	20,079	17%	6%	28%	16%
AGE	Under 5 Years	2,711	171	271	3,153	15%	3%	34%	13%
	5-14 years	4,798	341	456	5,595	16%	3%	27%	13%
	Above 64 Years	6,377	464	587	7,428	20%	12%	27%	20%
RACE AND ETHNICITY	Nonwhite	12,669	1,037	1,405	15,111	11%	3%	26%	10%
	Hispanic	1,791	41	64	1,896	14%	1%	27%	10%
GENDER AND FAMILY STATUS	Female Population	21,687	1,742	2,141	25,580	16%	5%	30%	15%
	Families	11,333	908	1,107	13,348	18%	5%	29%	16%
	Single Parent Families	1,752	125	167	2,044	12%	3%	23%	11%
EDUCATION	Over 25 Years with less than High School Education or Equivalent	2,541	419	556	3,516	12%	11%	24%	13%
OCCUPATION AND EMPLOYMENT	Employed Population	19,607	1,488	1,852	22,957	17%	6%	30%	16%
	Service-Sector Employees	11,227	755	1,046	13,028	17%	6%	32%	16%
INCOME AND POVERTY	Median Income	Inundation cannot be measured with readily accessible data.							
	Families in Poverty	728	81	102	911	10%	3%	24%	9%
	Single Parent Families in Poverty	458	56	60	534	10%	2%	21%	8%
	Single Mother families in Poverty	415	28	51	494	10%	2%	18%	8%
HOMELESS	Sheltered Unsheltered Total	Inundation cannot be measured with readily accessible data.							
HOUSING AND THE BUILT ENVIRONMENT	All Housing Units	19,807	1,574	2,577	23,958	17%	6%	30%	16%
	Owner-Occupied Housing Units	11,742	975	1,128	13,845	20%	8%	27%	19%
	Renter-Occupied Housing Units	5,447	338	453	6,238	13%	3%	31%	12%
	Vacant Housing Units	2,624	263	996	3,882	16%	8%	34%	17%
	Median Home Value Median Monthly Rent	Inundation cannot be measured with readily accessible data.							
	Manufactured Housing	1,466	470	730	2,634	26%	9%	29%	20%
MODE OF TRANSPORTATION	Households with No Vehicle Access: Home Owners Households with No Vehicle Access: Renters Total of Households with No Vehicle Access	Inundation cannot be measured with readily accessible data.							
DISABILITY		This variable is not measured for small geographies.							
SOCIAL CAPITAL		This variable is difficult measure quantitatively.							

Figure 3.1 – Population Density and Sea Level Rise

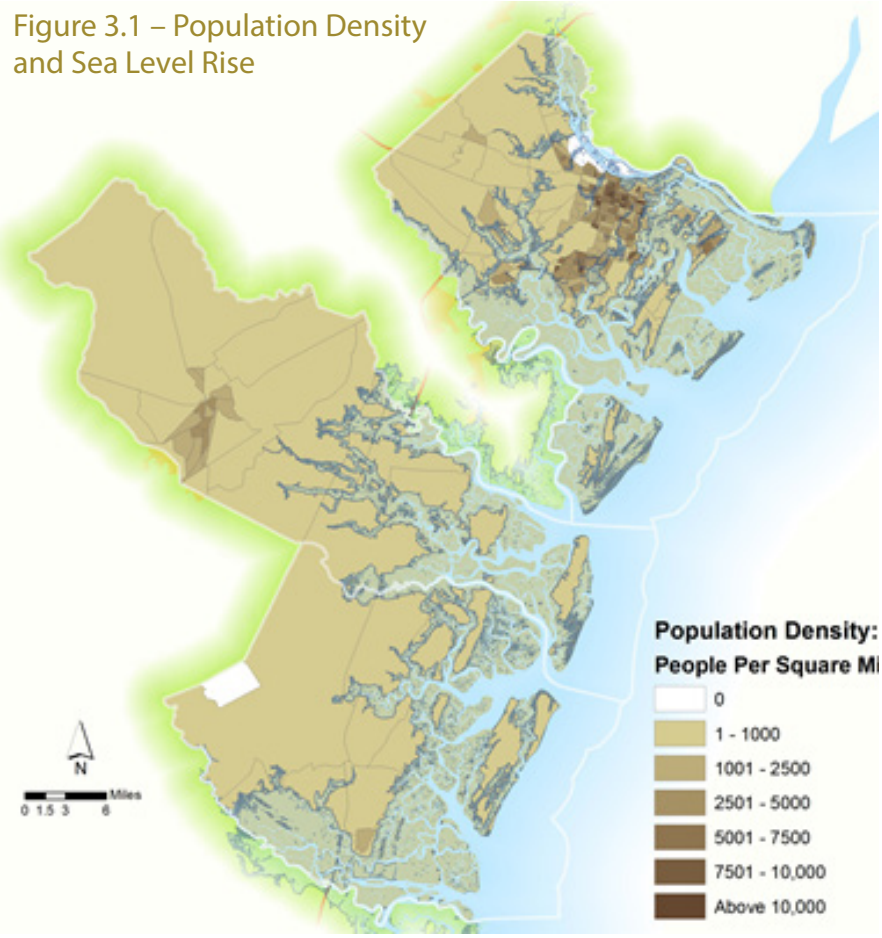
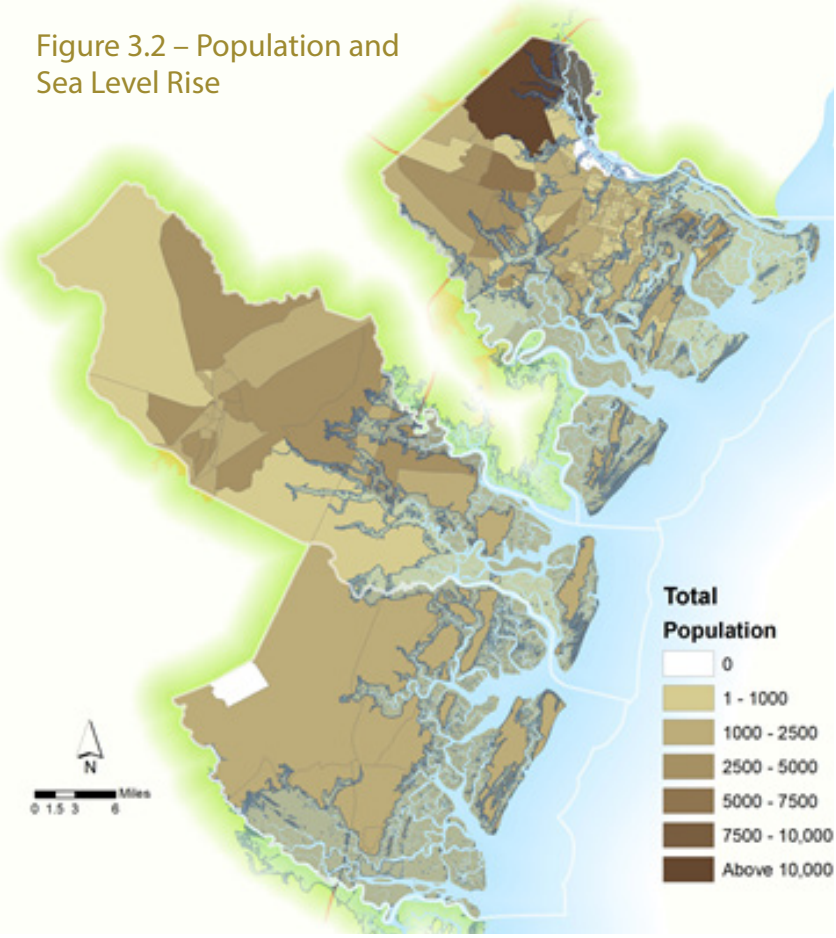


Figure 3.2 – Population and Sea Level Rise



total populations of people under the age of 15 and people over the age of 64 by block group, respectively. In McIntosh, the population under the age of 15 is higher in the eastern part than the western part, while in Liberty and Chatham, the younger population is proportionately smaller along the eastern coast. There is a concentration of the population over the age of 64 in the northern part of Skidaway Island, which was redeveloped as a retirement community 30 years ago.

The studies we reviewed highlight age as a measure in defining social vulnerability (Clark, Moser et al. 1998; Schmidtlein, Deutsch et al. 2008; de Oliveira Mendes 2009; Florida Department of Health 2012; Shepard, Agostini et al. 2012). We also reviewed governmental regulations. For child labor laws, both the Federal Government and the State of Georgia have limitations on the amount of hours, types of environments, and times of year that children under that age of 15 can work. The Social Security Administration suggests that many people are likely to stop working by age 64 (U. S. Department of Labor 2010). Social Security payments normally begin between ages 62 and 67. However, these payments are frequently less than to what retirees are accustomed. These lesser payments may not be adequate, too, in the absence of substantial savings and given the reduction in defined benefit pension systems, in which case vulnerability is increased.

Race and Ethnicity

Two important factors that appear in the literature on social vulnerability are race and ethnicity. These characteristics stand as important indicators of one's ability to cope with environmental hazard events due largely to inequalities built into the social fabric of many American communities (Cutter, 2003). Both social inequalities and the traditional marginalization of these populations restrict access to resources and guide minority groups to live in communities more susceptible to damage. Inequality plays a significant role in creating barriers for minority groups attempting to avoid or react to hazard events. Consensus among vulnerability studies hold that non-white and non-English speaking populations are among the most vulnerable (Clark et al. 1998, de Oliveira Mendes 2009, Schmidtlein et al. 2008, Shepard et al. 2011).

Figure 3.3 – Population Below the Age of 15

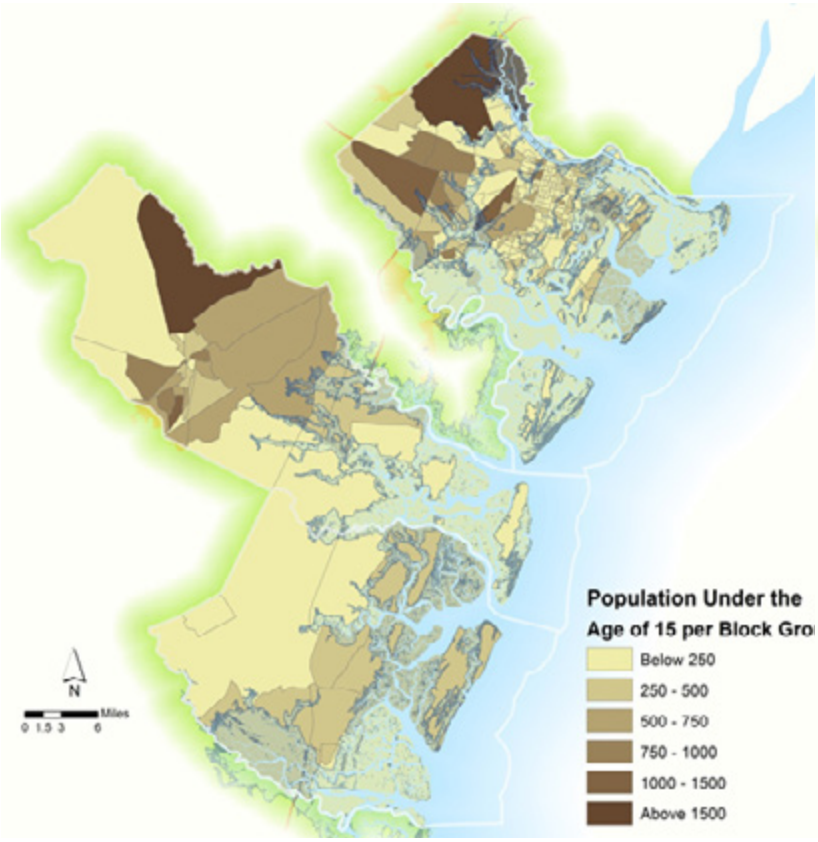


Figure 3.4 – Population Over the Age of 64

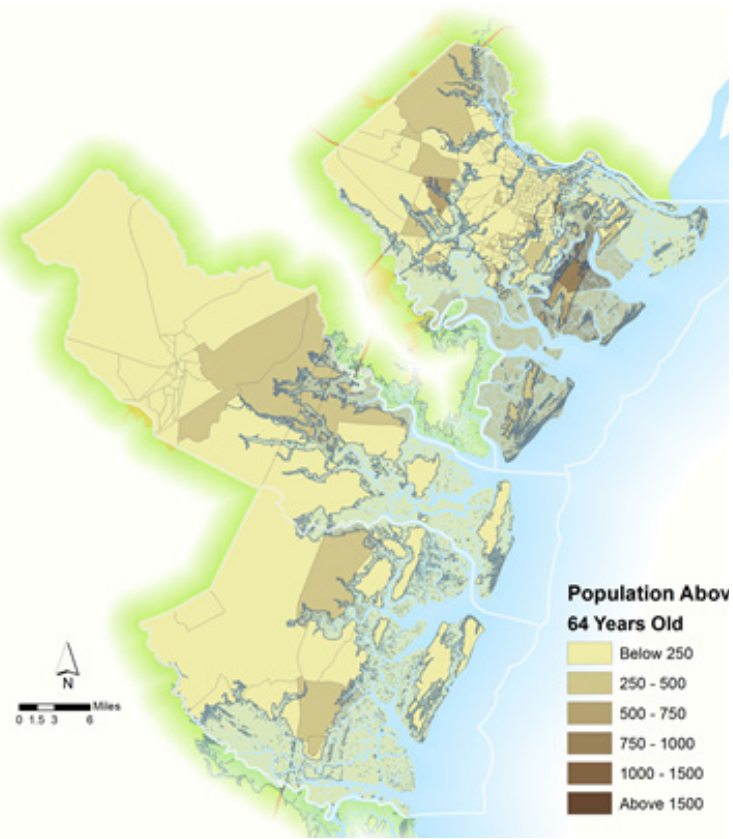


Table 3.1 outlines the key racial characteristics of the study area. Of the three-county area's 334,099 residents, 177,820 (53.2%) residents of the population are white while 156,279 (46.8%) residents are non-white. Of the total population 256,428 (76.8%) residents reside in Chatham County. The population is majority white, with 139,303 (54.3%) people living in Chatham County, followed by 117,125 (45.7%) non-white residents. In Liberty County, the resident population is 63,854, accounting for 19.1% of the three-county population. However, it is a majority-minority county with 30,047 white (47.1%) to 33,807 (52.9%) non-white residents. McIntosh County has the smallest population of the three counties, with 13,817 residents (4.1% of the three-county population). The population is predominantly white, with 8,470 (61.3%) white people living in McIntosh County, followed by 5,347 (38.7%) non-white residents (Figure 3.5).

Table 3.1 also outlines the ethnic makeup of the study area by dividing the population of the three counties into their Hispanic and non-Hispanic ethnicity. While 94.4% of the total population is non-Hispanic, there are 18,817 (5.6%) people with Hispanic heritage. Similarly, English is the primary language in 90.8% of the households in the area, but there are 11,803 (3.5%) households that use a language other than English on a regular basis (Table 3.1). Liberty County has the highest concentration of Hispanic residents (9.5%) and non-English speaking households (14.5%). Overall, vulnerability due to ethnicity applies to a relatively small proportion of the population recorded in the ACS, but these populations should remain an area of focus.

The limitations of present ethnicity analysis are described in the results of the study of housing access in Savannah conducted by Keating and Mailloux (2012). In that study, the authors found that local activists, religious officials and service providers believed that the officially recorded Hispanic population was just a fraction of the true number living in the county, and estimated that Chatham alone had as many as 20,000-30,000 Hispanic residents, which would more than double the officially reported numbers if true. Their research suggested that fear prevented both legal and undocumented immigrants from responding to Census surveys. If the estimates are even close to the true population, then Hispanic residents are a much more significant faction than previously reported and require even greater attention.

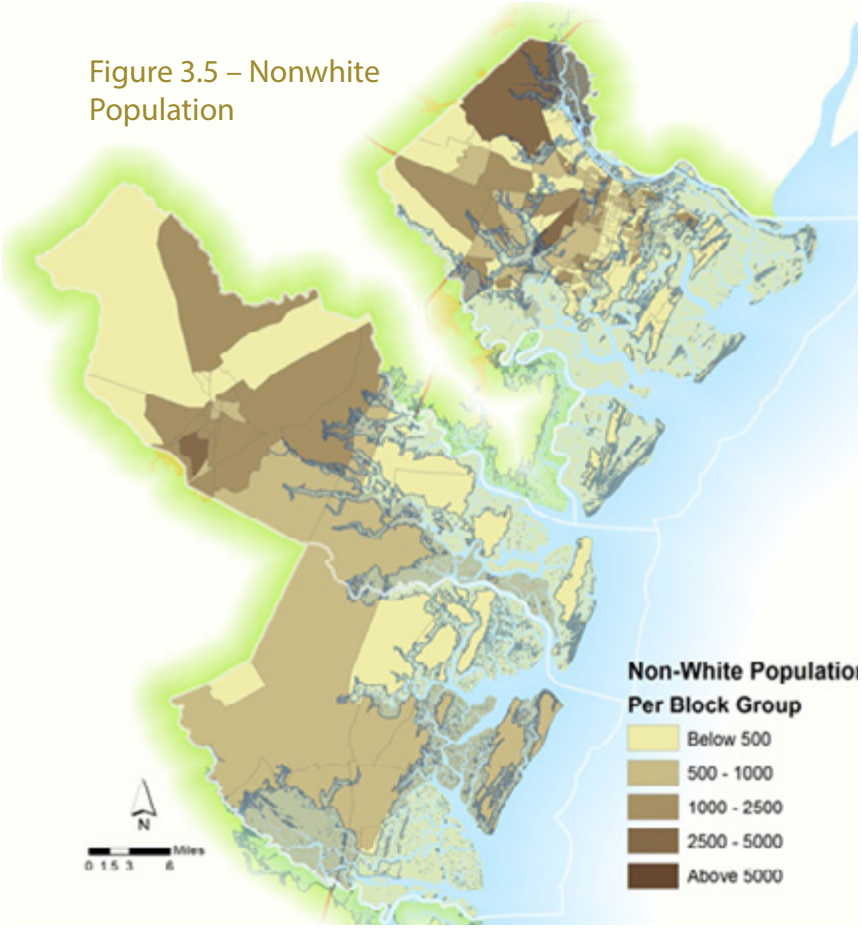
Gender and Family Status

Single-parent households, and, more specifically, single-mother households, are an additional variable that researchers have used to identify populations with higher vulnerability to any disruption of the physical landscape due to lower household incomes, diminished support systems, and increased responsibilities falling on one person (Schmidtlein et al., 2008; Shepard et al., 2011). Table 3.1 includes the number of single-parent households in the three-county area. Chatham County has the highest concentration of this vulnerable group, with 85.7% of the 2,044 single parents in the region.

Education

Education level plays a role in measurements of social vulnerability because it is an indicator of wealth, social mobility, and adaptability. In the studies conducted of social vulnerability, researchers often classify adults

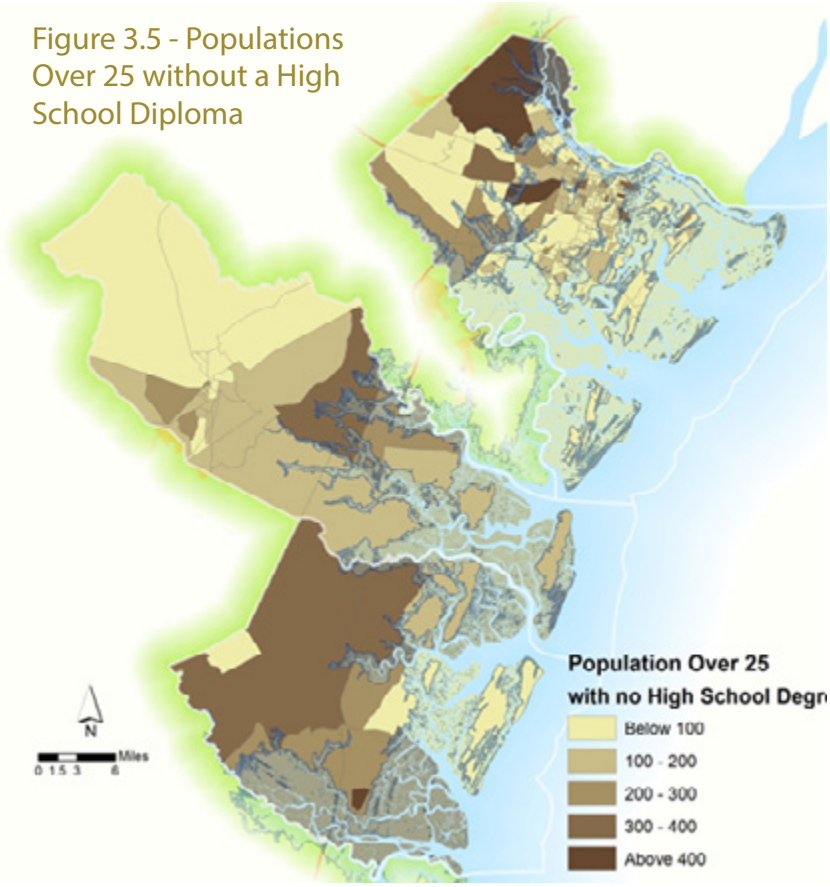
Figure 3.5 – Nonwhite Population



without high school diplomas as markedly vulnerable. These researchers define "adult" as a person over the age of 25 (de Oliveira Mendes, 2009; Schmidtlein et al., 2008; Shepherd et al., 2011). Individuals with low levels of education may lack access to or the ability to understand and make use of information about the risks they face. Education enhances the understanding of necessary steps to avoid a threat and the capacity to access bureaucracies to obtain post-crisis assistance. Furthermore, education is, to an extent, correlated with age and wealth, as less educated people tend to be older and have lower incomes. These three risk factors reduce less-educated individuals' ability to adapt to unforeseen circumstances (Cutter et al., 2003).

Table 3.1 illustrates the population over the age of 25 without a high school diploma in each of the three counties. There are 27,039 people in the study area that fall into the category, with most (76.9%) residing in Chatham County (Figure 3.5). Thirteen percent (13.0% / 3,516 people) of the people lacking a high school diploma face inundation, 72.3% of whom live in Chatham County. In mostly rural McIntosh, nearly one-quarter of the population lacking a diploma (24.1% / 556 of 2,306) will be inundated. The proportion of people lacking a high school education is declining over time and will be smaller when inundation occurs, but the higher relative incidence will present particular challenges to rural counties such as McIntosh as their governments are the least well prepared to respond.

Figure 3.5 - Populations Over 25 without a High School Diploma



Occupation and Employment

Employment is a critical component in assessing the economic impact due to sea level rise. In earlier hazard studies considering effects beyond direct damage, job losses are the major component of indirect losses (Hallegatte, et al., 2010).

The jobs impacted are derived from the OnTheMap dataset, which is composed of data from Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES) of U.S. Census Bureau (OnTheMap, 2010). The data for 2010 includes: Origin-Destination data (OD), residence area characteristic data (RAC), and workplace area characteristics (WAC) data. The estimation of jobs impacted due to sea level rise is calculated using WAC data. Assuming that jobs are distributed uniformly among workforce areas, the number of jobs impacted is calculated by multiplying the available jobs with the percentage of land loss due to sea level rise area in the future.

(Jobs Impacted)
=(Jobs)*(Land Loss%)
=(Jobs)*(Land Loss)/(Land Area)

The jobs impacted in the work place can be projected to employment impacted in residential areas by using RAC and OD data. The potential employment loss based on residences can be calculated to show where the employees with jobs impacted are likely to live.

The estimation shows that the number of jobs impacted due to sea level rise is 6,957 (86.3% of which are in Chatham County) in the region, which accounts for 4.9% in the total available jobs. The proportion of jobs impacted are less than one-third the proportion of residents inundated (4.9% versus 15.0%) because residences have moved into vulnerable coastal and water oriented sites to a much greater extent than jobs have. Moreover, it should also be noted

Table 3.4 - Estimated Jobs Impacted by County and Monthly Salary

	Study Region	Chatham	Liberty	McIntosh
Total Jobs	141,653	126,919	12,998	1,736
Salary<$1250	42,720	37,838	4,165	717
Salary $1250-3333	53,889	47,930	5,269	690
Salary >$3333	45,044	41,151	3,564	329
Jobs Impacted	6,957	6,007	626	324
Salary<$1250 Impacted	2,308	1,996	140	171
Salary $1250-3333 Impacted	2,914	2,533	275	107
Salary >$3333 Impacted	1,734	1,478	211	46
Salary<$1250 in Jobs Impacted	33.2%	33.2%	22.4%	53.0%
Salary $1250-3333 in Jobs Impacted	41.9%	42.2%	43.9%	33.0%
Salary >$3333 in Jobs Impacted	24.9%	24.6%	33.7%	14.1%
Unemployment rate for Salary <$1250	5.4%	5.3%	3.4%	23.9%
Unemployment rate for Salary $1250-3333	5.4%	5.3%	5.2%	15.5%
Unemployment rate for Salary >$3333	3.9%	3.6%	5.9%	13.8%

that the percentage of jobs impacted in McIntosh is 18.7%, which is well above the regional level. McIntosh residents are likely to experience higher rates of unemployment.

Table 3.4 shows the jobs impacted grouped by monthly salary. The middle-income group constitutes 41.9% of the jobs and the high-income groups hold 24.9%. The unemployment rate is calculated by dividing the jobs available by the jobs impacted, which represents the likelihood of job losses for employees in this group. The unemployment rate for the high-income group is over one-quarter less than the other two groups.

Figure 3.6 - Jobs Impacted Due to Sea Level Rise per Square Mile

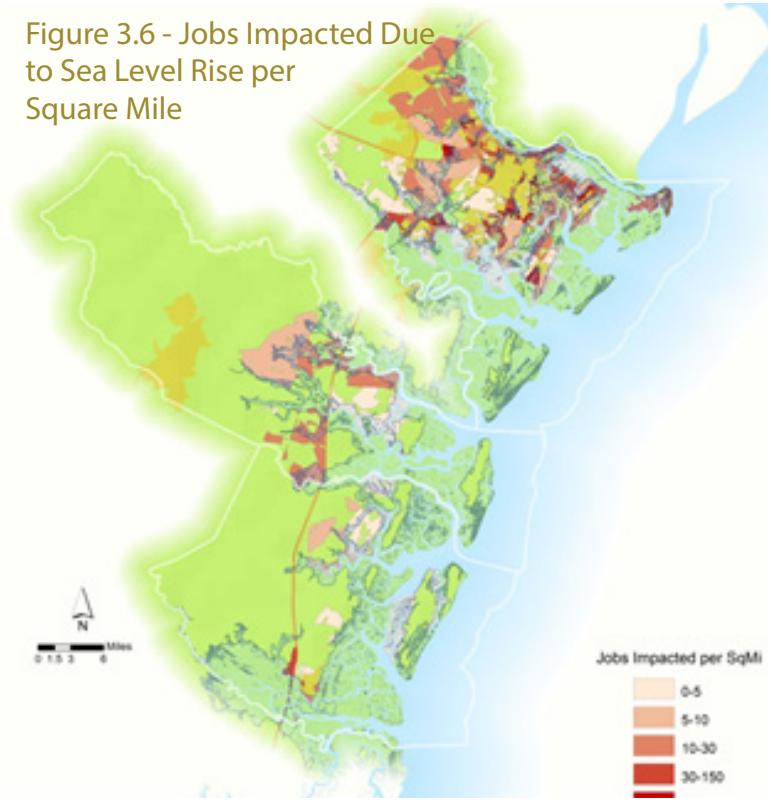


Figure 3.7 - Jobs Impacted Due to Sea Level Rise in Chatham County per Square Mile

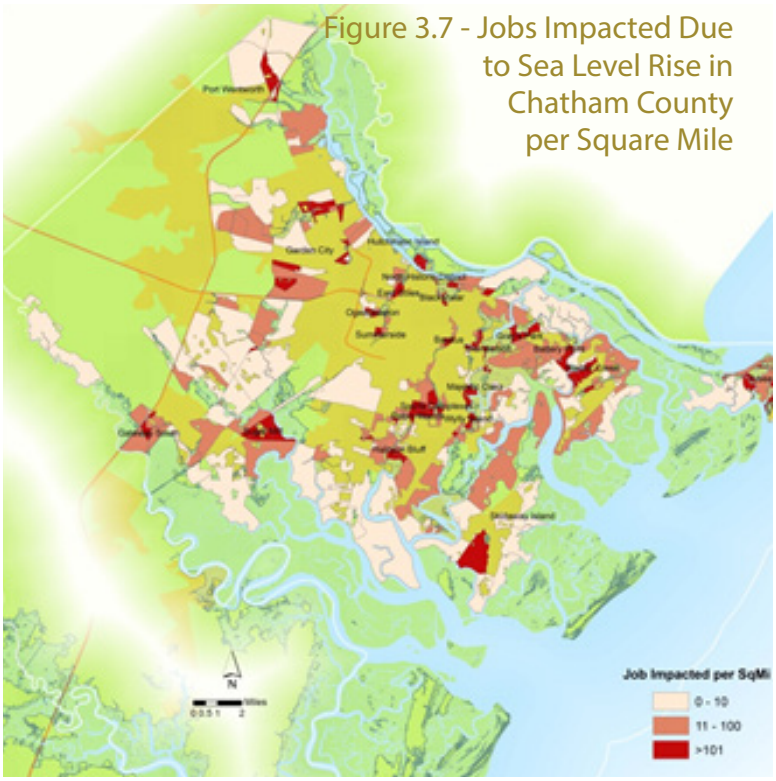


Table 3.5 - Estimated Jobs Impacted by County and Race

	Study Region	Chatham	Liberty	McIntosh
Total Jobs	141,653	126,919	12,998	1,736
White	87,524	78,874	7,383	1,267
Black	48,915	43,453	5,038	424
Indian, Alaska Native	459	398	58	3
Asian	3,187	2,843	312	32
Native Hawaiian	171	136	34	1
Multiple Races	1,397	1,215	173	9
Jobs Impacted	6,957	6,007	626	324
White Impacted	4,314	3,744	322	247
Black Impacted	2,380	2,029	282	69
Native Indian Impacted	31	28	3	-
Asian Impacted	155	141	7	6
Native Hawaiian Impacted	10	8	2	-
Multiple Races Impacted	67	56	10	10
White in Jobs Impacted	62.0%	62.3%	51.4%	76.5%
Black in Jobs Impacted	34.2%	33.8%	45.1%	21.2%
Native Indian in Jobs Impacted	0.4%	0.5%	0.5%	0.0%
Asian in Jobs Impacted	2.2%	2.3%	1.2%	1.9%
Native Hawaiian in Jobs Impacted	0.1%	0.1%	0.3%	0.0%
Multiple Races in Jobs Impacted	1.0%	0.9%	1.5%	0.4%
Unemployment rate for White	4.9%	4.7%	4.4%	19.5%
Unemployment rate for Black	4.9%	4.7%	5.6%	16.2%
Unemployment rate for Native Indian	6.7%	7.0%	5.2%	0.0%
Unemployment rate for Asian	4.9%	5.0%	2.4%	19.3%
Unemployment rate for Native Hawaiian	5.8%	6.0%	5.2%	0.0%
Unemployment rate for Multiple Races	4.8%	4.6%	5.6%	14.9%

Table 3.5 describes job losses by race. The white population holds 62.0% of the jobs impacted and 34.2% of the jobs impacted are presently held by the black population. Only 1.8% of the employed population were other races. In the SLR scenario, the unemployment rate does not differ greatly between different racial groups. Exceptions to the general pattern are McIntosh County where 76.5% of the impacted jobs are held by white people and Liberty County where 45.1% of the impacted jobs are held by black people.

The impacts based on North American Industry Classification System (NAICS) job categories are shown in Table 3.6 and Table 3.7. The current top 5 largest employers in the study region are hotels and restaurants, retail trades, health care, manufacturing, and education, each with over 12,000 employees. Correspondingly, hotel and restaurant, retail trade and health care employment categories will experience the highest percentage of jobs impacted (16.2%, 10.7% and 11.6%). Manufacturing and education are not as severely impacted in comparison, making up only 6.0% and 1.1% of the total jobs impacted. NOTE: Please kill 2nd half of Table 3.7

An analysis of jobs impacted by education level is shown in Table 3.8. The data is only collected for employees over age 30, so the total number does not add to 6,957 jobs as other tables do. It shows over one-half (55.6%) of the impacted jobs are presently occupied by people with some college or a college education. The percentage of education levels in jobs impacted does not vary greatly across three counties. The highest unemployment rate, 5.1%, occurs with employees of education below high school and the lowest unemployment rate, 4.0%, occurs with

Table 3.6 - Estimated Jobs Impacted by County and NAICS Industry

	Study Region	Chatham	Liberty	McIntosh
Total Jobs	141,653	126,919	12,998	1,736
Agriculture &fishing, forestry	102	67	28	7
Mining, and oil	29	25	-	4
Utilities	595	324	267	4
Construction	5,968	5,118	789	61
Manufacturing	12,588	11,074	1,477	37
Wholesale trade	4,998	4,919	53	26
Retail trade	19,211	16,939	1,828	44
Transportation	8,904	8,035	826	43
Information	2,185	1,997	127	61
Finance and insurance	3,515	3,252	240	23
Real estate and renting	2,209	1,796	382	31
Professional service	5,058	4,502	529	27
Company management	2,070	1,997	-	73
Administration	10,498	9,820	674	
Educational services	12,120	10,847	917	356
Health care	16,094	14,765	1,301	28
Arts and recreation	1,781	1,765	11	5
Hotel and restaurant	19,496	17,590	1,651	255
Other services	4,649	3,696	920	33
Public administration	9,583	8,391	978	214
Jobs Impacted	6,957	6,007	626	324
Agriculture &fishing, forestry Impacted	8	-	2	5
Mining, and oil Impacted	6	4	-	2
Utilities Impacted	23	4	17	2
Construction Impacted	415	314	79	22
Manufacturing Impacted	418	191	227	-
Wholesale trade Impacted	426	418	2	6
Retail trade Impacted	747	535	19	192
Transportation Impacted	511	330	164	16
Information Impacted	26	17	-	9
Finance and insurance Impacted	46	44	-	3
Real estate, and renting Impacted	126	124	2	-
Professional service Impacted	198	189	4	5
Company management Impacted	403	403	18	-
Administration Impacted	721	701	9	2
Educational services Impacted	79	70	48	-
Health care Impacted	805	754	-	3
Arts and recreation Impacted	458	458	9	-
Hotel and restaurant Impacted	1,125	1,071	24	45
Other services Impacted	197	169	2	4
Public administration Impacted	221	211	2	8

Table 3.9 - Employment impacted in large cities and towns

City/Town	Employments Im	High Earning Employments Impacted
Thunderbolt	31	9
Talahi Island	32	10
Darien	33	6
Bloomingdale	40	18
Isle of Hope	60	27
Tybee Island	62	13
Montgomery	83	22
Skidaway Island	101	46
Port Wentworth	110	41
Pooler	148	49
Whitemarsh Island	152	44
Garden City	165	36
Georgetown	173	40
Hinesville	193	49
Wilmington Island	374	105
Savannah	1,778	311
Total	3,532	824

employees of education above Bachelor's degree. The distribution of impacted work places is shown in Figure 3.6; the blocks are mapped using the number of jobs impacted per square mile. The work places with the highest concentration of SLR impacted jobs are distributed around Savannah and Tybee Island. Most of these places are located on Tybee Island, in the north of the Historic District along the Savannah River, Garden City, Thunderbolt, Robin Woods & Sports Complex, Hutchinson Island, and Port Wentworth. Figure 3.7 is a magnified version of Figure 3.6 that shows work places near Savannah with the highest concentration

Figure 3.8 - Working Places with Intense Concentration of Jobs that are Impacted per Square Mile

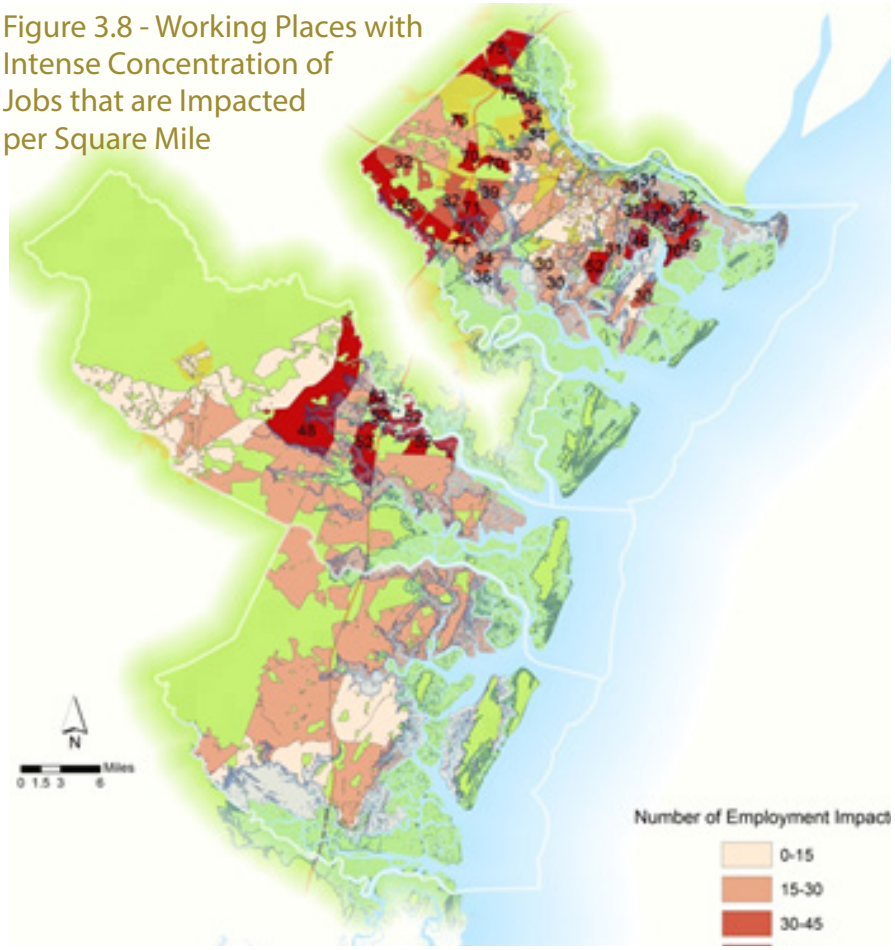


Table 3.7 - Estimated NAICS Percentage in and Unemployment Rate for Jobs Impacted

	Study Region	Chatham	Liberty	McIntosh
Agriculture &fishing in Jobs Impacted	0.1%	0.0%	0.3%	1.6%
Mining, and oil in Jobs Impacted	0.1%	0.1%	0.0%	0.5%
Utilities in Jobs Impacted	0.3%	0.1%	2.7%	0.5%
Construction in Jobs Impacted	6.0%	5.2%	12.6%	6.9%
Manufacturing in Jobs Impacted	6.0%	3.2%	36.3%	0.0%
Wholesale trade in Jobs Impacted	6.1%	7.0%	0.4%	1.8%
Retail trade in Jobs Impacted	10.7%	8.9%	3.0%	59.5%
Transportation in Jobs Impacted	7.3%	5.5%	26.2%	5.1%
Information in Jobs Impacted	0.4%	0.3%	0.0%	2.9%
Finance and insurance in Jobs Impacted	0.7%	0.7%	0.0%	0.8%
Real estate and renting in Jobs Impacted	1.8%	2.1%	0.3%	0.1%
Professional service in Jobs Impacted	2.8%	3.1%	0.6%	1.5%
Company management in Jobs Impacted	5.8%	6.7%	0.0%	0.0%
Administration in Jobs Impacted	10.4%	11.7%	3.0%	0.6%
Educational services in Jobs Impacted	1.1%	1.2%	1.4%	0.0%
Health care in Jobs Impacted	11.6%	12.5%	7.7%	0.8%
Arts and recreation in Jobs Impacted	6.6%	7.6%	0.0%	0.0%
Hotel and restaurant in Jobs Impacted	16.2%	17.8%	1.4%	13.8%
Other services in Jobs Impacted	2.8%	2.8%	3.8%	1.2%
Public administration in Jobs Impacted	3.2%	3.5%	0.3%	2.4%
Unemployment rate for Agriculture &fishing	7.5%	0.3%	7.8%	74.7%
Unemployment rate for Mining and oil	20.5%	16.8%	0.0%	43.7%
Unemployment rate for Utilities	3.8%	1.2%	6.4%	43.7%
Unemployment rate for Construction	7.0%	6.1%	10.0%	36.5%
Unemployment rate for Manufacturing	3.3%	1.7%	15.4%	0.0%
Unemployment rate for Wholesale trade	8.5%	8.5%	4.3%	22.9%
Unemployment rate for Retail trade	3.9%	3.2%	1.0%	43.3%
Unemployment rate for Transportation	5.7%	4.1%	19.9%	38.1%
Unemployment rate for Information	1.2%	0.8%	0.0%	15.4%
Unemployment rate for Finance and insurance	1.3%	1.3%	0.0%	11.4%
Unemployment rate for Real estate and renting	5.7%	6.9%	0.4%	1.0%
Unemployment rate for Professional service	3.9%	4.2%	0.8%	17.6%
Unemployment rate for Company management	19.5%	20.2%	0.0%	0.0%
Unemployment rate for Administration	6.9%	7.1%	2.7%	44.6%
Unemployment rate for Educational services	0.6%	0.6%	1.0%	0.0%
Unemployment rate for Health care	5.0%	5.0%	3.7%	9.6%
Unemployment rate for Arts and recreation	25.7%	26.0%	0.0%	0.0%
Unemployment rate for Hotel and restaurant	5.8%	6.0%	0.5%	17.6%
Unemployment rate for Other services	4.2%	4.6%	2.6%	12.1%
Unemployment rate for Public administration	2.3%	2.5%	0.2%	3.6%

Table 3.8 - Estimated Jobs Impacted by County and Education Level

	Study Region	Chatham	Liberty	McIntosh
Education <highschool (HS)	13,135	11,579	1,406	150
Education =highschool (HS)	32,882	29,204	3,265	413
Education = college (Co.)	34,342	30,855	3,074	413
Education >= Bachelor (Ba.)	23,211	21,258	1,703	250
Edu <HS Impacted	711	612	77	22
Edu =HS Impacted	1,641	1,421	154	66
Edu = Co. Impacted	1,610	1,384	155	71
Edu >=Ba. Impacted	921	818	75	28
Edu <HS in Jobs Impacted	14.6%	14.4%	16.8%	12.0%
Edu =HS in Jobs Impacted	33.6%	33.6%	33.4%	35.2%
Edu = Co. in Jobs Impacted	33.0%	32.7%	33.6%	37.8%
Edu >=Ba. in Jobs Impacted	18.9%	19.3%	16.3%	15.1%
Unemployment rate for Edu <HS	5.4%	5.3%	5.5%	15.0%
Unemployment rate for Edu=HS	5.0%	4.9%	4.7%	16.0%
Unemployment rate for Edu = Co.	4.7%	4.5%	5.0%	17.2%
Unemployment rate for Edu >= Ba.	4.0%	3.8%	4.4%	11.3%

Note: the statistics for employees' education is only conducted for employees 30 years of age and older. The total jobs impacted in this table does not coincide with the total number of 6,957 jobs as noted in the other jobs tables.

of jobs impacted. The specific location of blocks with the highest concentration are shown in Figure 3.8 with the label showing jobs impacted per square mile.

The total number of resident employees impacted is 3,865 in Chatham, 435 in Liberty, and 167 in McIntosh. Another 2,490 impacted employees live in areas outside of the study region, i.e., in areas further inland. A slight majority of impacted employees within the study region live in Savannah. The number of resident impacted employees based in various cities and towns is given in Figure 3.9. The resident employment impacted within the listed cities and towns totals 3,532, which accounts for 79% of the impacted employment within the study region.

Income and Poverty

Household income and poverty status are among the most basic variables used to indicate social vulnerability (Clark et al., 1998; Schmidtlein, Deutsch, Piegorsch, & Cutter, 2008; Shepard et al., 2011). Most commonly, researches use the federal poverty level of $23,050 for a family of four to identify populations that may be at risk of hardship in the face of disaster or drastic change in the physical landscape. There is also a substantial literature that concluded that the federal definition of poverty is badly out of date and significantly understates the measurement of poverty. Unfortunately, the census processes the only family-size sensitive measure of poverty, and it uses the federal definition. Consequently, this is the variable that we will use to analyze the three-county study

Figure 3.9 - Number of Employment Impacted

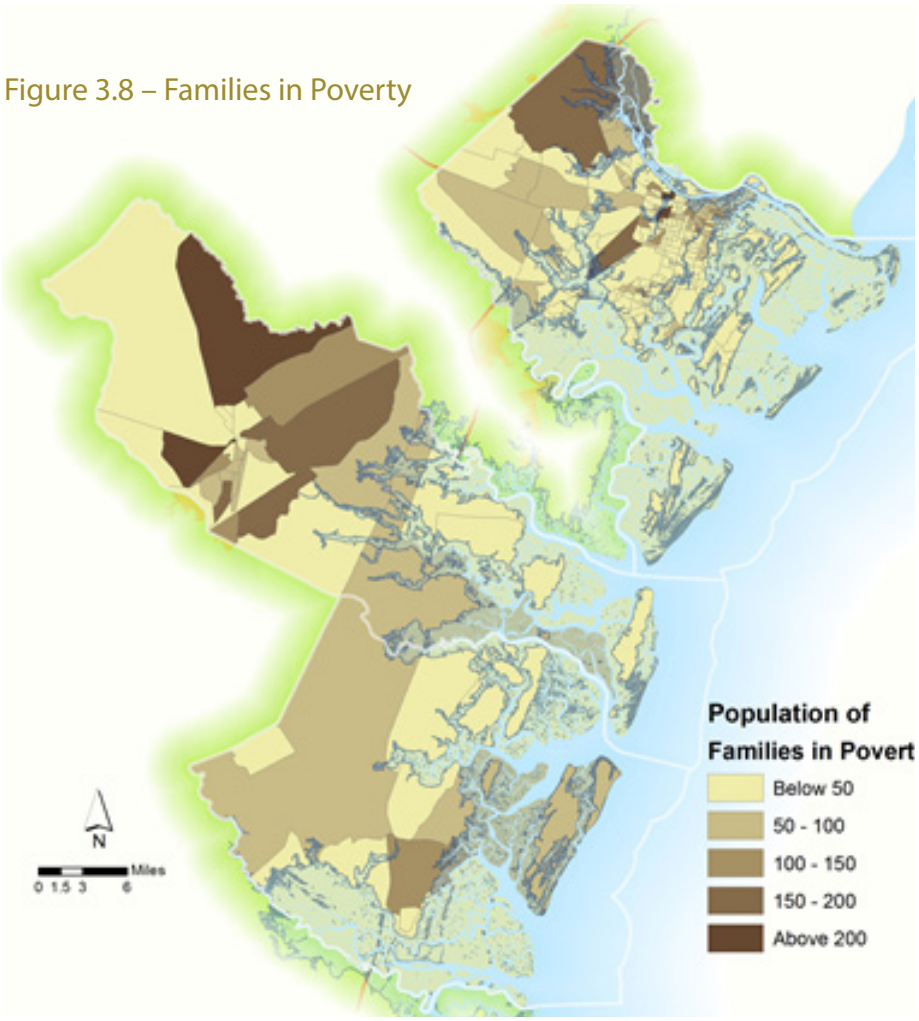
area. Figure 3.8 depicts the families below the poverty level. A review of this map shows that the areas with the highest numbers of families below poverty are generally more inland. The exception is the Savannah region. This region has areas of high poverty that will experience inundation due to sea level rise, particularly along the Savannah River west of the port.

Over three-quarters (79.9%) of the poverty level families subject to inundation live in Chatham County, and 60% of these families (438 ÷ 728 = 60.2%) are single parent, most of which (95.7%) are single female householders. In relative terms, 10.1% of impoverished Chatham County households will be inundated. The comparable figures for Liberty and McIntosh are 3.2% and 23.9%. The higher proportion in McIntosh derives from the fact that poor families live in Darien which will be inundated by both coastal waters and tidal portions of the Altamaha River.

Housing and the Built Environment

Vacant housing serves as both a measure of social vulnerability as well as an indicator of potential for adaptation. Although single-digit proportions of vacant housing should be considered normal in any neighborhood, an excessive level of vacant housing, as noted by Immergluck and Smith (2006), can reduce stability and increase crime risk. Current vacancy rates are higher than either stable rental and ownership markets would generally produce. Overall residential vacancies were 13.9% in Chatham, 13.9% in Liberty and 33.8% in McIntosh County. More precise data would help reveal whether the Chatham and Liberty County figures reflect the lingering effects of the housing and economic crisis that began in 2007 or lack of demand in particular segments of rental or ownership markets. The McIntosh County figure is

Figure 3.8 – Families in Poverty



well above normal market conditions even for the recent crisis. Further research is required to isolate the roles that market failures, rural depopulation and mis-classification of seasonal vacancies play in such a high proportion of unoccupied units. Within the study area, block groups with the highest number of vacant units are in the coastal areas of Liberty and McIntosh Counties (Figure 3.9).

Renter- and owner-occupied housing face different forms of vulnerability within the context of SLR (Figures 3.10-3.11). Compared to homeowners, renters are less likely to be insured against the personal property damage that may result from SLR, and are less likely to be knowledgeable about their personal risk living in a given area (Shepard et al 2012). However, because they have fewer financial ties to their homes, they may somewhat more easily relocate when necessary.

Regionally, more than one in six (13,845 ÷ 74,734 = 18.5%) owner-occupied homes will be threatened by inundation. More than one in ten (6,238 ÷ 54,029 = 11.5%) renters face inundation. But the highest proportion of inundated residences will be manufactured homes – 19.6% (2,634 ÷ 13,432). Taken together, 20,083 (15.6%) occupied homes will have to confront water at high tide or more frequently.

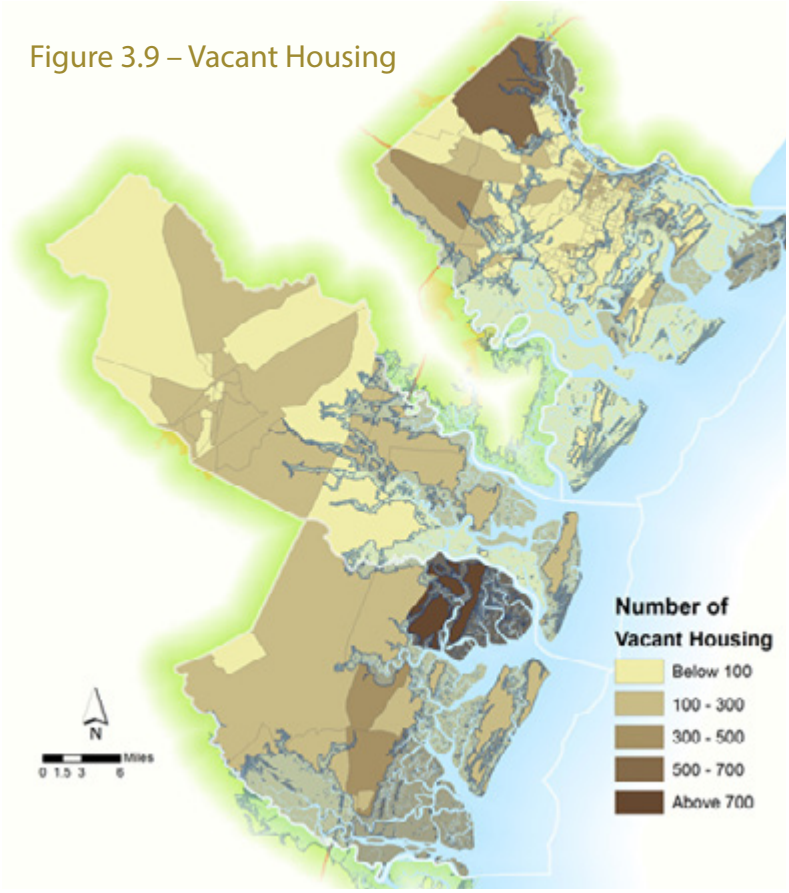
The highest proportion of owner-occupied homes facing inundation is in McIntosh County at over one-quarter (26.6%; 1,128 ÷ 4,247). Nearly one-fifth (11,742 ÷ 58,989 = 19.9%) of Chatham's owners face inundation, but Liberty's inundated owners will be both fewer in absolute number (975) and proportionately (8.5%).

Rental impact proportions will vary from 3.0% in Liberty County to 13.1% in Chatham to a high of 31.5% in McIntosh County.

Manufactured homes will lose 19.6% (2,634 ÷ 13,432) of their number to water. Both Chatham (26.3%) and McIntosh (29.0%) will lose over one-quarter of their manufactured homes. Liberty County will lose 8.8%.

Future local research should further identify the particularly vulnerable proportions of the 15,914 people in group homes in the region. Some of these residents will be students who are not, by themselves, especially vulnerable. Others will be in nursing homes and other facilities that will require substantial assistance. Determination of inundation for these facilities was not possible with the present data.

Figure 3.9 – Vacant Housing



A final housing-based variable that should be incorporated into any study of vulnerability is homelessness. People experiencing homelessness are subject to the negative effects of sea level rise because of their lack of permanent shelter, because of the particular reasons that precipitated their homelessness and because of their disconnect from information sources. Table 3.3 shows that there are currently 1,238 people in the study region who are homeless.

Mode of Transportation

Transportation-related variables are included in the indexes of Clark et al. (1998) and Shepard et al. (2012). Regionally there are 10,274 households that lack access to an automobile. It was not possible to determine how many of these households directly face inundation, but most are vulnerable to almost any form of hazardous event stemming from sea level rise because of their immobility. Most (84.0%) are in Chatham County, few (306 / 3.6%) are in McIntosh and 1,342 (15.6%) are in Liberty County.

Disability

Disability hinders the ability to cope with storms and storm damage (Clark, 1998). As a result, special measures for preparedness and evacuation considerations for need to be taken into consideration in the case of increased frequency of storm surges. Emergency evacuation plans should be adjusted to assure earlier warning and evacuation and the transportation for the physically less able or those with limited mobility (Clark, 1998). This data is suppressed in McIntosh County; however, an analysis in the other two counties reveals that 11% of the population in Chatham County is disabled; 31% of this population will be affected by sea level rise. In Liberty county 10% of the population is disabled; 15% of this population will be inundated. Although, data was available for these two areas, further data collection needs to be conducted in McIntosh County. The disabled population is among the most vulnerable and is at risk of entrapment during hazardous events if advance provisions are not put in place. Particular attention should be paid to elderly residents of high rise housing, where entrapment is probable. Locating these residents prior to hazardous events substantially decreases response time and allows for better preparation during an emergency. It is the responsibility of local governments to complete the data collection regarding the disabled population to ensure the highest standard of emergency preparedness.

Gullah-Geechee

Another important characteristic of the three county region is the Gullah-Geechee culture which is derived from West African ethnic groups who were enslaved on barrier islands from North Carolina to north Florida to grow rice, indigo, and cotton beginning in 1750. West African slaves were more desirable because of their ability to cope with the weather in the South and their knowledge and familiarity with the crops grown along the coast (New Georgia Encyclopedia, 2010). The heritage of these slaves survived to become the Gullah-Geechee culture, with rice, language, and spirituality persisting as cultural threads into the twentieth century. Because the Gullahs have preserved so much of their African culture, they are arguably the most clearly authentic African American

Figure 3.10 – Renter-Occupied Housing

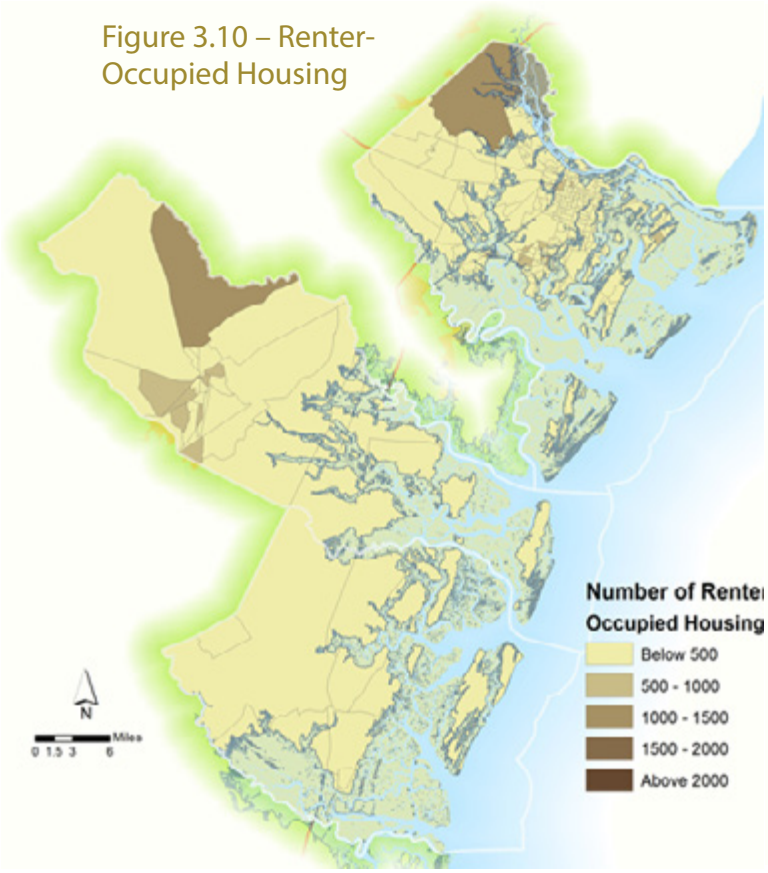
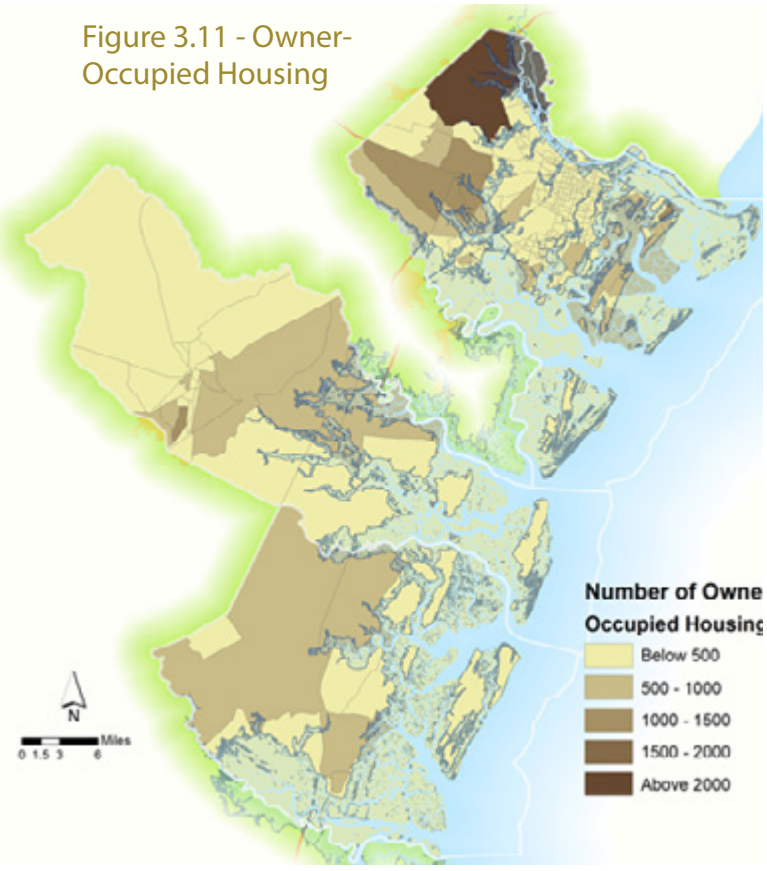


Figure 3.11 - Owner-Occupied Housing

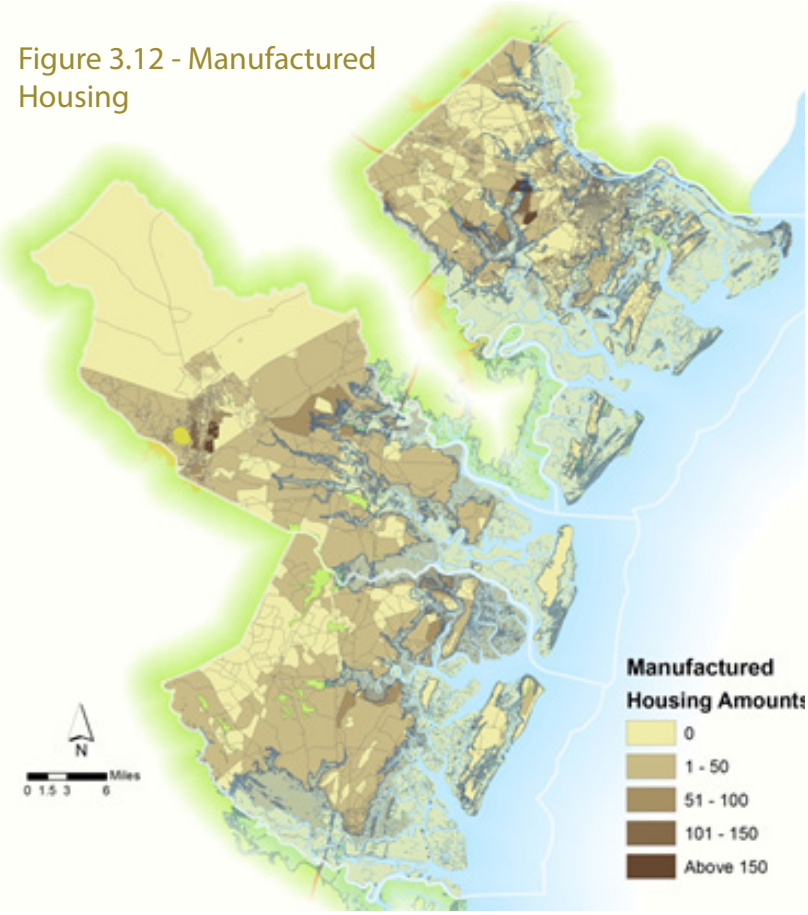


community in the United States (Walcott, 2002). The authenticity springs in part from their longevity in one place and strong sense of family and community, which has helped preserve the Gullah-Geechee language, a separate creole with roots in many West African languages. Additional cultural linkages are the weaving of baskets from sweetgrass, which were tools with a wide range of uses, from fanners to separate rice to storage for firewood and the harvesting of sugar cane to make rum, still practiced at sites such as the Geechee Kunda in Riceboro, Georgia (New Georgia Encyclopedia, 2010). The Gullah-Geechee have a strong tie to the lands of the Georgia coast and have survived in part by using the resources provided by the land. The community is presently struggling with issues of land ownership. In particular, difficulty with proving land ownership, disputes regarding taxes on land that has substantially increased in value, and lagging income among landowners bedevil residents.

Along with the difficulty in proving that one actually owns the land, increased property taxes have made it increasingly difficult for those who want to remain on their land. In some instances there are a large number of owners of one parcel of land that contacting all of the owners substantially delays any course of action related to the property. This is the case in a small area where many of the remaining Gullah-Geechee live, Hog Hammock on Sapelo Island. With the exception of a small number of recent sales that have increased both prices and taxes, the Gullah-Geechee land on this island is the only private land left in this area; the state owns the remaining 97%, which has been given over to nature preserves, marine research projects and a plantation built in 1802 (Severson, 2012). Of the land that is still owned by the Gullah-Geechee, increasing county taxes and a shifting economy have become a major cause for concern for those who still own property. The Gullah-Geechee face an uphill battle with respect to the financial and legal issues regarding their land.

Gullah-Geechee migration away from the coast and their remaining enclaves on their barrier islands and the immigration of African Americans, has made it difficult to determine from available census data how many Gullah-Geechee live in the Georgia Coastal area (National Park Service, ND). However, notable

Figure 3.12 - Manufactured Housing



concentrations of Gullah-Geechee population exist in the Pinpoint and Sandfly communities of Chatham County and the Hog Hammock community of McIntosh County (Chatham County Meeting Minutes, 2009). According to the 2010 Census, 77 residents live in Hog Hammock. The census data does not identify how many are Gullah-Geechee because the census does not track culture. The vulnerability that the Gullah-Geechee face is magnified because the population is difficult to identify and locate, but also because the unique and isolated areas where the Gullah-Geechee are located.

The isolation of the land where the Gullah-Geechee are located contributes to the cultural uniqueness. Hog Hammock consists of 434 acres of land on Sapelo Island, of which most is designated naturally and environmentally sensitive (Dowse et al., 2005). Nearly 90% of the marsh is covered by one species of plant, smooth cordgrass, Spartina alterniflora. To survive in estuarine areas, marsh plants are uniquely designed to tolerate the salt water that floods the marshes twice daily at high tide. The effect of sea level rise on Sapelo Island and Hog Hammock is magnified because water surrounds the land on all sides; 95% of the population lives in areas where sea level rise is projected to occur. Many presently on Sapelo Island travel by ferry to seek work; boats and ferries are the only mode of transportation to and from the island. The Gullah-Geechee who have maintained their community in Hog Hammock are not likely to want to move. A careful assessment of the risks and danger the community faces as the sea level rises should precede judgments about relocation. The Gullah-Geechee should be full participants in these assessments and the decisions that flow from them. It is too early to talk about imminent relocation, but not too early to begin to think about how to preserve both the community and the culture that resides in Hog Hammock. This can be achieved in a variety of ways but all necessitate the need for creative thinking. Increased emphasis on traveling by boat and educating the Gullah-Geechee on the effects of sea level rise are steps that can be taken while the overall process of planning for sea level rise in its nascent stages. If it proves feasible to retain the Gullah-Geechee residential community on the island, infrastructure needs to upgraded, because a majority of the roads on the island are not elevated or paved. Implementing infrastructure redesign could help allow the Gullah- Geechee to remain on or close to their land in Hog Hammock. Creative thinking will be required to preserve the remaining Georgia island outpost of Gullah-Geechee; however, Gullah-Geechee areas located inland will face similar challenges.

The Sandfly community is a historic African American community containing a core of Gullah-Geechee located on the outskirts of Savannah. Its borders include: Bacon Park Drive to the north, Howard Foss Drive to the east, Montgomery Cross Road to the south and Sallie Mood Drive to the west. Harry Truman Parkway divides the community down the center; this essentially creates west and east Sandfly. According to the 2010 Census, the population of Sandfly was 1,123 residents; this population was calculated using data from the census as well estimations for overlapping blocks.

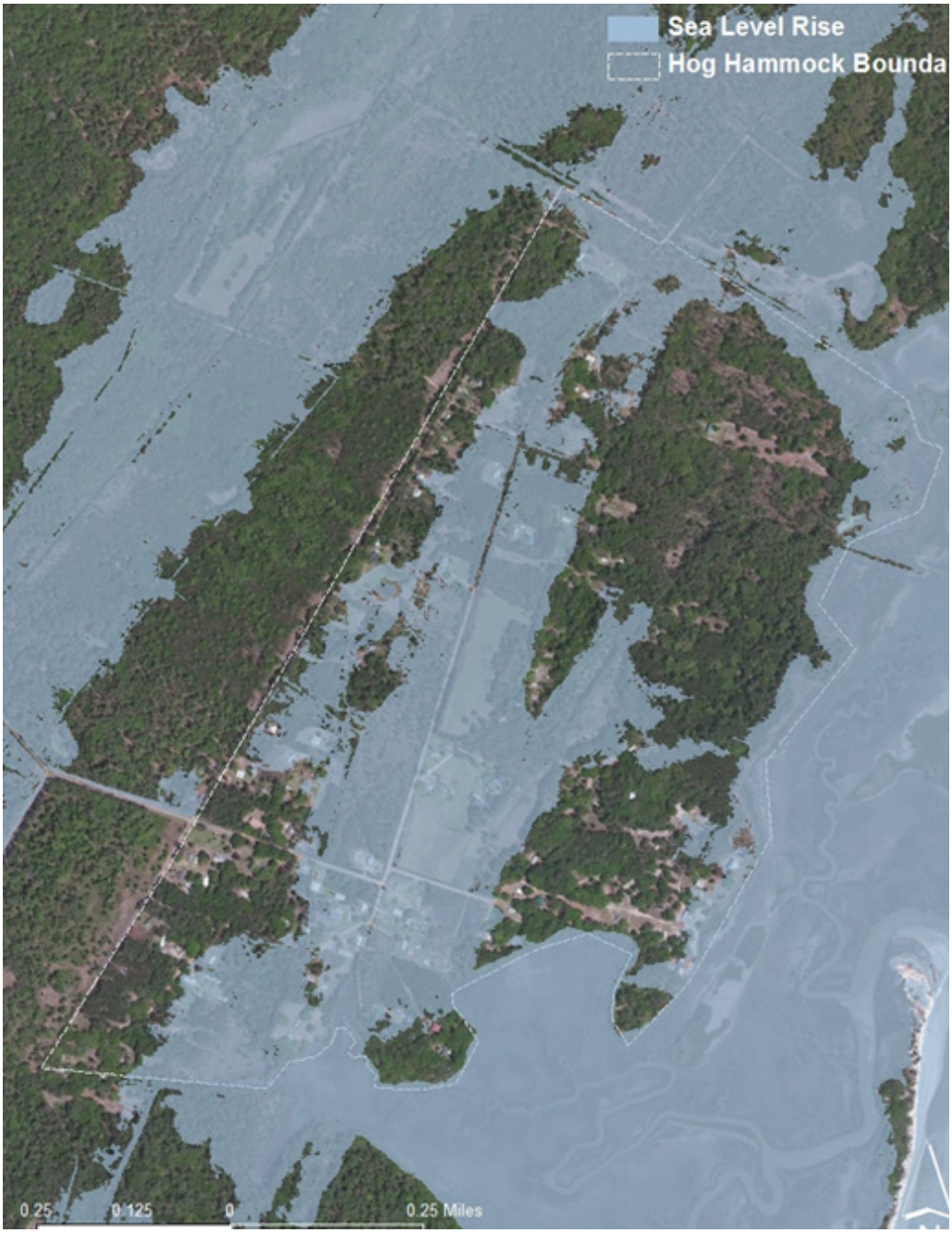
Some of its most important blocks will be affected by sea level rise. Census Block 1002, located just west of Harry Truman Parkway, is home to 132 residents and is also the site of the Georgia Regional Hospital at Savannah. Roads leading to this block will face partial inundation which will have an effect on health and personal care as well as employment. Chatham Aquatic Center, which is located on Census Block 1005 in southwest Sandfly, will be completely inundated unless a plan for protection implemented.

Approximately 60 historic sites in Georgia are listed in the Gullah-Geechee Heritage Corridor Management Plan and in the National Register of Historic Places (NRHP). These sites have a tie to either Gullah-Geechee history or culture (Gullah-Geechee Heritage Corridor Management Plan, 2012). Hog Hammock and Pinpoint are two communities listed, and they both contain historic districts that will be affected by sea level rise; Midway and West Darien both have historic districts that will also be affected. These areas are also home to several Gullah-Geechee.

Much of the information needed to assess the effects of sea level rise on individual Gullah-Geechee historic sites has been suppressed to preserve the sites. This suppression should not be allowed to retard preservation. A separate new analysis should be conducted to assess the threat of sea level rise to these sites and to develop recommendations for their protection and preservation.

Another area with prominent Gullah-Geechee connections is Pinpoint, which will face partial

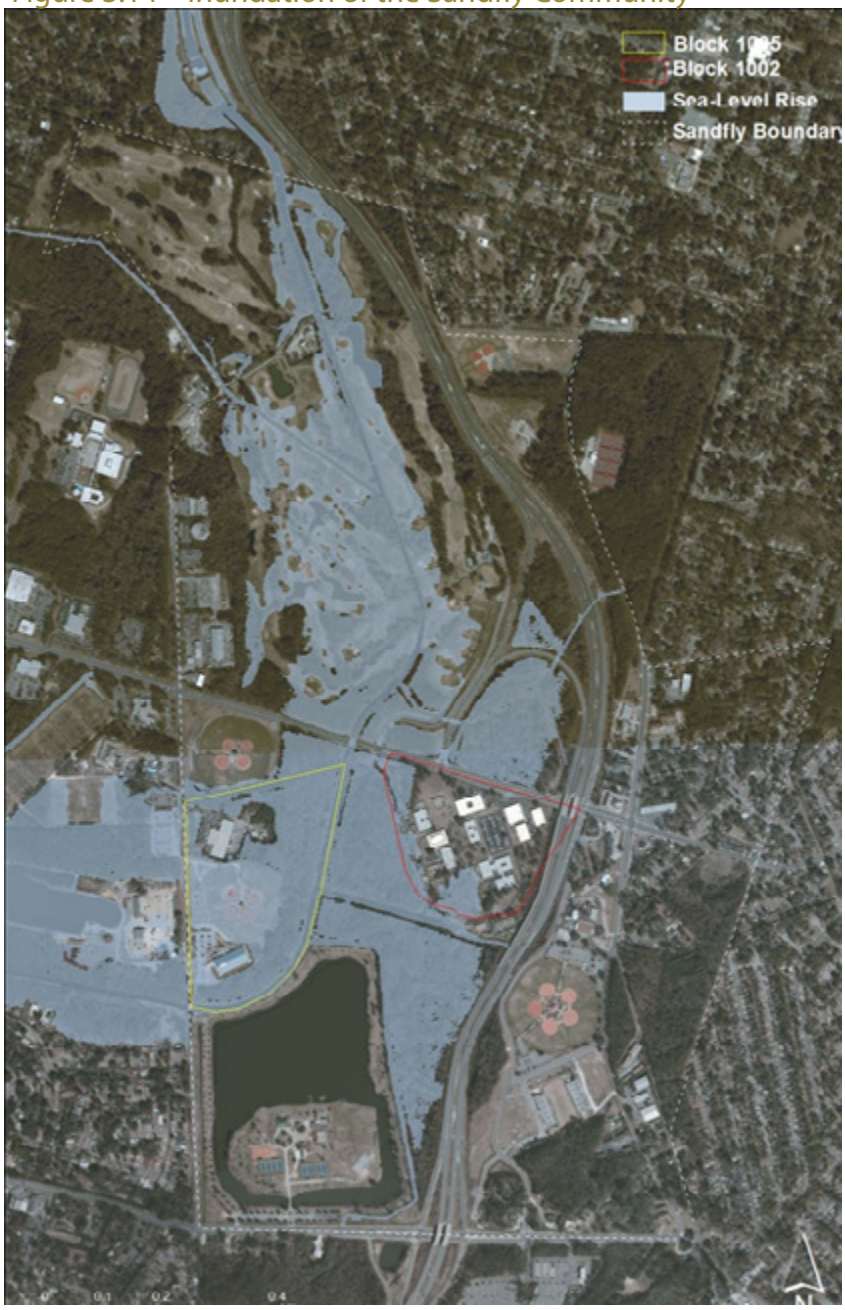
Figure 3.13 – Inundation of Hog Hammock



inundation. This area contains approximately 150 acres of land that includes river, forests, and wetland. Its boundaries are located north of the centerline of Bond Avenue, on the east by the centerline of the Diamond Causeway, on the south by Moon River, and on the west by specific parcels of land. According to the 2010 Census, this secluded area of Chatham County is home to 107 residents; 90 of whom live on Census Block 4011. This block is located less than one mile from the Pinpoint Heritage Museum. Preserving the museum identifies and preserves historic sites that are associated with the Gullah-Geechee culture for the benefit and education of the public. It also recognizes the important contributions made to American culture by the Gullah-Geechee. These objectives align with those identified in the Gullah-Geechee Corridor Management Plan. Preservation will be key in Pinpoint because sea level rise will have an impact on nearly one-half of the land.

Approximately 69 acres of land, made up of water, marsh, and wetlands will be inundated by sea level rise. Sea level rise will also limit access to the Pinpoint area. Diamond Causeway is the major thoroughfare connecting to Pinpoint. Sea level rise will inundate portions of the causeway east of Pinpoint making

Figure 3.14 – Inundation of the Sandfly Community



access very difficult. The residents located in Block 4011 will face a significant change, because sea level rise will cause the Moon River to rise and reach their property lines, which will likely place them in a floodplain. The intent to preserve the historic sites such as the Pinpoint Museum is one reason why the Gullah-Geechee Corridor Management Plan was adopted. To understand how this plan will assist in combating the effects of sea level rise, a better understanding of the plan is important.

The Gullah-Geechee Corridor Management Plan is intended to be a catalyst for future action and creates a comprehensive plan for the Gullah-Geechee. The plan affects the entire corridor which covers 12,000 square miles along the coast of from Wilmington, N.C., to St. Augustine, Florida (Gullah-Geechee Cultural Heritage Corridor Plan, 2012). Specific objectives outlined in the plan address education, economic development, and documentation and preservation related to the Gullah-Geechee culture. The educational component focuses on recognizing the important contributions made to American culture and history by the Gullah-Geechee, on assisting public and private entities to interpret the story of the Gullah-Geechee and preserving Gullah-Geechee folklore, arts, crafts, and music; and on assisting in identifying and preserving sites, historical data, artifacts, and objects associated with the Gullah-

Geechee for the benefit and education of the public (Gullah-Geechee Management Corridor Plan, 2012). The economic development portion focuses on the economic sustainability of the Gullah-Geechee people and their communities; this includes the need for additional employment opportunities, adequate job training programs, and education opportunities in the corridor (Gullah-Geechee Management Corridor Plan, 2012). Finally, documentation and preservation recommendations focus on preserving Gullah-Geechee resources, primarily through documentation. The plan identifies documenting tangible and intangible resources as a foundation for preservation of assets, educational opportunities, and also identifies increased heritage tourism as a means to not only preserve the culture for the current generation but also for future generations (Gullah-Geechee Management Corridor Plan, 2012). A Federal Commission will work with the National Park Service and several state historic offices also will work with government representatives and the Gullah-Geechee to resolve obstacles that hinder the Gullah-Geechee from achieving the goals set forth in the Management Plan.

The Gullah-Geechee view the earth and sea as the sacred resting places of the departed (Gullah-Geechee Management Corridor Plan). This relationship is key in identifying areas and historical sites to preserve in the face of sea level rise. Behavior Cemetery, located 1.25 miles west of the Hog Hammock Historic District, is a post-Civil War African American burial ground. The oldest tombstone death date is 1890, however, tradition holds that burials have taken place this location since antebellum times (National Register of Historic Places). This cemetery is believed to be a slave burial ground because it is located close to the former slave quarters of Thomas Spalding's Plantation (National Register of Historic Places). The Georgia Department of Natural Resources has recently directed the documentation of multiple historic resources along the coast and on Sapelo Island. For security reasons, the location and documentation of many of these resources are not public information. As sea level rise threatens Sapelo Island and other areas central to the Gullah-Geechee, care needs to be taken to develop means to preserve these resources.

The Gullah-Geechee are a proud people that have overcome obstacles from enslavement in Africa to their struggles to keep their land. The culture is now threatened by mainstream societal norms, pressure from developers, and by their access to the land and water on which they depend. A clear method to help preserve these lands in the case of sea level rise will be crucial in keeping the Gullah-Geechee people safe, as well as preserving elements of culture.

Data limitations

Although we sought to include the most comprehensive and rigorous data and analysis available in our assessment of social vulnerability, there are several limitations to the data that we used. Most data was obtained from the 2006-2010 American Community Survey (ACS), although additional data was also obtained from the 2010 Census and the 2010 Longitudinal Employer-Household Dynamics Origen-Destination Statistics (LODES 2010).

American Community Survey Data

The American Community Survey, which replaced the Census long form used until 2000, is a yearly survey administered by the Census to collect detailed demographic information from a sample of United States households. The ACS is intended to provide a "continuous stream of updated information… [which] will revolutionize the way we use data to understand our communities" (Census 2008). ACS data is released on one-, three-, and five-year bases, with data from multiple years aggregated to provide greater precision and reliability than is possible with a sample from a single year. However, the ACS data comes with several caveats. ACS data used in this analysis is from the five-year 2006-2010 data release in order to enable the use of the most reliable and precise figures made available. Because data is combined over five years, it is less current than data released from a single year, such as 2010. Even over the five-year time span, the block group level is the smallest geography for which data is released. Furthermore, over this time span, some data remains unavailable at the block group level. In particular, information on people with disabilities and transportation modes is not available at a geography we were able to utilize.

United States Census Data

The US Census records basic information about the entire US population on a ten-year basis. Although the US Census provides the most exhaustive and accurate records of population, it contains only a limited set of variables (Census 2008). As a result, for consistency

and comprehensiveness, data from the ACS was used except for our block-level population and household inundation analysis. At the block level, only Census data is available.

LODES Data

The general economic pattern and employment loss are derived from LEHD Origin-Destination Employment Statistics (LODES) dataset (OnTheMap, 2010). This dataset is released as part of the OnTheMap application and in raw form as CSV text files. The most recent published data is in 2010 and the block is defined by the Census Bureau TIGER file 2010. This project is supported by the Employment and Training Administration (ETA) at the U.S. Department of Labor. The employment data with LODES comes from several sources: Unemployment Insurance (UI) Wage Records reported by employers and maintained by each state for the purpose of unemployment insurance system, the Office of Personnel Management (OPM), and the Quarterly Census for Employment and Wages (QCEW) collected by each state under an agreement with the Bureau of Labor Statistics (BLS). Age, earnings, and industry profiles are compiled by the Census

Figure 3.15 – Inundation of the Pinpoint Community

Bureau from a state's records and are supplemented with other Census Bureau source data. And since final compilations are performed by the Census Bureau, LODES is consistent with the data provided by Census Bureau.

Methodology

Finally, although we took pains to use methodologies supported by our review of the literature, we must note that they remain imperfect. First, it is difficult to measure some variables such as social capital and site-specific variables quantitatively. Without reliable measures that are supported by the literature, we chose to exclude these variables from most of our quantitative analyses. Second, our methodologies attempt to quantify social phenomena and to compare things that are not always directly comparable. All methodologies should be taken with a grain of salt, since they are necessarily imprecise. In particular, the magnitudes of the populations which will be exposed to sea level rise should be considered rough estimates. Additionally, the social vulnerability assessment should be viewed as an attempt to identify areas that will need special attention in preparation for sea level rise, and not a precise estimate of the locations that will be impacted by sea level rise.

TEMPORAL ANALYSIS

While it is important to look at the sum of the impacts of one-meter sea level rise at the end of the study period, it is also useful to examine temporal scope of those effects. This can be helpful for two reasons: 1) understanding the dynamics of change, and 2) timing adaption efforts. In order to project sea level rise during the interim periods, a high-resolution digital elevation model (DEM) was used to create new data. The impacts on various factors were then calculated using this new data, the results of which are presented following an overview of the data and methods used.

Temporal Analysis

Sea level rise for four periods (2040, 206, 2085, and 2100) were estimated using the digital elevation model based on Tevrejeva, Moore and Grinstead's projections (2012). The primary focuses of the temporal analysis are inundation of primary roads, facilities (an aggregation of historic resources, landfills, sewage and hazardous waste sites, and land cover. Methods are described in more detail in Appendix III.

2040: 0.2 Meter Sea Level Rise

By 2040, nearly 10% of all land in the three county area is projected to be inundated by the 0.2 meter rise of sea level, with the majority of all inundation occurring in Chatham County (68.65 square miles, 16.32% of total land area). Overall, it is clear most of this initial inundation is composed of wetlands in all three counties (127.19 out of 130.02 square miles inundated, 97.82%), easily attributed to the low-lying nature of wetland. While over one-third (36.70%) of all wetland in Chatham county will be submerged by 2040, one-quarter (25.97%) of

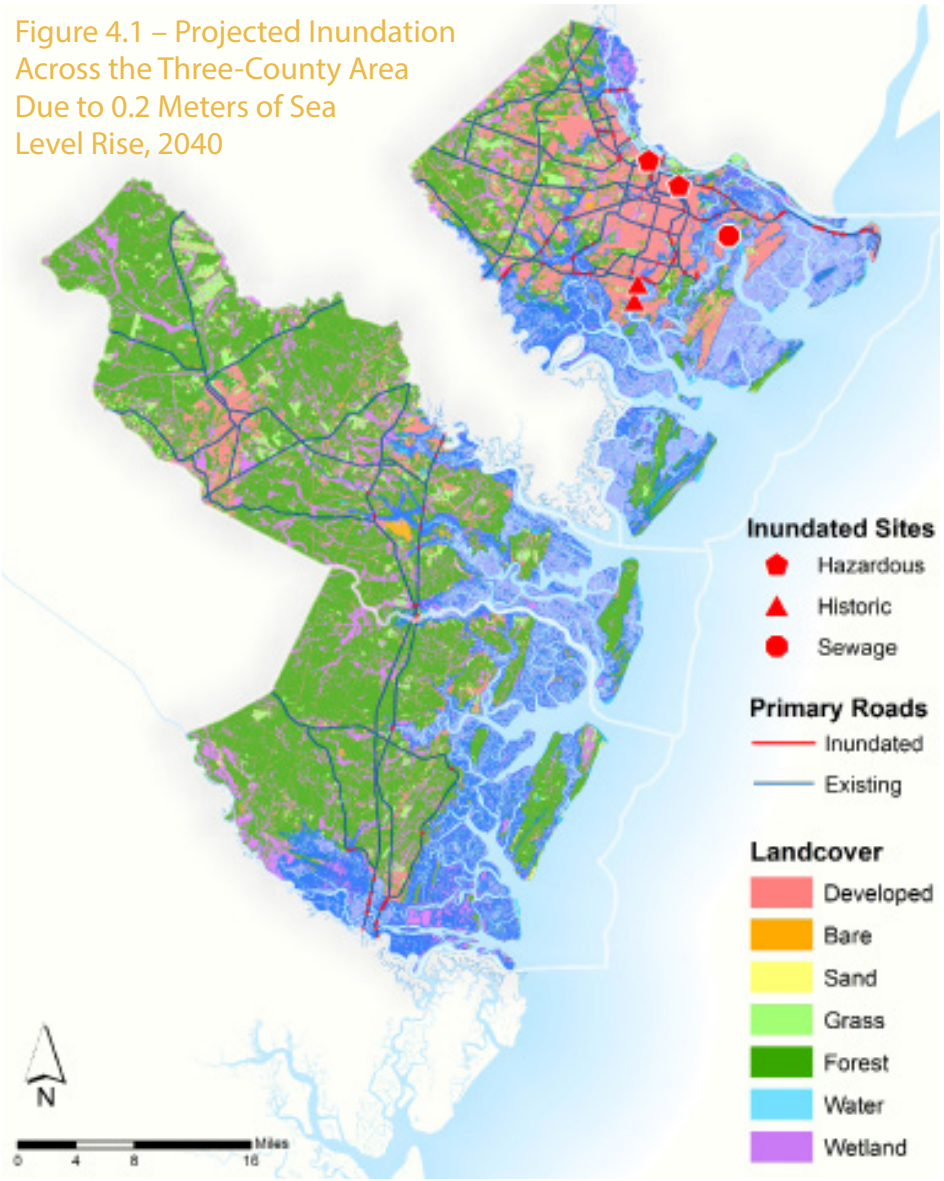
Table 4.1 – Overall and Wetland Inundation in the Three-County Area Due to 0.2 Meters of Sea Level Rise, 2040

	Area (sq. miles)	Area Inundated (sq. miles)	% of Area Inundated	Wetland Area (sq. miles)	Wetland Inundated (sq. miles)	% of Wetland Inundated
Chatham	420.74	68.65	16.32%	181.91	66.76	36.70%
Liberty	509.44	27.09	5.32%	132.65	26.76	20.18%
McIntosh	419.11	34.29	8.18%	175.19	33.67	19.22%
Overall	1349.29	130.02	9.64%	489.75	127.19	25.97%

Table 4.2 – Developed Land and Infrastructure Inundation in the Three-County Area Due to 0.2 Meters of Sea Level Rise, 2040

	Developed Area (sq. miles)	Developed Inundated (sq. miles)	% of Developed Inundated	Primary Roads (miles)	Primary Roads Inundated (miles)	Facilities	Inundated Facilities
Chatham	112.21	0.41	0.37%	211.18	3.70	151	3
Liberty	50.36	0.03	0.07%	141.11	0.23	27	0
McIntosh	24.43	0.22	0.88%	83.04	0.76	16	0
Overall	187.00	0.66	0.35%	435.33	4.70	194	3

Figure 4.1 – Projected Inundation Across the Three-County Area Due to 0.2 Meters of Sea Level Rise, 2040



the three county area's wetland be inundated overall.

Developed areas will not be significantly affected by 2040; overall, under 1% of developed areas will be affected. Most of the impacts will be in Chatham County, which is by far the most urbanized area in the region.

Containing nearly half of all the region's primary roads, Chatham County will also be loci to most of the inundation (3.7/4.7 miles inundated) of this factor. This is also the case with Chatham's facilities: three will be partially or completely inundated by 2040. This includes a historic area (Vernonburg Historic District), a sewage site, and a hazardous site located adjacent to Truman Parkway.

2065: 0.4 Meter Sea Level Rise

The addition of another 0.2 meters of sea level rise from 2040 to 2065 will double the total amount of land inundated in all three counties, rising to encompass almost one-fifth (19.32%) of the overall area. Once again, most of this land will be wetland, with over one-half (51.85%) of all pre-existing wetlands submerged in the three county area.

As wetlands continue to gradually shrink, developed land will remain mostly protected from sea level rise in 2065. Overall, fewer developed areas will be inundated from 2040 to 2065 than from the base year to 2040, with much of it again occurring in Chatham County.

The inundation to primary roads will continue in Chatham County, although at a reduced rate. Two more facilities will be inundated in

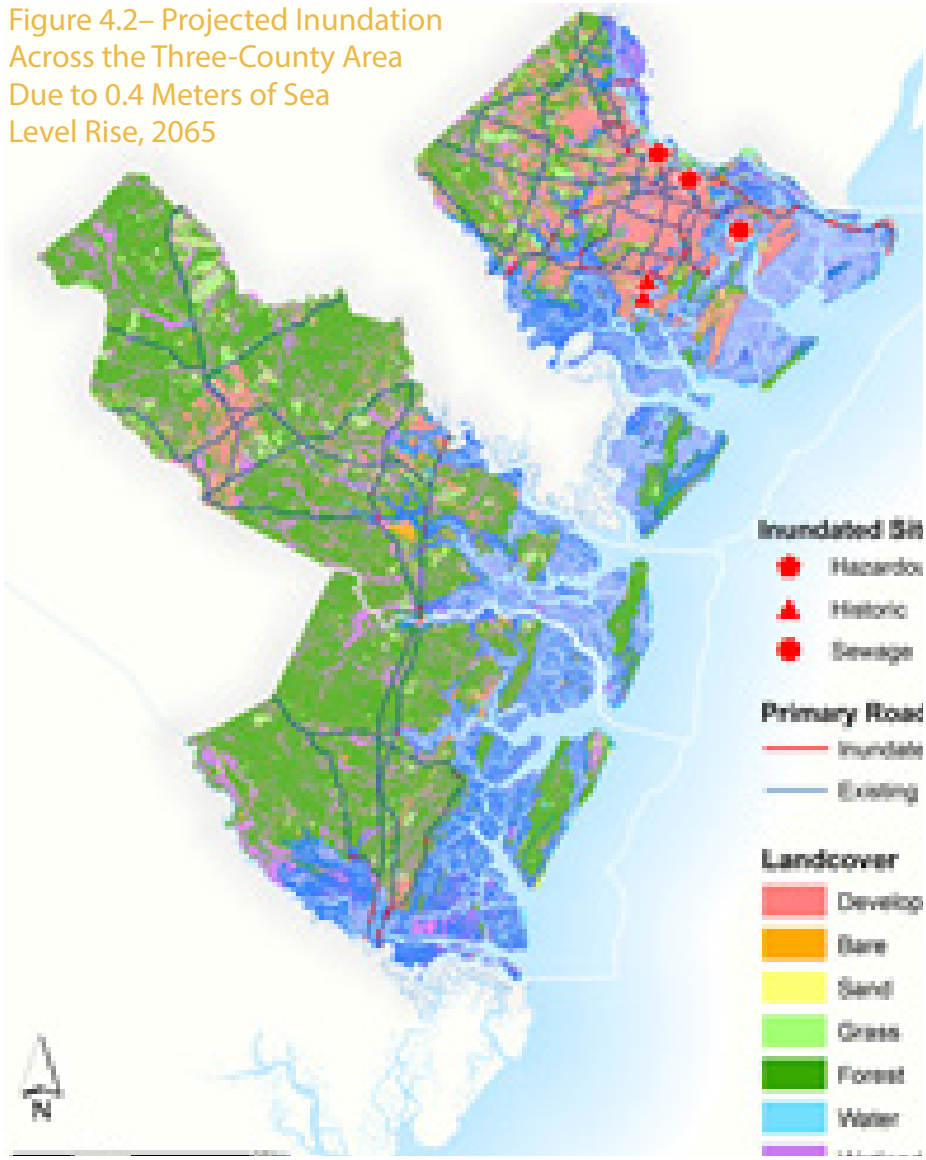
Table 4.3 – Overall and Wetland Inundation in the Three-County Area Due to 0.4 Meters of Sea Level Rise, 2065

	Area (sq. miles)	New Area Inundated (sq. miles)	Total Area Inundated (sq. miles)	% of Area Inundated	Wetland Area (sq. miles)	New Wetland Inundated (sq. miles)	Total Wetland Inundated (sq. miles)	% of Wetland Inundated
Chatham	420.74	51.02	119.66	28.44%	181.91	48.74	115.50	63.49%
Liberty	509.44	23.28	50.37	9.89%	132.65	22.82	49.58	37.38%
McIntosh	419.11	56.36	90.64	21.63%	175.19	55.16	88.83	50.71%
Overall	1349.29	130.65	260.68	19.32%	489.75	126.72	253.91	51.85%

Table 4.4 – Developed Land and Infrastructure Inundation in the Three-County Area Due to 0.4 Meters of Sea Level Rise, 2065

	Developed Area (sq. miles)	Developed Inundated (sq. miles)	% of Developed Inundated	Primary Roads (miles)	New Primary Roads Inundated (miles)	Total Primary Roads Inundated (miles)	Facilities	New Inundated Facilities	Total Inundated Facilities
Chatham	112.21	0.75	0.67%	211.18	2.40	6.10	151	2	5
Liberty	50.36	0.06	0.12%	141.11	0.10	0.33	27	0	0
McIntosh	24.43	0.30	1.24%	83.04	0.20	0.96	16	0	0
Overall	187.00	1.12	0.60%	435.33	2.70	7.40	194	2	5

Figure 4.2– Projected Inundation Across the Three-County Area Due to 0.4 Meters of Sea Level Rise, 2065



Chatham, including an additional section of the Vernonburg Historic District and the Central of Georgia RR/Bernuth-Lembcke hazardous site.

2085: 0.6 Meter Sea Level Rise

With 0.6 meters of sea level rise, total inundation will slow down across the three county study area, although a smaller portion of it will affect wetlands. By this time, however, over two-thirds (67.97%) of all existing wetlands will be displaced, much of this in Chatham and McIntosh counties.

As the majority of wetlands across the three county area become inundated, less total land is affected by the additional 0.2 meter sea level rise by 2085. Despite this fact, a greater portion of non-wetland is impacted than in the previous periods, including developed land. Almost half of the total developed land inundation that will occur by 2085 will happen due to the 0.2 meter sea level rise in the 20-year period between 2065 and 2085.

Between 2065 and 2085, a significant amount (4.46 miles) of primary roads will be inundated in Chatham County by the addition of 0.2 meters in sea level. An additional two facilities will be partially submerged at this point, including the Fort King George historic site in Chatham County and the ARAMARK Uniform Services hazardous site in McIntosh County.

2100: 0.8 Meter Sea Level Rise

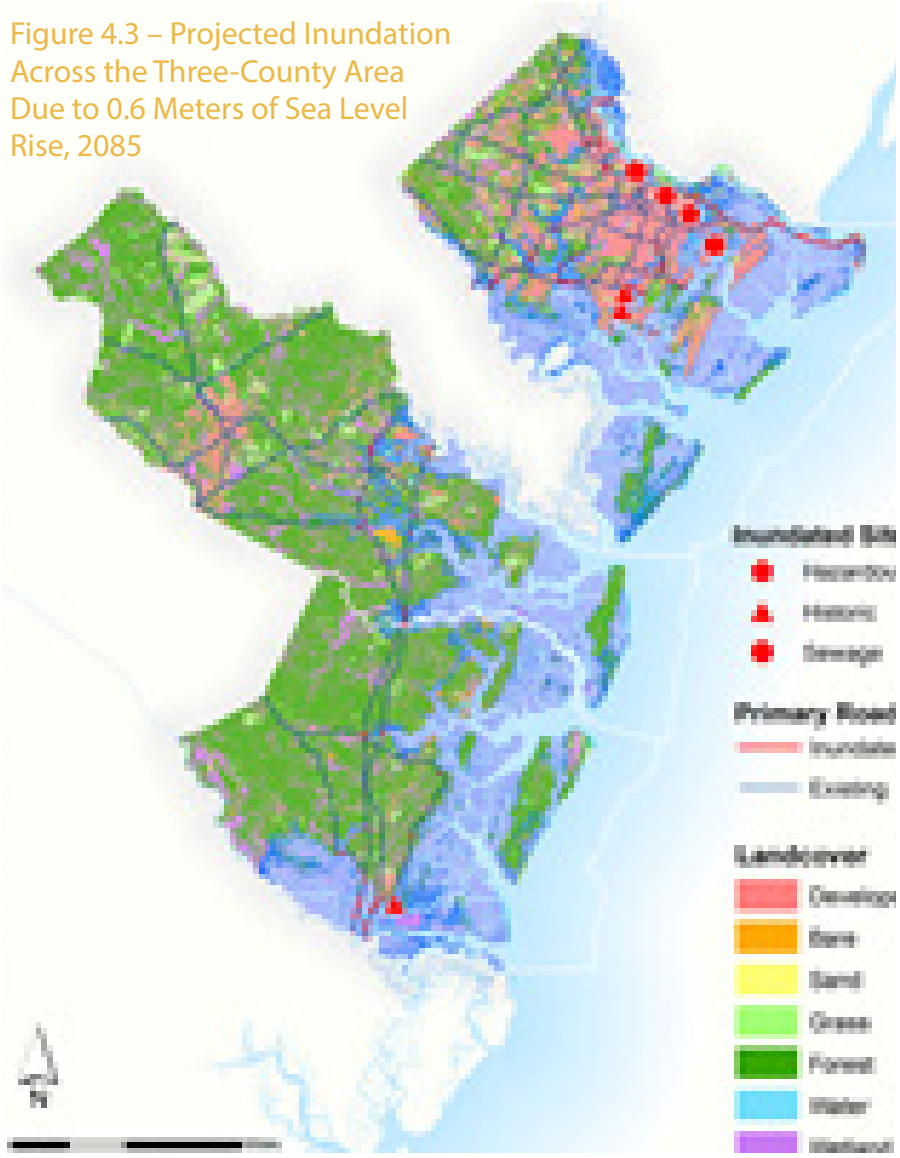
Table 4.5 – Overall and Wetland Inundation in the Three-County Area Due to 0.6 Meters of Sea Level Rise, 2085

	Area (sq. miles)	New Area Inundated (sq. miles)	Total Area Inundated (sq. miles)	% of Area Inundated	Wetland Area (sq. miles)	New Wetland Inundated (sq. miles)	Total Wetland Inundated (sq. miles)	% of Wetland Inundated
Chatham	420.74	34.22	153.88	36.57%	181.91	29.48	144.98	79.70%
Liberty	509.44	14.41	64.79	12.72%	132.65	11.10	60.68	45.75%
McIntosh	419.11	41.65	132.30	31.57%	175.19	38.40	127.23	72.62%
Overall	1349.29	90.29	350.96	26.01%	489.75	78.98	332.89	67.97%

Table 4.6 – Developed Land and Infrastructure Inundation in the Three-County Area Due to 0.6 Meters of Sea Level Rise, 2085

	Developed Area (sq. miles)	Developed Inundated (sq. miles)	% of Developed Inundated	Primary Roads (miles)	New Primary Roads Inundated (miles)	Total Primary Roads Inundated (miles)	Facilities	New Inundated Facilities	Total Inundated Facilities
Chatham	112.21	1.37	1.22%	211.18	4.46	10.57	151	1	6
Liberty	50.36	0.19	0.38%	141.11	0.46	0.79	27	0	0
McIntosh	24.43	0.52	2.11%	83.04	0.73	1.69	16	1	1
Overall	187.00	2.08	1.11%	435.33	5.66	13.06	194	2	7

Figure 4.3 – Projected Inundation Across the Three-County Area Due to 0.6 Meters of Sea Level Rise, 2085



Wetland inundation approaches saturation, with just one-fourth their original extent remaining. Nearly half of all the inundation that does occur during this period is non-wetland area, however, having ramifications on developed land.

Square miles of developed land inundated will nearly double (from 2.08 to 3.83) across the study area with the addition of 0.2 meter of sea level from 2085 to 2100. As a consequence, both population and buildings will experience the most significant loss with a 0.8 meter total rise in sea level than during any other period. Most of this again occurs in Chatham County; overall, these losses will double their affected areas in these 15 years.

Despite the increasing inundation of developed land, no new road length will be affected by the 0.2 meter sea level rise from 2085 to 2100. Five new facilities are affected in Chatham County, however, including four sewage sites and portions of the Fort Pulaski National Monument.

2110: 1.0 Meter Sea Level Rise

The final 0.2 meter rise in sea level during the ten-year period from 2100 to 2110 will continue the trend of less overall land inundated, with wetlands again making up a smaller portion. By this point, the majority of the 27.42 square miles inundated will occur in non-wetland areas, with much of it affecting developed land. It is apparent from that data that Liberty will experience the overall effects of sea level rise far less than

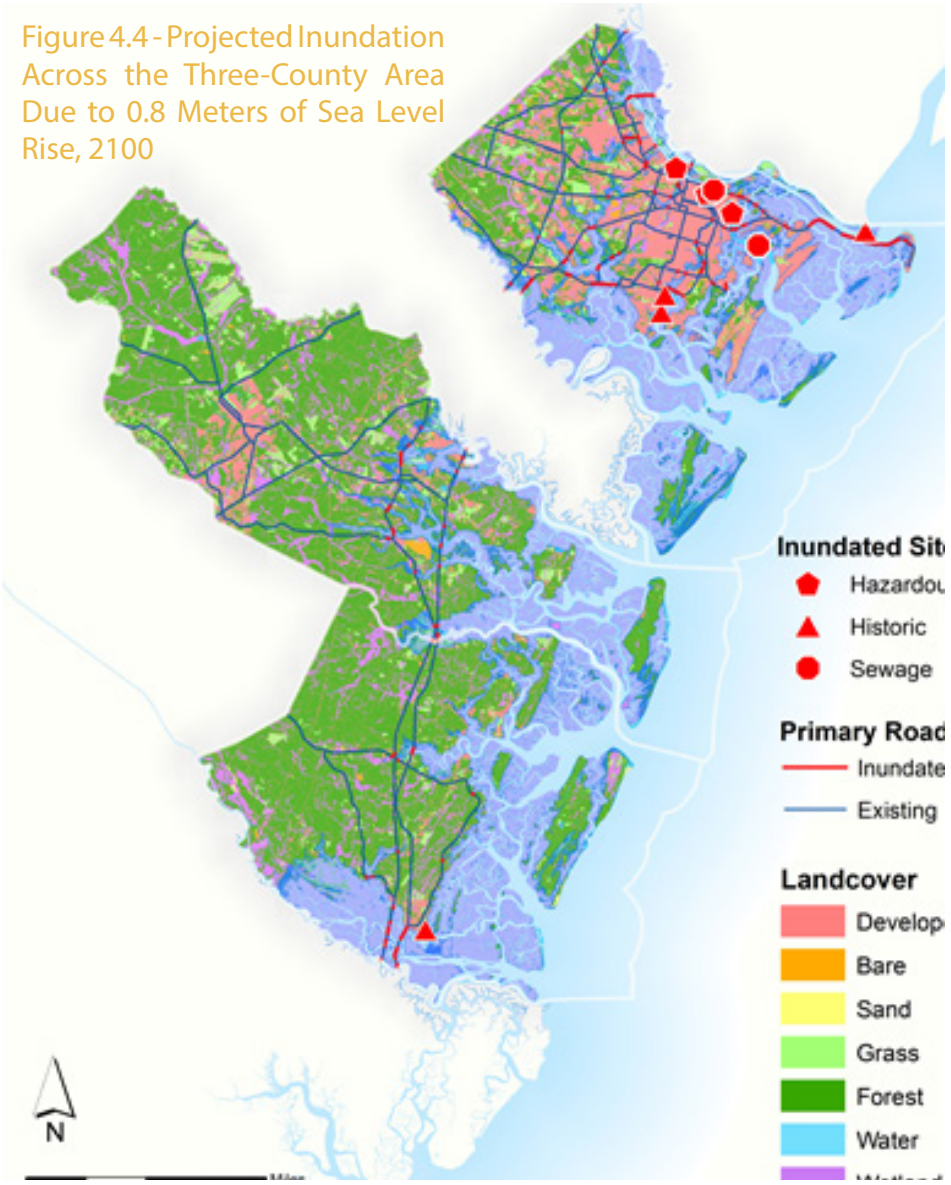
Table 4.7 – Overall and Wetland Inundation in the Three-County Area Due to 0.8 Meters of Sea Level Rise, 2100.

	Area (sq. miles)	New Area Inundated (sq. miles)	Total Area Inundated (sq. miles)	% of Area Inundated	Wetland Area (sq. miles)	New Wetland Inundated (sq. miles)	Total Wetland Inundated (sq. miles)	% of Wetland Inundated
Chatham	420.74	16.37	170.25	40.46%	181.91	9.39	154.37	84.86%
Liberty	509.44	11.10	75.89	14.90%	132.65	6.10	66.78	50.34%
McIntosh	419.11	13.07	145.36	34.68%	175.19	8.36	135.59	77.39%
Overall	1349.29	40.54	391.50	29.02%	489.75	23.84	356.74	72.84%

Table 4.8 – Developed Land and Infrastructure Inundation in the Three-County Area Due to 0.8 Meters of Sea Level Rise, 2100.

	Developed Area (sq. miles)	Developed Inundated (sq. miles)	% of Developed Inundated	Primary Roads (miles)	New Primary Roads Inundated (miles)	Total Primary Roads Inundated (miles)	Facilities	New Inundated Facilities	Total Inundated Facilities
Chatham	112.21	2.55	2.27%	211.18	0.00	10.57	151	5	11
Liberty	50.36	0.49	0.97%	141.11	0.00	0.79	27	0	0
McIntosh	24.43	0.80	3.26%	83.04	0.00	1.69	16	0	1
Overall	187.00	3.83	2.05%	435.33	0.00	13.06	194	5	12

Figure 4.4 - Projected Inundation Across the Three-County Area Due to 0.8 Meters of Sea Level Rise, 2100



both Chatham and McIntosh counties.

As is clear from these results, developed land will indeed see the biggest jump in area inundated than during the entire previous period, increasing from the 3.83 square miles inundated by 0.8 meters of sea level to 7.02 square miles. This 0.2 meter rise from 2100 to 2110 will result in an additional 3.19 square miles of developed land across the three counties, an increase of 83.3 percent.

Primary roads will continue to be inundated from 2100 to 2110, once again mostly occurring in Chatham County. Furthermore, three more facilities will be submerged, including a sewage site and the CSX Transportation - Powell Duffryn hazardous site in Chatham, as well as parts of the Hog Hammock Historic District in McIntosh County. Overall, 22.83 miles of primary roads and 15 facilities will be affected by 1 meter of sea level rise in the three county area.

Overall Temporal Analysis

When observing overall inundation across the three-county study area throughout time, there are two primary trends. Most of the total area of land inundated occurs due to the 0.4 meter of sea level rise from 2010 to 2065, decreasing gradually after that period. To reinforce this point, 260.68 square miles of total area will be inundated

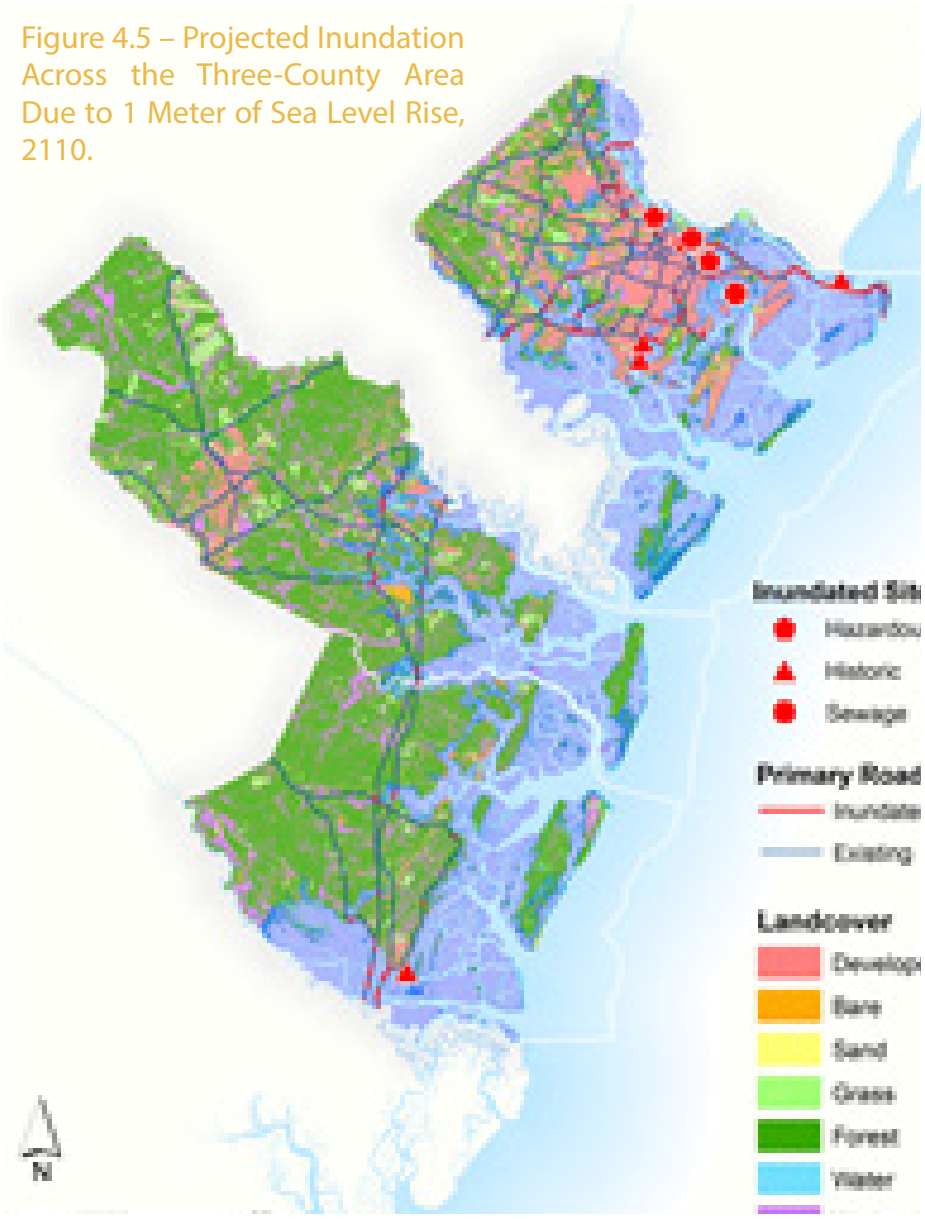
Table 4.9 – Overall and Wetland Inundation in the Three-County Area Due to 1 Meter of Sea Level Rise, 2110

	Area (sq. miles)	New Area Inundated (sq. miles)	Total Area Inundated (sq. miles)	% of Area Inundated	Wetland Area (sq. miles)	New Wetland Inundated (sq. miles)	Total Wetland Inundated (sq. miles)	% of Wetland Inundated
Chatham	420.74	11.99	182.24	43.31%	181.91	3.03	157.39	86.53%
Liberty	509.44	8.06	83.95	16.48%	132.65	3.45	70.22	52.94%
McIntosh	419.11	7.37	152.73	36.44%	175.19	2.32	137.91	78.72%
Overall	1349.29	27.42	418.92	31.05%	489.75	8.79	365.53	74.64%

Table 4.10 – Developed Land and Infrastructure Inundation in the Three County Area Due to 1.0 Meter of Sea Level Rise, 2110

	Developed Area (sq. miles)	Developed Inundated (sq. miles)	% of Developed Inundated	Primary Roads (miles)	New Primary Roads Inundated (miles)	Total Primary Roads Inundated (miles)	Facilities	New Inundated Facilities	Total Inundated Facilities
Chatham	112.21	4.97	4.43%	211.18	7.84	18.41	151	2	13
Liberty	50.36	0.89	1.76%	141.11	1.03	1.82	27	0	0
McIntosh	24.43	1.16	4.76%	83.04	0.90	2.60	16	1	2
Overall	187.00	7.02	3.75%	435.33	9.77	22.83	194	3	15

Figure 4.5 – Projected Inundation Across the Three-County Area Due to 1 Meter of Sea Level Rise, 2110.



from the original 0.4 meters, while only 67.96 square miles will be impacted during the latter period from 2085-2110. This same trend is reflected in wetland inundation, which experiences the majority of its loss from the initial 0.4 meters of sea level rise. This can be attributed to the low-lying qualities of wetlands; the opposite trend occurs with inundation of the assumed higher-lying developed areas.

Despite there being a decreasing amount of total land area inundated following 2065, developed land both makes up a larger portion this total loss and increases in raw inundation in each successive period. Consequently, both buildings and population are increasingly vulnerable from each successive 0.2 meter of sea level rise. Both roads and facilities do not adhere to a consistent pattern, with both becoming sporadically affected as the sea level rises to 1 meter.

Table 4.11 – Temporal Scale of Inundation of Various Factors in the Three-County Area, 2040-2110

	Total Area Inundated (sq. miles)	% of Area Inundated	Total Wetland Inundated (sq. miles)	% of Wetland Inundated	Total Developed Inundated (sq. miles)	% of Developed Inundated	Total Primary Roads Inundated (miles)	Total Inundated Facilities
2040 - 0.2 meters	130.02	9.64%	127.19	25.97%	0.66	0.35%	4.70	3
2065 - 0.4 meters	260.68	19.32%	253.91	51.85%	1.12	0.60%	7.40	5
2085 - 0.6 meters	350.96	26.01%	332.89	67.97%	2.08	1.11%	13.06	7
2100 - 0.8 meters	391.50	29.02%	356.74	72.84%	3.83	2.05%	13.06	12
2110 - 1.0 meter	418.92	31.05%	365.53	74.64%	7.02	3.75%	22.83	15

Figure 4.6 – Projected Inundation Across the Three-County Area, Represented Temporally

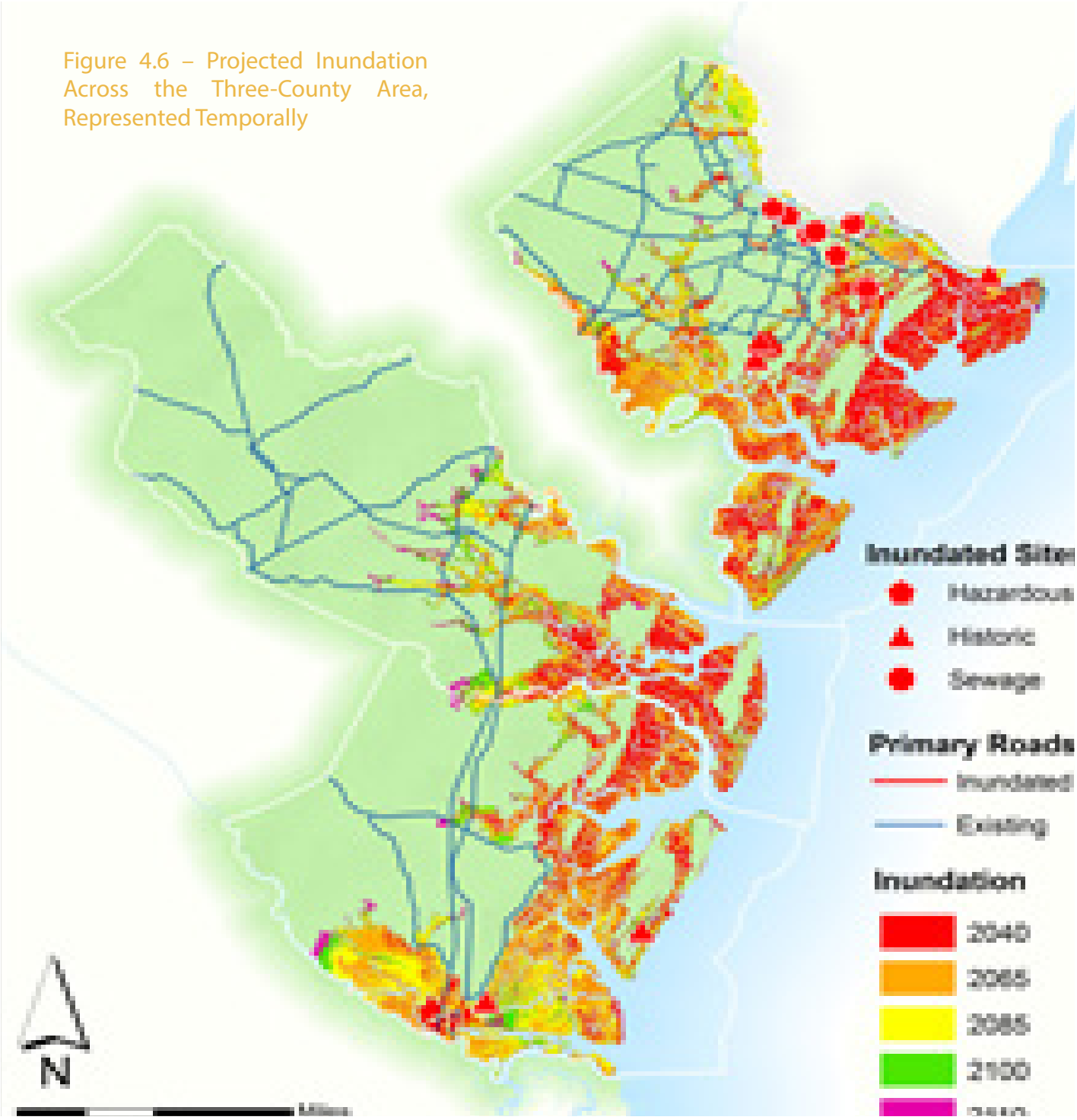
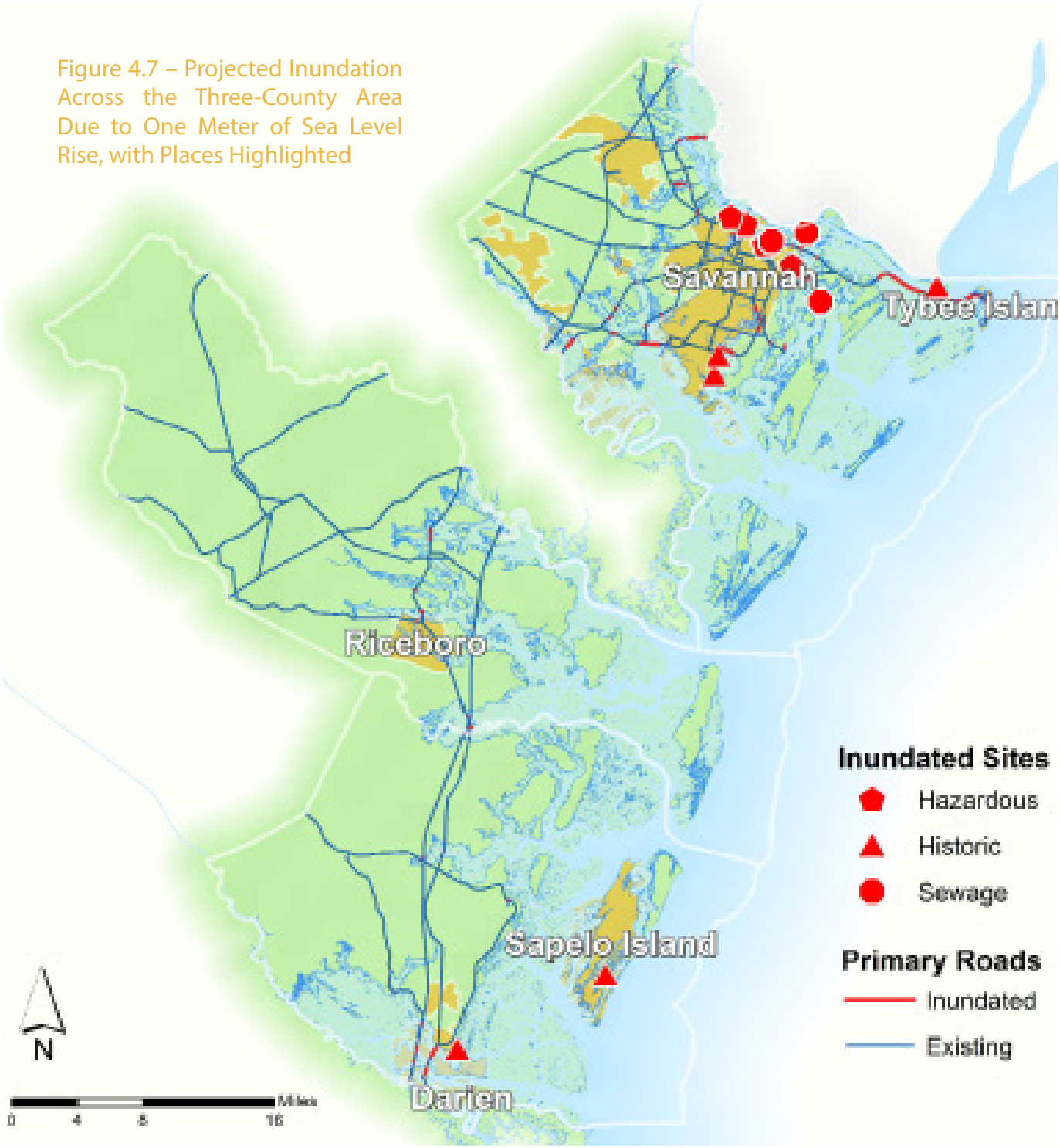


Figure 4.7 – Projected Inundation Across the Three-County Area Due to One Meter of Sea Level Rise, with Places Highlighted



SPATIAL ANALYSIS

The following five locations of particular importance, were analyzed more closely:

- Darien, seat of McIntosh County
- Riceboro, costal city in Liberty County
- Sapelo Island, loci for the Gullah-Geechee culture
- Savannah, seat of Chatham County and primary city in the region
- TybeeIsland,denselypopulatedcoastalcommunity

A table showing the results for additional places in the region is included in the appendix.

Darien

The effects of a one-meter rise in sea level on Darien was studied because it is the county seat of McIntosh County. A summary of these losses is as follows:

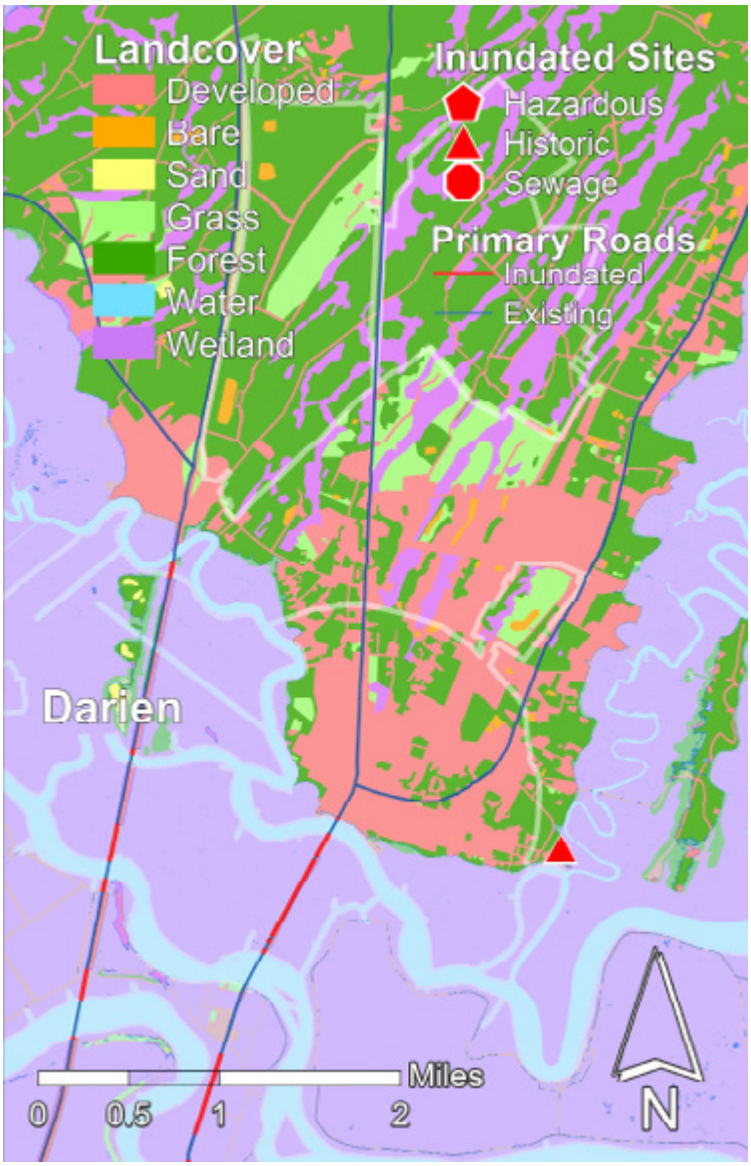
Overall

- Area: 21.21 square miles
- Area Inundated: 13.34 square miles
- % of Area Inundated: 62.9%
- Wetland Area: 15.84 square miles
- Wetland Inundated: 13.60 square miles
- % of Wetland Inundated: 85.9%

Developed Land and Infrastructure

- Developed Area: 1.82 square miles
- Developed Area Inundated: 0.38 square miles
- % of Developed Area Inundated: 20.9%
- Primary Roads: 7.03 miles

Figure 4.8 – Projected Inundation of Darien Due to One Meter of Sea Level Rise



- Primary Roads Inundated: 2.20 miles
- Facilities: 0
- Inundated Facilities: 0

By 2100, over three-fifths (62.9%) of all existing land area covered by Darien will be inundated. Most of this inundation will occur in wetlands, which will nearly disappear completely (85.9% loss). Over 20% of all its developed land will be inundated, which is reflected in a projected loss of both buildings and population. Overall, the effects of one meter of sea level rise on Darien will be significant.

Riceboro

While Hinesville is the seat and primary city of Liberty County, its inland location protects it from all the effects of one meter of sea level rise. As a coastal city of in Liberty, Riceboro will be impacted by this inundation, the effects of which are summarized:

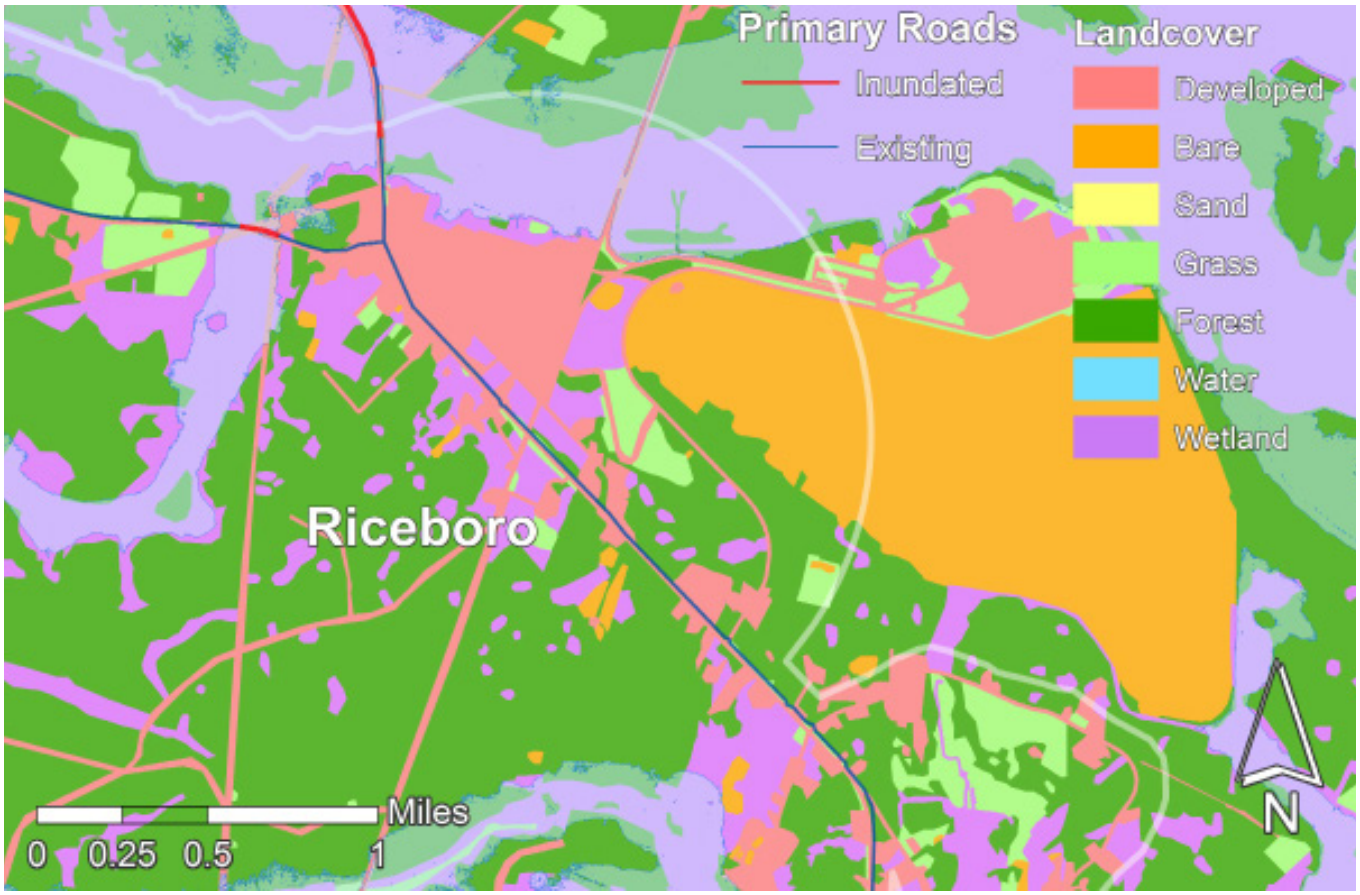
Overall

- Area: 11.38 square miles
- Area Inundated: 1.48 square miles
- % of Area Inundated: 13.0%
- Wetland Area: 2.01 square miles
- Wetland Inundated: 0.94 square miles
- % of Wetland Inundated: 47.0%

Developed Land and Infrastructure

- Developed Area: 1.53 square miles
- Developed Area Inundated: 0.03 square miles
- % of Developed Area Inundated: 1.95%
- Primary Roads: 10.29 miles
- Primary Roads Inundated: 0.51 miles
- Facilities: 0
- Inundated Facilities: 0

Figure 4.9– Projected Inundation of Riceboro Due to One Meter of Sea Level Rise



With one meter of sea level rise, only 13.02% of Riceboro's total land area will be inundated, with most of this consisting of wetlands. A tiny portion of Riceboro's developed land will be effected, so populations and buildings are not particularly vulnerable to sea level rise. While Riceboro contains a substantial length of primary roads, just one-half a mile of them will be inundated by 2100. Overall, the effects of sea level rise on Riceboro reflect those of the larger Liberty County area: limited.

Sapelo Island

As one of the loci for Gullah-Geechee culture in Georgia, it is critical to look at the effects of sea level rise on Sapelo Island, located in McIntosh County. While it does not contain a large population base, the effects are nonetheless substantial:

Overall

- Area: 29.25 square miles
- Area Inundated: 16.26 square miles
- % of Area Inundated: 55.6%
- Wetland Area: 11.60 square miles
- Wetland Inundated: 10.62 square miles
- % of Wetland Inundated: 91.5%

Developed Land and Infrastructure

- Developed Area: 1.04 square miles
- Developed Area Inundated: 0.24 square miles
- % of Developed Area Inundated: 23.0%
- Primary Roads: 0 miles

Figure 4.11 – Projected Inundation of Sapelo Island Due to One Meter of Sea Level Rise.

- Primary Roads Inundated: 0 miles
- Facilities: 1

By 2100, over one-half (55.57%) of Sapelo Island's total land area will be inundated, manifesting most prominently in wetlands, which will lose 91.52% of their area. While developed land only covers one square mile of Sapelo, nearly one-quarter will be inundated by a one-meter rise in sea level. The loss of population and buildings this will incur includes partial inundation of the historic district, a significant loss to an already struggling community.

Savannah

While it is important to look at the impacts of sea level rise on Savannah from the perspective that it is the county seat of Chatham, it is also the primary city of the three-county region. Thus, the loss of population and buildings is of the greatest magnitude here:

Overall

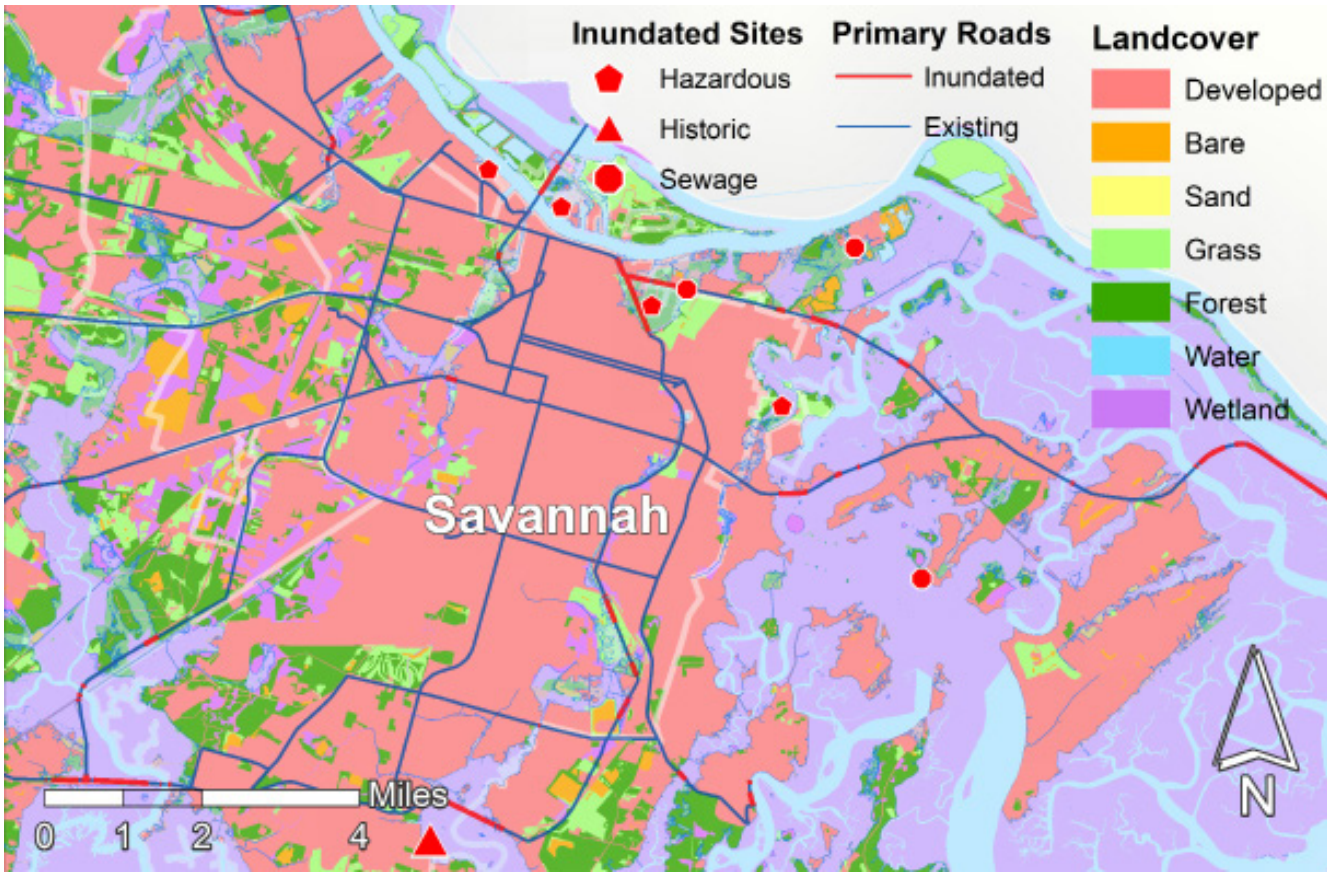
- Area: 104.42 square miles
- Area Inundated: 22.90 square miles
- % of Area Inundated: 21.9%
- Wetland Area: 27.84 square miles
- Wetland Inundated: 18.41 square miles
- % of Wetland Inundated: 66.1%

Developed Land and Infrastructure

- Developed Area: 44.58 square miles
- Developed Area Inundated: 0.77 square miles
- % of Developed Area Inundated: 1.7%
- Primary Roads: 19.57 miles
- Primary Roads Inundated: 4.91 miles
- Facilities: 3
- Inundated Facilities: 3

Over one-fifth (21.9%) of the total land area within Savannah's city limits will be inundated by 2100, the brunt of it composed of wetlands, which will

Figure 4.12 – Projected Inundation of Savannah Due to One Meter of Sea Level Rise



diminish in extent by nearly two-thirds (66.13%). Although Savannah is nearly 50% developed (44.58 square miles), only 1.72% of it will be inundated; this is nevertheless substantial considering the density of development here. Additionally, over one-fourth (4.91 miles) of the total length of primary roads will be submerged by 2100. Finally, three facilities will be affected within Savannah's city limits, including sections of the Vernonburg Historic District, Truman Parkway hazardous site, and the Central of GA RR/ Bernuth-Lembcke hazardous site.

Tybee Island

As it is both densely developed and adjacent to the ocean, Tybee Island is particulary vulnerable to sea level rise. An overview of these effects is as follows:

Overall

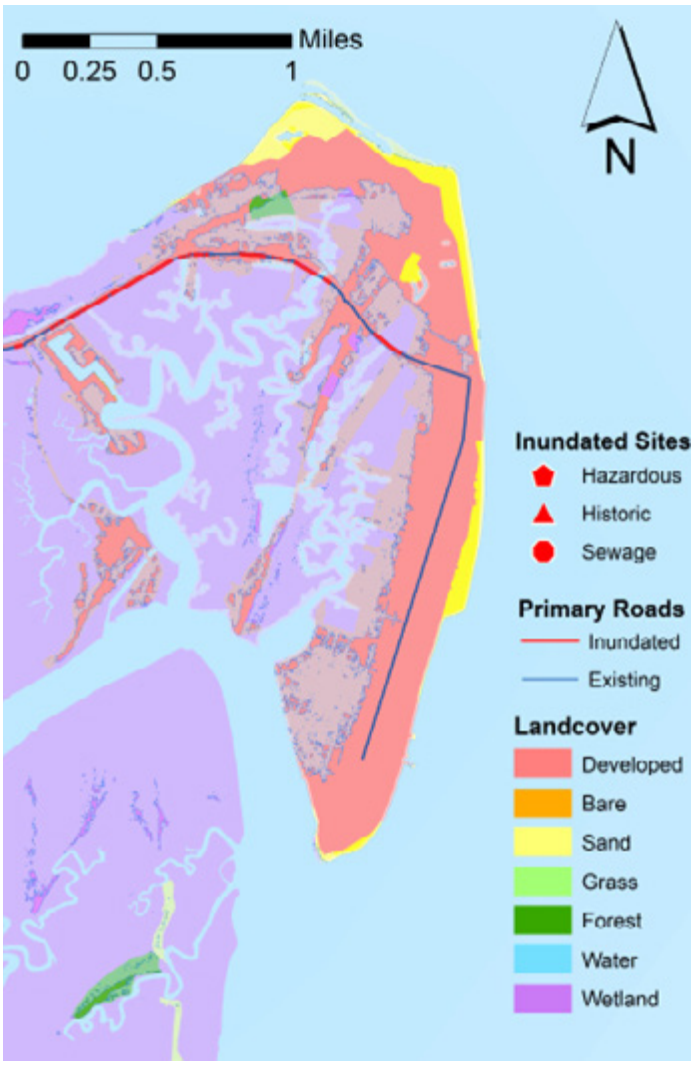
- Area: 2.50 square miles
- Area Inundated: 1.41 square miles
- % of Area Inundated: 56.4%
- Wetland Area: 0.98 square miles
- Wetland Inundated: 0.82 square miles
- % of Wetland Inundated: 83.5%

Developed Land and Infrastructure

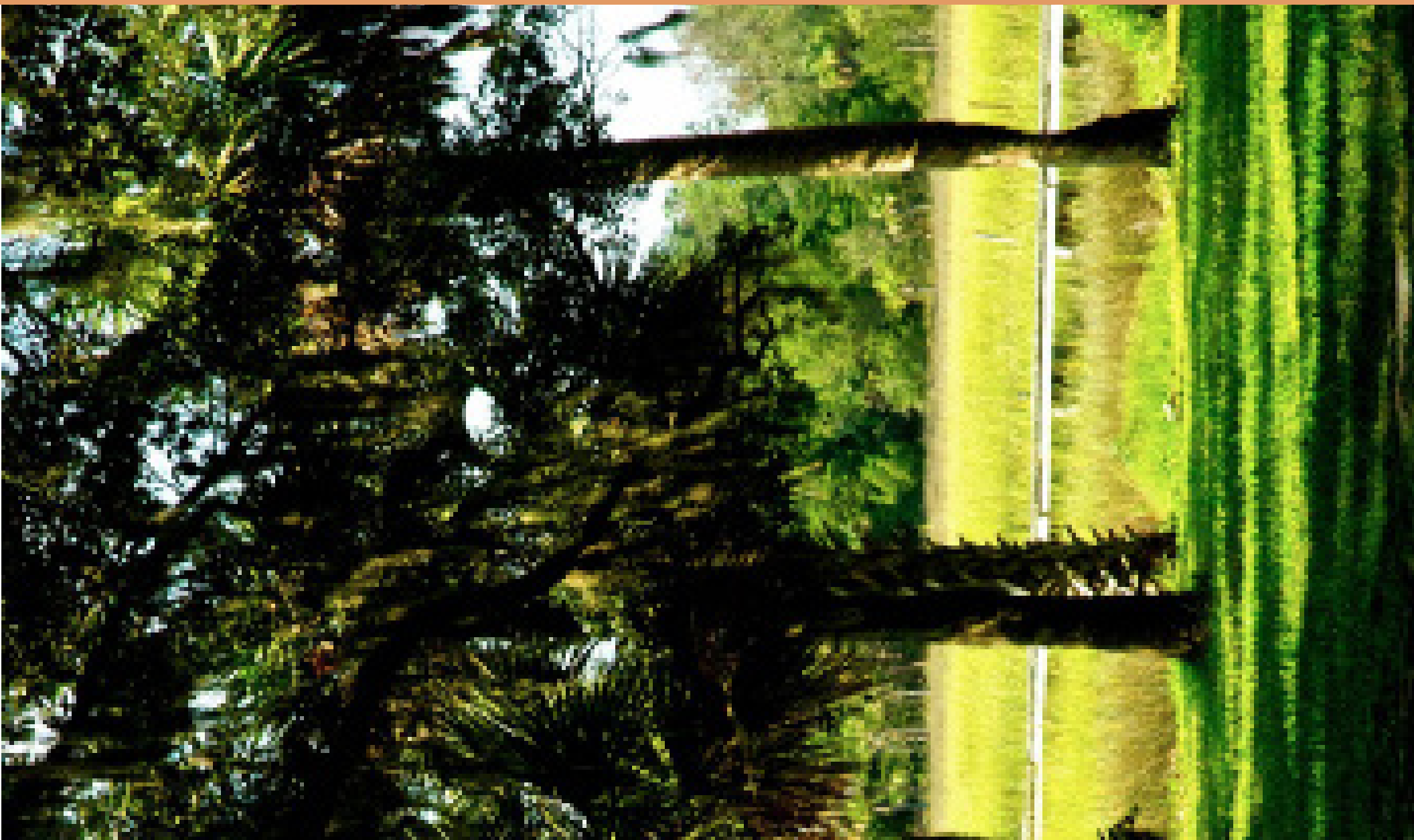
- Developed Area: 1.31 square miles
- Developed Area Inundated: 0.54 square miles
- % of Developed Area Inundated: 41.0%
- Primary Roads: 2.73 miles
- Primary Roads Inundated: 1.43 miles
- Facilities: 0
- Inundated Facilities: 0

The impacts of sea level rise on Tybee Island will be far-reaching, including a 56.4% reduction of total land area. While most (83.5%) of Tybee's wetland area will generally become submerged, inundation of developed land will make up much of the remainder. This 0.54 square mile inundation of developed land is a loss of over 40%, which would manifest in substantial population and building loss. Finally, a substantial portion (over 50%) of primary road length will be submerged; this is a critical loss, considering it connects to Tybee's only land-based route to the mainland. When considering the culmination of all these impacts, it is extremely important that adaptation efforts are focused on protecting the population and infrastructure of Tybee Island.

Figure 4.13 – Projected Inundation of Tybee Island Due to One Meter of Sea Level Rise



ADAPTATION



In previous sections of this report, we assessed the impact of sea level rise on vulnerable areas based on social and physical variables. In this section, we outline adaptation methodologies to counteract the negative impact on these vulnerable areas. The hope for appropriate adaptation methodologies is that residents, businesses, and government agencies will respond to sea level rise prior to impact or to reduce impact already incurred.

Adaptation responses to sea level rise may range from completely holding the increased sea level back (full protection) to absolutely no human intervention and allowing the shore to retreat without barriers (full retreat). Various forms of accommodation lie between these two extremes.

Full protection requires the protection, defense, and armor of vulnerable areas through hardscaping, beach replenishment, and other means of shore protection, especially near developed areas. Generally, governing bodies implement and are responsible for such types of coastal protection. In contrast, a full retreat means absolute abandonment of land and structures in vulnerable areas and the resettlement of inhabitants and development to higher or farther inland ground. A few routes to implement full retreat are through anticipatory land use regulations, building codes, or economic incentives. Accommodation, though, allows strategic continued occupancy and use of vulnerable areas. It generally requires strengthening preparation, regulatory action, and educational programs.

Full Retreat

Full retreat yields vulnerable areas to the sea, moving critical infrastructure and housing to safer ground and prohibiting building and rebuilding in vulnerable or inundated areas. However, "retreat" should not be confused with "abandonment," since it is incorporated into long-term planning and carefully managed. Through retreat, communities may realize large savings compared to the implementation of shoreline protection measures. However, in retreat, investment in existing structures and infrastructure is lost as the sea claims the area. New investment is also required to relocate communities and infrastructure out of harm's way (Institution of Civil Engineers, 2009). This option is often unpopular with coastal governments and economic interest. Planning for full retreat requires sufficient study to show the benefits of balancing costs and to gain support from stakeholders affected by this strategy.

Several strategies are required to implement a full retreat: preventing most development in vulnerable areas, allowing limited conditional development to be abandoned after inundation, providing subsidy adjustments for affected stakeholders, and providing public information about associated risks. Beginning early in the retreat process, authorities must limit development in areas projected to be affected early or heavily through land acquisition, land use restrictions, prohibition of reconstruction of property damaged by storms, reduction of subsidies and incentives for development in vulnerable areas, as well as possible compensatory payments to relocators. These regulations can reduce future expenditures for adaptation. In less heavily affected areas, the government may take a more limited role of setting rules but allowing investors to evaluate uncertainty in the benefit of development. Usually this approach prohibits protective structures and entails expiration of ownership and leases when the sea reaches a particular level. Finally, eliminating subsidies available to developers in impacted areas while providing accurate and timely information on the risks of development allows the private market to gradually migrate inland as natural resources and productive lands are transformed. Development will presumably cease if developers, lenders and insurers become unwilling to accept the risks.

Retreat can enable wetlands to migrate inland. In areas with a significant amount of potentially available land away from sea level increases, such as coastal Georgia, retreat strategies can be implemented along the coast in the interest of allowing coastal ecosystems, particularly tidal wetlands, to adjust to sea level rise through a slow landward migration. The potential economic implication of responses over periods ranging from fifty to one hundred years are hard to quantify. In densely populated and developed areas, retreat may prove not to be an economically viable response option given the magnitude of the loss of capital investment. Large-scale resettlement would tax the region's planning, infrastructure, and distributive capabilities. Accommodation for displaced inhabitants must be provided and requires assistance of regional institutions. However, the slow rate of sea level rise permits appropriate planning

and incremental implementation of retreat options and may reduce costs. In a retreat, places of cultural and historic significance could be lost completely. In addition, the loss of the environment that has traditionally sustained the local economy and culture could disrupt family life and create social instability. Situations where an individual's or a community's identity is closely associated with a particular piece of land or local resources can have implications which are difficult to resolve. For Georgia's Gullah-Geechee community, the loss of heritage sites and ancestral lands would be a deep wound.

Full Protection

Full protection prevents sea levels from entering the existing developed environment. Defense measures can be categorized as an array of "hard" and "soft" structural solutions, which can be applied alone or in combination depending on the specific conditions. Hard structural options may include such structures as dikes, levees and floodwalls for flood protection; seawalls and heavy revetments along open coastal areas to defend land against severe wave attacks; lighter revetments and bulkheads as secondary lines of defense along the open coast or as the first lines of defense along more sheltered interior shores to moderate wave exposure; and groins placed perpendicular to the shoreline trap to sediment moving along the shore and prevent eroding. However, hard defensive measures are costly to maintain and improve, and many have been criticized for reducing access to water, intervening beach, wetlands, and other intertidal zones.

Furthermore, although most states allow armoring along bays, many either prohibit it along the ocean or have strong ocean-beach nourishment programs that make it unnecessary (Titus, 1995). In this case, soft structural solutions may also provide shoreline protection. Examples include elevating land surfaces, which can allow wetlands and beaches to survive; beach filling and sand renourishment which add sand along the shore to maintain a desired beach width and shoreline position; and dune building and wetlands creation through strategic placement of appropriate vegetation. Currently, defensive practice is conducted in a piecemeal fashion, owing to the number of bodies involved and funding available (Institution of Civil Engineers, 2009).

Environmental consequences of full protection include the loss of coastal wetlands due to hard structures which block their natural migration, while structures such as groins and detachable waterbreaks trap sediment moving along the shore but protection of one area is generally at the cost of increased erosion downdrift. However, an eroding shore can be prevented by means of beach nourishment. The economic benefits of protection depend on the value of the protected land, including the prevention of physical damage, the prevention of loss of economic production and income, the prevention of land loss, and the preservation of natural resources. In areas such as the Port of Savannah, valuable, concentrated economic resources would benefit from protective structures. On the other side, costs include capital, operation and maintenance of the protective measures, as well as the corresponding change in culture environments and social structures. For areas heavily dependent on tourism, such as Tybee Island, the loss of natural beaches may have serious adverse consequences.

Protection has fewer identified social and cultural implications. However, hard structures are likely to reduce the aesthetic value of the original environment and restrict access to the shore and impair recreation. The loss of biological resources resulting from protection could also be of cultural significance. Structural protection must incorporate the risk of the failure of protective measures. Since people and economic resources will have incentives to intensify use of protected areas, significant loss of life and property could result if structures fail. Each type of structure is different and each requires some type of maintenance in order to perform as designed. When the entity responsible for maintenance is different from the entity which designed and constructed the structure, it may be difficult to assess any liability for damage resulting from a failure of the structure.

Accommodation

Accommodation is an approach that involves communities that continue using land that is affected by sea level rise, but adapt their use to permit encroaching water to rise. This requires amending building codes to specify minimum floor elevation and elevating coastal structures on pilings for protection from floods. Improved and strengthened drainage structures, storm warning

systems, and preparedness plans are required for successful adaptation. Changes in land use are also frequently desirable, for example, converting agriculture to fish farming, or growing flood or salt tolerant crops. Human activities that destroy the natural protective abilities of coastal areas, such as the diminishment of coastal wetlands, should be prohibited. Filling wetlands, damming rivers, mining coral and beach sand, cutting mangroves, and pumping and withdrawal practices should be limited or prohibited. In vulnerable areas, requiring private insurance coverage serves as an important method to compensate injuries and damages caused by natural disasters. It forces landowners to consider whether risks are worth taking and provides important funding sources for repair.

Accommodation is a compromise between retreat and protection. However, if resource exploitation practices change and flood control efforts alter water flow patterns the coastal environment could be affected. Accommodation provides opportunities for inundated land to be used for new purposes and derive compensatory economic benefits. Nonetheless, considerable costs may be involved in the planning and restructuring of land use. Moreover, the preparation for extreme events induced by climate change may generate significant additionalspending. Accommodation could change the economic activities of an area which could change lifestyles. Both retreat and accommodation could have transboundary implications. Authorities to encourage relocation and to deal with the use of abandoned lands may be needed. Legal authorities are needed to both to ensure the integrity of natural coastal protection and to avoid placing coastal populations in jeopardy from sea level rise.

From this point, we will approach suggestions for adaptation to sea level rise through a combination approach, which relies primarily on accommodation, while pursuing elements of both protection and retreat in limited circumstances. While protection and retreat offer solutions to some of the challenges of sea level rise, either one would ultimately be too disruptive and costly to be adopted in full. Accommodation, in contrast, allows a compromise between the most costly forms of protection and the most disruptive retreat. By advocating primarily for accommodation, along with the strategic implementation of shoreline protection in key economic centers, and rolling retreat in undeveloped areas with an existing natural coastline, our methods strive to ensure the smoothest possible adaptation to coming sea level rise on the Georgia coast.

Triple Bottom Line: Vulnerability justification

As recently witnessed by the damaging impacts of Hurricane Sandy to the Eastern coastal cities in late October 2012, the United States is experiencing more extreme weather and a higher frequency of this weather pattern. With the more extreme weather, comes change to places, to people, and to the economy. To understand how changes to these three components affect planning of a region, state, county, or community, a framework must be in place to better comprehend the components' intricacies and their relationship with each other.

One framework that the leadership in the three county study region area might use to begin to think about adaptation to the effects of sea level rise, is the Triple Bottom Line (TBL). This concept accounts for the sustainability of place, people, and economy and how these elements might be sustained over time. To reframe our thinking of what "sustainability" and "sustainable development" mean, we must understand that these concepts have more than an environmental connotation. The Bruntland Commission Report of the World Commission on Environment and Development defines "sustainability" and "sustainable development" as "development to ensure that it meets the needs of the present without compromising the ability of future generations to meet their needs" (WCED, 1987). Another avenue to thinking of "sustainability" as it pertains to planning is

to use the American Planning Association's dimensions (APA, 2000):

- We want to sustain communities as good places to live, and that offer economic and other opportunities to their inhabitants.
- We want to sustain the values of our society, things like individual liberty and democracy.
- We want to sustain the biodiversity of the natural environment, both for the contribution that it makes to the quality of

human life and for its own inherent value.

- We want to sustain the ability of natural systems to provide the life-supporting "services" that are rarely counted by economists, but which have recently been estimated to be worth nearly as much as total gross human economic product.

Using these tools to reframe previous thoughts, sustainability not only pertains to how the environment and places will be altered, but also how society and people will be positively or negatively impacted, how the economy will either shrink or reinvent itself, and how one factor influences the other two factors all in the context of sea level rise.

With this framework as the new background of sustainability, having a sustainable place now can now mean how to protect the current surroundings for the present generation but also for this generation's progeny. As an example, if full retreat is an option, a discussion should be made as to what this means in terms of the environmental landscape of the three county study region study area, or if there is full protection, the expected changes to shorelines, environmentally-sensitive facilities, and wetlands should be a topic of conversation among the stakeholders and policy actors. With regards to how society and people will be positively or negatively impacted, again, like with changes to place, the avenue of how the socially vulnerable residents should be prepared for or educated about inundation and whether they will have the ability and opportunity to move to way from the inundated places in an equitable manner is conversation to be had among stakeholders and other actors. And finally, in speaking of economic shrinkages or reinventions due to the impacts of sea level rise, the costs for full protection or full retreat need to be discussed and what this means for the county residents. If there is a shrinking economy in an area because of job loss (the place of employment is no longer present) or loss of infrastructure (flooded roads or loss of means of transportation), the discussion of how to either deal with the situation or how to reinvent a new economy born out of these losses should be a consideration when formulating ideas about how to move forward to adapt to changes due to sea level rise.

For the purposes of the adaptation section, a more in depth look about how place, people, and economy will be impacted will be discussed.

People

Social equity is defined as the fair access to livelihood, education and resources; full participation in the political and cultural life of the community; and self-determination in meeting fundamental needs (Ecotrust, 2011). Sea level rise on the Georgia coast will test the bounds of social equity in many regards, such as access to employment and land for resettlement. Preparation in these key areas will increase the adaptive capacity of the vulnerable population. Whether full retreat or full protection strategies are selected to combat the effects of sea level rise, resettlement plans need to be comprehensive in scope, covering a range from a voluntary migration to forced migration strategies. Furthermore, it should specifically address the resources available for refugees, evacuees and those forcibly displaced by environmental changes such as sea level rise and increased storm surges (Cernea 1995; Cernea 1997; Cernea 1999; Muggah 2000). The impact assessment provided in this document has identified several areas that can ensure successful resettlement.

Successful resettlement should focus on identifying the vulnerable population, assessing their needs, and ensuring that these needs are provided or access to them has been granted. The vulnerable populations across the three counties included: the 11.3% above the age of 64, the 7.5% of the below the age of 5, the 46.8% of non-whites among others . Although those younger than 5 will not need access to public transportation directly, they and their parents may need access. Similarly, the older than 64 population will need access to pharmacies, public transportation, as well as a location accessible to hospitals. The handicap population will have needs similar to the older population, however the process of adaptation will be more complex depending on the ailments the individuals have. The population below the poverty level will need affordable housing that does not marginalize their position within the community, yet provides a decent quality standard of living. The goal is to provide a plan that moves the population out of projected areas of inundation, yet attempts to keep social ties in place. However, communicating the plan for a migration has its own

impediments to success.

Education can serve as a barrier during the adaptation process if proper planning is not utilized. First, for those who are not educated on the effects of sea level rise it will be difficult to educate and move them out of their houses without evoking the feeling that one is being unjustly forced out of his or her home. Community input can allay feelings that one is being displaced. Secondly, education plays a major role in how the message of sea level rise can be conveyed. The message should be one that emphasizes the benefits of avoiding projected areas of inundation, whether through protection or relocation. Community input should reflect the choice of the community, rather than implement a forced bureaucratic agenda. Finally, education will play a role when identifying the jobs available because it is an indicator of social mobility and adaptability. Identifying and assessing the needs of the vulnerable population is key in the adaptation process, however including community input plays a substantial role in ensuring that peak utility is achieved and justice is served.

Place

The concept of place is the first that we will focus on for developing adaptation strategies. For our purposes, the term "place" includes both the natural environment and structures or landscapes made by people. Place is an important focus for adaptation because, inevitably, the environment is affected by natural and anthropogenic forces. However, there are several ways by which, the negative effects of sea level rise can be reduced, in order to protect vulnerable populations and places.

Georgia has approximately 193 miles of shoreline, and almost half of that is located in Chatham, Liberty and McIntosh Counties. Shoreline protection is a viable strategy to combating the effects of sea level rise. "Shoreline protection consists of engineered structures or other solutions meant to slow erosion by rising sea levels and storm wave action (Science Encyclopedia, 2012). Shoreline protection can include depositing rocks to form a barrier along the coast.

Another possible strategy for combating negative effects of sea level rise includes hardscaping, at a large scale. Hardscaping is typically a term used in landscaping and refers to non-plant structures, both natural and human-made, typically those made of stone or cement, but this is typically small-scale. Like shoreline protection, hardscaping, at a large-scale, could provide protection from the effects of sea level rise by providing a barrier. Hardscaping will likely involve the same procedure as shoreline protection: depositing large stones, or even constructing walls, in order to provide protection.

Protection is also necessary for hazardous sites throughout the region. Hazardous sites such as: landfills and wastewater treatment plants require protection from the effects of sea level rise, in order to prevent dangerous materials or substances from escaping the sites, and to protect vulnerable populations residing within close proximity to the sites. The aforementioned hardscaping may prove to be a viable solution to effectively protect hazardous sites. Hardscaping may help in preventing hazardous substances from infiltrating the water table.

Approximately 37 percent of Chatham, Liberty, and McIntosh Counties are wetlands, and with an inevitable rise in sea level, the health and livelihood of these wetlands are in-danger. Because wetlands provide a natural filtration system, wetlands are not only vital for plants and animals living in them, but they are also vital for the people living within close proximity to them. Therefore, strategies such as hardscaping, or even the diversion of saltwater infill streams may be necessary to prevent saltwater intrusion, in order to preserve the biomes within these wetlands, as well as, to preserve the integrity and health of these wetlands so that they perform at an optimum level. Conservation of water is important when devising strategies to combat the effects of sea level rise, because saltwater encroachment is always a possibility. Strategies to conserve fresh water will likely need to be employed to prolong the period of time before saltwater intrusion becomes a concern.

In summary, it can be concluded that an environmental focus is certainly necessary when developing adaptation strategies for combating the effects of sea level rise in Chatham, Liberty, and McIntosh Counties. Although five strategies were mentioned: shoreline protection; hardscaping at a large-scale; protection of hazardous sites; protection of wetlands; and conservation of freshwater, there are many more strategies that may need to be employed

to combat the effects of sea level rise.

Economy

In the standard triple bottom line framework, the economic aspect is related the sustained profitability of an organization and can be measured using variables such as income, expenditures, taxes, business climate factors, employment, and business diversity factors (Indiana).

In the context of our study, the economic aspect of the triple bottom line is related to maintaining and promoting the health and vitality of the economies within the three counties of our study area. The current and future overall well-being of our study area is extremely dependent on the health and strength of the local economies in the area. A healthy economy will stimulate job growth, population growth, and innovation within the study area and will allow for the quality of life of the citizens to be continually improved as time goes on. As we plan for and recommend sea-level rise adaptation strategies for the area, it is important to choose strategies that will prevent or reduce the potential harm inflicted on the economic viability of the study area.

As we recommend strategies to reduce the negative impacts that sea level rise will have on the people and the environment in the area, we also have to consider the impacts that those strategies will have on the economy of the area. Many consider the health of the economy to be equally as important as the health of the people and the environment of the area. Additionally, the maintenance of a strong and healthy economy also allows for reinvestment into protecting the people and the environment within the study area (Cascade).

Economic Impacts in the Study Area

Numerous significant negative effects on the economies of the study area were identified through our analysis of the impacts of sea-level rise. Many jobs are projected to be lost due to sea-level rise especially in the food services, retail, and the fishing and shrimping industries, which will have a devastating effect on the economies of the area. Tybee Island is projected to lose 41.0% of its developed areas. This will have negative effects since the economy of Tybee Island is strongly tied to the tourism industry. The loss of many commercial, industrial, and residential structures throughout the three counties will redistribute and reduce the tax base in many areas depending on if and where industries decide to relocate. Another major impact of sea-level rise on the economy is the negative effects on the Port of Savannah and the freight movement industry. From the transportation analysis we found that some of the rail lines projected to be inundated are located around the Port of Savannah. There will be a loss to the economies of the greater Savannah area if freight movement from the Port of Savannah is impeded. Maintaining the vitality of the local economies is crucial to sustaining the well-being of the study area into the future.

Adaptation techniques relating to protecting economic strength of the area include analyzing the costs associated with full protection, analyzing the costs associated with reverting inundated land back to a natural state, investigating the effects of providing compensation to landowners for the loss of their lands, and the idea of conducting a full cost/benefit analysis for any other adaptation techniques considered.

OUR ADAPTATION APPROACH: MIXED METHODOLOGIES

Policies for Guiding Future Development

Comprehensive Planning

Sea level rise is a process which occurs over a long term during which it may be difficult for stakeholders to perceive the necessity of planning. Given that the annual progress of sea level rise may range from a few millimeters to a few centimeters, and the expectation that the full extent of the one meter sea level rise will not be realized until at least 2110, some today perceive sea level rise as an issue that need not be considered in the short term. However, adapting comprehensive planning strategies to prepare for sea level rise today will allow communities to avoid the costs of damages and relocation over the one hundred year planning term. Furthermore, the temporal analysis shows that some areas will begin to see the effects of sea level rise well before 2100; in these areas, planning today will avert hazards in the next twenty to fifty years, a time frame over which many of today's stakeholders will remain in

the region.

The state of Georgia mandates that communities conduct a comprehensive planning process and update their comprehensive plan at a minimum every five years. Comprehensive plans are the primary vehicle through which communities assess their current state, delineate their vision for future development, and set policy goals to achieve this vision. Currently, all three counties within the study area maintain comprehensive plans in accordance with this requirement; however, none have fully incorporated sea level rise into their comprehensive plans. Given the strength of the comprehensive planning process to guide future development, we recommend that communities within the study area incorporate sea level rise adaptation into their comprehensive planning strategies.

Local comprehensive plans should include a section that describes the sea level rise impact areas and creates guidelines for how the community will ideally change as it adapts to the impacts of sea level rise. This vision will help guide the policies that should be implemented in the comprehensive plan that relate to sea level rise. Areas that planning for sea level rise can be incorporated into comprehensive plans are within: infrastructure planning, land use policies, zoning regulations, and water conservation planning. Through infrastructure planning new development can be guided away from areas within the sea level rise impact zone and incentivized in areas outside of the impact zone. The placement of infrastructure such as roadways, utilities, sewer lines, and drinking water lines, will guide new development. Local comprehensive plans can also consider including guidelines and plans for phasing infrastructure and services out of areas that are projected to become inundated by sea level rise in the relatively near future.

The land use policies and zoning regulations described in local comprehensive plans can control the type and density of development that is allowed within the impact areas versus what is allowed outside of the impact areas. This can be a further tool for controlling what happens within these two different types of areas. Land use and zoning regulations within the impact areas could preserve some areas as undeveloped, agricultural, or conservation lands and could also limit the density of development that does occur in other sections of the impact zone. These strategies will further prepare these areas for future inundation and will make the potential impacts less severe. Land use policies and zoning regulations could be used in the areas outside of the impact zone to allow increased density of developments so that new development is incentivized in these areas. This incentivizing can also be enhanced through the implementation of a transferred development rights program as is discussed later.

Water conservation strategies and planning should also be incorporated into local comprehensive plans in relation to planning for sea level rise impacts. One of the consequences of sea level rise is that as the sea encroaches on the land, saltwater can begin to infiltrate the underground aquifers, which can contaminate drinking water supplies. Additionally, fresh water could become scarcer if saltwater from the sea infiltrates into the fresh water supply in the system of rivers along the coast. For these reasons it is important to describe strategies within local comprehensive plans to conserve the water supply such as setting restrictions on water usage, recycling rainwater, building with permeable asphalt, implementing water efficient technologies, etc.

Effects on People

The comprehensive planning process involves a wide array of stakeholders, all of whom will play a role in determining the ability to tailor the comprehensive planning process to consider the implications of sea level rise in the study area. The comprehensive planning process must be conducted in accordance with regulations from the Georgia Department of Community Affairs, which mandates that communities incorporate a Community Assessment to determine the baseline state of the community, a Community Participation Program to elicit input from local stakeholders, and a Community Agenda which delineates the community's short, medium, and long-term policy goals over the planning horizon. Planning officials and consulting agencies within each community are responsible for conducting the planning process. Community members whose input is sought during the process include developers, landowners, residents, business owners, and members of vulnerable populations.

Effects on Place

As part of the comprehensive planning process, communities will have to recast their vision their existing land use plans to account for the effect of sea level rise. We recommend that development be reoriented away from areas that will be inundated (sending areas) and towards areas that will remain protected (receiving areas). In selecting areas in which to focus new development, communities may also wish to make alterations to zoning regulations to implement their new land use vision. Suggested changes include increasing the density of development allowable in newly identified receiving areas, while maintaining the existing allowable density of sending areas. Communities may also wish to consider the feasibility of downzoning in receiving areas.

Effects on Economy

To implement the changes in development vision for the comprehensive planning process, communities within the study area may utilize tools such as changes to the building code. Adapting the building code to reflect more stringent requirements for building in inundated areas will have the effect of increasing the cost of development. This will deter some property owners from developing land within the inundated area.

Shifting development from the inundated areas to areas of higher elevation will also require the construction of new public infrastructure such as roads, bridges, sewer systems, and utilities. In addition, existing infrastructure will be lost after inundation. Communities must carefully plan for both the construction of new infrastructure, and the maintenance of existing infrastructure until inundation occurs. Encouraging both new development as well as the relocation of existing businesses and residents away from inundated areas will help the shift to happen more rapidly; in this case, existing infrastructure may be able to be retired from maintenance sooner than would otherwise happen.

Additionally, strategically prioritizing investments in infrastructure in desired locations away from the coast over infrastructure located in inundated areas will indirectly guide development, as areas with newer infrastructure will be more desirable than those with older infrastructure.

Flood Insurance

Coastal and riverine areas are exposed to the risk of periodic severe flooding which has the potential to cause property damage. In response to this risk, the National Flood Insurance Program (NFIP) provides flood insurance to residents, business owners, and landowners in areas with flood risk. Exposure to flood risk is correlated with a place's elevation and its proximity to water sources. As a result, areas subject to inundation from sea level rise are also exposed to periodic flood risk. Therefore, we propose that the NFIP may provide an avenue through which to prepare property owners for sea level rise, as well as to influence development patterns in exposed areas over the coming decades. This may be achieved through both the existing NFIP as well as further policy actions to be taken at the state and local levels, which we discuss below.

The National Flood Insurance Program

Congress created the National Flood Insurance Program in 1968 to protect homeowners at risk of property damage due to flooding. In addition to homeowners, renters and business owners can receive insurance. However, for a community to be eligible for participation in the NFIP, it must meet or exceed the Federal Emergency Management Agency's (FEMA) requirements for reducing the risk of flooding through adequate floodplain management. Insurance policies are purchased from private insurers, although rates for an area are set by FEMA and do not vary by provider. In high-risk areas, the government may mandate the purchase of flood insurance. This is required for structures mortgaged by federally insured or regulated lenders and which are in the 100-year floodplain. For these structures, there is a 1% chance of flooding in any given year and a 26% chance of flooding over the life of a 30-year mortgage (FEMA). In low- to moderate-risk areas, homes and businesses are not required to have flood insurance, but this insurance is strongly recommended. People outside of high-risk areas file 20% of NFIP claims and receive one-third of assistance (FEMA). In addition, individual lenders may require flood insurance in order to approve a loan, regardless of federal requirements.

Flood insurance can provide coverage for either

buildings or contents. Building insurance insures the structure, foundation, and certain items like built-in appliances and permanently installed carpeting against damage sustained by flooding, while contents insurance insures personal belongings, furnishings, and portable appliances.

All incorporated communities within the study area participate in the NFIP (FEMA 2012). Most communities joined the NFIP in the 1970s, although Gumbranch and Walthourville in Liberty County joined only in 2008. The unincorporated areas of the three counties have all participated since the 1970s (FEMA 2012).

Policy Proposals to Adapt Flood Insurance for SLR Mitigation

- Participation in the NFIP is mandatory only for owners of property that is exposed to high risk of flooding, with mortgages which are federally insured. Property owners without mortgages are not required to maintain flood insurance even in high-risk zones, and owners of property in low- or moderate-risk zones are never required to maintain flood insurance. In order for the NFIP to have influence over development, flood insurance uptake for property owners and residents for whom it is not mandatory should be high. Therefore, state and local authorities should work to educate property owners, business owners, and residents about their potential flood risk and the availability of NFIP insurance.
- Participation in the NFIP is not limited to property owners. Renters can also benefit from contents insurance, which insure personal belongings such as clothing and furniture. State and local authorities should educate these individuals about the availability of NFIP insurance.
- As sea level rise advances, floodplains will continue to change. State authorities should coordinate with FEMA to ensure that a plan is in place for regular updating of flood zone maps which determine which property owners are required to obtain flood insurance.
- Flood insurance has the drawback of subsidizing development in flood-prone areas. At the federal level, consideration should be given to prohibiting the provision of flood insurance in extremely high-risk areas, such as those within the 25-year or the 50-year floodplain. At the state level, authorities should consider what actions they can take to limit or prohibit the provision of insurance to property owners in these areas.
- Property owners should be required to maintain flood insurance for properties that they rent to residential tenants. This will protect both renters and landlords in the case of a severe flood event that causes property damage. State authorities should consider what action they can take to encourage or mandate the maintenance of flood insurance by landlords.
- The Coastal Barrier Resources System (CBRS) area should be expanded to include property that will be inundated by sea level rise. Expanding this system to prohibit the sale of flood insurance to newly built properties in these areas will reduce the rate of development within the inundated area.

Effects on People

Numerous stakeholders are affected by the NFIP in coastal Georgia. At the federal level, FEMA is responsible for determining the requirements for participation in the NFIP, as well as setting flood insurance rates for high, moderate, and low risk areas. Along with FEMA, the State of Georgia is responsible for updating and maintaining flood risk maps which determine the required or recommended level of insurance for properties in any given location. Property owners are required to maintain flood insurance if the property is located in a high flood risk zone and they have a federally insured mortgage. Property owners in moderate or low flood risk zones, or who do not have a federally insured mortgage, are not required to purchase flood insurance, but are recommended to maintain insurance as the risk of flood damage remains present. Residents and business owners in all levels of flood risk zones should be aware of their flood risk, even if they rent, since they may be able to obtain content insurance which covers their personal or business property.

Flood insurance can provide both advantages and disadvantages to individual residents or business owners. Flood insurance protects individuals from catastrophic damage to personal property or structures. However, the cost of flood insurance may place individuals with lower incomes at a disadvantage. They may be unable to purchase

property in flood zones, or if they already own property or reside in these areas, flood insurance may be out of their reach, placing them at risk of financial hardship due to flood damage. The elderly also tend to be at risk of financial hardship due to flood damage, as they are more likely to have paid off mortgages and no longer be subject to flood insurance requirements.

Effects on Place

Within the study area, significant portions of are located within the 500-year-floodplain, which is the zone in which there is a 0.2% risk of a flood event in any given year. Currently, the Georgia flood mapping program is in the process of updating the state's riverine and coastal floodplain maps for all counties. While riverine flood maps, which include the most inland portions of the study area, will be updated by December 2013, the update of coastal flood maps will not be complete until late 2015 (EPD).

Evaluation of flood risk is based primarily on elevation and proximity to water sources. As sea level rise occurs, both of these factors will change within the study area. As a result, flood risk will shift, with high and moderate flood risk zones moving into areas that are currently considered low risk. In general, elevations subject to flood risk can be expected to rise in tandem with the rise in sea levels. Hence, a one-meter sea level rise by 2100 will result in the expansion of each flood zone by one meter above current elevations. However, the increase in elevations will occur gradually over time, and will occur at a changing rate, as the rate of sea level rise is not expected to be constant over the timeframe. In order to understand how these zones are changing, Georgia's flood mapping program must continue to update flood maps on a regular basis. High-risk areas that require flood insurance are particularly sensitive to these updates, as property owners will find that they must purchase new flood insurance policies.

Within the Coastal Barrier Resource System, which covers the barrier islands of the study area, flood insurance is only available to property owners if structures on the property were built prior to 1982 (FEMA). As a result, flood insurance is not available to the owners of newly built property within the coastal barrier islands. The intent of the CBRS and its enabling act was explicitly to limit the impact of development on the natural resources contained within this zone. Expanding the CBRS zone to encompass the entire area anticipated to be inundated by 2100 would dampen development within the zone. In this case, it would make sense to apply this restriction only to structures built after the zone is expanded. However, the CBRS can also be used to strip flood insurance from property owners in the expected inundated area following a major flood event that destroys the property.

Effects on Economy

Flood insurance is often criticized for encouraging continued development within floodplains by subsidizing the cost of rebuilding after flood events. In a report studying the impact of NFIP on development, Rosenbaum and Boulware (2006) found that community developers, floodplain administrators, and homeowners rated the availability of flood insurance as one of the most important factors to consider in owning floodplain property. This suggests that flood insurance is perceived as a safety net that ameliorates the hazards of purchasing property within a floodplain. In addition, Rosenbaum and Boulware found that individuals tended to perceive a lower exposure to flood risk for their property than actually existed. Furthermore, while purchasing flood insurance was preferred, a majority of policyholders would not be swayed from purchasing, building, or staying in a floodplain without insurance. An Army Corps of Engineers meta-analysis (1998) found insufficient evidence to conclude that flood risk is capitalized into the fair market value of properties within the floodplain.

However, rates charged by the NFIP are not currently actuarially sound; Rosenbaum and Boulware estimate that 25% of policyholders currently receive a substantial discount on their premiums relative to a actuarially sound estimate of the cost of insuring (2006). Adjusting these rates to their actuarially sound level could discourage some property owners from purchasing land within flood zones. Raising premiums beyond the actuarially required levels would also have the effect of further dampening property owners' enthusiasm for the floodplain. Rosenbaum and Boulware note that while 35% of property owners would be willing to continue buying mandatory flood insurance if their premiums increased by 10%, only 10-15% would be willing to

maintain flood insurance with premiums that were 100% or more above their current levels.

Land Compensation

Over time residents of coastal areas will become increasingly aware of the existence of sea level rise and its potential effects and implications. As landowners within the impact areas begin to realize their properties may not continue to be viable indefinitely into the future, they may begin to consider their options for moving or relocating. An issue that is likely to widely occur is that many of these landowners will not be able to find anyone interested in buying their land as the majority of people will have become aware of the diminishing potential of these lands. This brings up the question of how to structure policies for land compensation so that these landowners are not forced to lose all of the assets tied to their land and property because they would like to relocate to an area away from the sea level rise impact areas.

Transfer of Development Rights (TDR) Programs

One potential way to correct this problem is through the implementation of a Transfer of Development Rights (TDR) program. Traditional TDR programs center on the idea of allowing the market to implement and pay for development density and location decisions. Through these TDR programs landowners are able to sever the development rights from properties that are within areas designated as low-density by the government (sending areas) and sell those development rights to developers who would like to build in areas designated as high-density by the government (receiving areas) (Hanly-Forde). These traditional forms of TDR programs may be helpful in the effort to protect existing wetlands, agricultural, and undeveloped areas within the impact zone from being developed. This program could be used to protect the undeveloped status of these lands that are projected to become inundated by sea level rise within the next 100 years and could also be used to protect potential wetlands migration areas. However, this traditional form of TDR programs does not directly address the issue of compensating landowners who are unable to sell their land that is already developed.

Collier County, Florida TDR Program

An example of an existing TDR program in a neighboring state is the Rural Land Stewardship Area (RLSA) Overlay Program in Collier County, Florida. The goal of the RLSA program is to promote smart growth patterns in the rural sections of the county in accordance with the county's Growth Management Plan. Within the RLSA program there is a Stewardship Sending Area (SSA) program that outlines a plan for identifying the most valuable environmental lands within the county and giving them priority to be protected and conserved. The program identifies large connected wetlands systems and significant habitat areas as zones of particular conservation importance. Once an expanse of land is listed in the SSA program, Stewardship Credits are created for that land and a Stewardship Agreement is developed that identifies any allowable land uses that remain on the property. The methodology within the Stewardship Credit Worksheet assigns the value of Stewardship Credits to an SSA property. The RLSA program differs from a traditional TDR program in that it assigns values for multiple layers of land use rights including: residential land uses, general conditional uses, earth mining and processing uses, recreational uses, agricultural uses, and agricultural support uses. These Stewardship Credits can then be transferred to lands within the RLSA that have been identified as Stewardship Receiving Areas (SRAs), which then allows an increase in the density of development or intensity of land uses in those areas. The RLSA program in Florida shows an example of how traditional TDR programs can be augmented to become applicable and useful in other land use conservation initiatives.

Extending TDR Programs

TDR programs could be modified and used in an innovative way as a tool for compensating owners of developed lands located within the impact area. Through this approach developed lands within the sea level rise impact areas could also be designated as sending areas in addition to undeveloped lands. Developed lands within the sea level rise impact area that are owned by socially vulnerable populations, that could comprise a preserved wetlands corridor, that have the greatest population density, that are going to be impacted by storm surges, or that are going to become inundated the soonest should be considered as priorities for being designated as

sending areas. Lands that are already marked for new development or increased development in local comprehensive plans could be designated as the receiving areas. Landowners with properties in the sending areas could sell their development rights to developers who could then increase density within the receiving areas. This form of the TDR program has the potential to correct the issue of who will pay for the compensation of the landowners in the impact area and to incentivize development within areas away from the impact zone.

The study area as well as coastal Georgia as a whole could consider implementing the new TDR program as a multi-county effort that extends beyond county and municipal boundaries. This would allow a sending and a receiving area to be located within multiple counties. This is especially important for the study area counties because Liberty and McIntosh Counties are much less developed and built-out than Chatham County. Some of the development rights sold from sending areas located within Chatham County could be used to increase development and density of development within Liberty and McIntosh Counties. In a report by the Georgia Coastal Regional Commission, "Initiatives for the Preservation of Significant Resources in the Coastal Georgia Region," that provides model ordinances for Transfer of Development Rights Programs provides language for creating an inter-jurisdictional TDR program and states

> ...[M]unicipalities and counties which are jointly affected by development are authorized to enter into intergovernmental agreements for the purpose of enacting interdependent ordinances providing for the transfer of development rights between or among such jurisdictions, provided that such agreements otherwise comply with applicable laws. Any ordinances enacted pursuant to this subsection may provide for additional notice and hearing and signage requirements applicable to properties within the sending and receiving areas in each participating political subdivision.

Potential Conflicts or Limitations

This new form of TDR program that allows development rights to be sold on currently developed lands is a workable concept that has the potential to be a method of transferring people out of future inundated areas, however, there are several potential conflicts associated with the concept that could have multiple ways of being addressed. One important question is what selling development rights to a property that has already been developed means? This question could be resolved by stating that some developed properties have not yet been developed to their full potential and that property owners are selling that full development potential or by stating that no further development will occur on that property and that the existing structures will no longer be used and will eventually be demolished or deconstructed. Another approach is to use a life of stay rule in which landowners are not allowed to heir their property. In this scenario these landowners would sell the development rights for their property, the landowners would continue to live on the properties until they pass away, and then the property would go to a land trust.

Other conflicts are related to what will become of the property once the development rights have been sold to developers. One question is what will become of the developed properties once the development rights to that property have been transferred to developers? One suggestion is that the landowner could donate the property to a land bank that will become responsible for maintaining the land as conservation land. Next is the question of who will be responsible for the demolition or deconstruction of the existing structures on these properties and who will pay for it? Two ideas for this issue are to require the developers who purchased the development rights for the property to work with the land bank to demolish or deconstruct the structures or for the land bank to work with a recycling company to deconstruct the materials of the structures.

There are several other issues related to this new form of TDR that must be taken into consideration as well. The existing language within chapter 66A, Transfer of Development Rights, of the Georgia Code must be updated to extend the use of a TDR program to developed properties in addition to undeveloped properties and to add additional guidance on regulating what happens to these developed properties once the development rights have been sold. Additionally the Georgia Code should be updated to add language about the

creation of a TDR program oversight organization that will be responsible for regulating aspects of the new TDR program. The creation of an outreach program to educate the public about the existence, availability, and workings of the new TDR program should also be considered. Also, the issue of finding and providing areas to which these landowners can relocate also needs to be considered. Will there be enough housing units available for these residents to relocate to, especially affordable housing units? Consideration of providing a relocation assistance program with a provision for lower-income housing should also be considered.

Effects on People

The new TDR program will have positive effects on the people living in the impact areas that choose to participate in the program as it will allow them to be compensated for their land, which will eventually become inundated by sea level rise. This will allow these landowners to maintain their investments that are tied to their lands and properties. Prioritizing the designation of the lands in which socially vulnerable populations live within the impact area as sending areas will benefit these socially vulnerable populations because it will give them the priority to choose to leave the impact area and to find an agreeable place to relocate. The implementation of the TDR program will also have positive impacts on the developers in the region because it will provide them with an avenue for building higher-density developments.

A negative effect of the TDR program is that it imposes losses on renters. If the owner of a rental property decides to participate in the TDR program, the renter will be forced to move but will not receive any compensation for their losses through the TDR program. Because renters do not have assets tied to the property to be at issue but will still encounter a hardship by losing their rental property against their will and could experience difficulties with finding somewhere to relocate. Governments within the study area may consider implementing additional programs to provide some compensation to renters and to provide renters with relocation assistance. An additional negative effect of implementing the TDR program is that it could require a substantial amount of work to oversee the program and to educate the public about the existence and mechanics of the program.

Effects on Place

A new TDR program could gradually transfer people out of the sea-level rise impact areas and could incentivize future development in the areas most beneficial for it to occur in addition to conserving currently undeveloped lands. Over time this program could help to convert the projected inundated areas that are currently residential, commercial, and industrial areas into conservation areas that will be able to withstand inundation with many fewer negative effects. Within the new TDR program particular emphasis should be placed on designating socially vulnerable areas within the impact area as sending areas. When designating these sending areas consideration should be taken of the temporal nature of the sea-level rise inundation and areas that are projected to become inundated the soonest should have a higher priority in being designated as sending areas. These provisions will allow for the most critical areas within the impact zone to be addressed and converted into conservation lands first. Additionally, the sending areas within the new TDR program could also include areas designated as potential wetlands migration areas. The use of the new TDR program in these areas could allow for the creation of a wetlands migration corridor. The TDR program will also allow for the conservation of currently undeveloped lands so that these lands are better prepared for future inundation or wetlands migration. Finally, the new TDR program would have positive effects in the receiving areas by increasing development and the density of development in areas that have been designated for high-density development through local comprehensive plans.

Negative effects on areas that the new TDR program could have are associated with the transition during the conversion of the developed impact areas from residential, commercial, or industrial lands into conservation lands. During the transition there could potentially be an issue with the existence of many vacant properties that are awaiting demolition or deconstruction. Additionally, conflicts could arise in relation to the provision of services and utilities to these areas once populations begin to dwindle. It may become more difficult to live in these areas as an increasing percentage of the population moves away. Other limitations of this policy are that any

historic or culturally significant physical structures within these areas could be lost and some cultural aspects of these communities could be lost as well. Careful planning can avoid these consequences.

Effects on Economy

The TDR program has the potential to have positive effects on the economy through its incentivizing of increased development within the receiving areas. In order to maintain a vibrant economy within the coastal Georgia counties during their adaptation to sea level rise, the area must continue to grow. The TDR program can help to spur development and will guide development to areas away from the impact areas where development has the potential to exist indefinitely. Also, instead of suffering substantial losses, the TDR program provides a mechanism to compensate landowners for their lands located within the impact zone, which will then allow these landowners to maintain their assets and continue to contribute to the local economies. Furthermore, as the TDR provides a method of compensating landowners for their lands it removes this burden from potentially landing on the governments and will allow the governments to use their limited resources on other issues.

A potential negative impact of the TDR program on the economy comes from the loss of usable capital prior to inundation. As people and businesses begin to leave the sending areas there will be a gap in time before inundation reaches those areas that could be significant and during which there will be a loss in potential revenues. There could also be negative effects on the economy associated with the shifting of businesses and industry from the sending areas to other locations. Some businesses and industries may be unable to relocate for various reasons especially some specialized industries such as the fishing and shrimping industries that have specific requirements for locating. The tax bases in these areas could also become completely realigned due to the shifting of development, which could negatively affect some areas.

Alternative for Shore Protection

In the engineering design for shore protection, the protection category can be divided into hard armoring (seawalls, bulkheads, etc.) for flooding, and moderation (groins, breakwaters, etc.) for shoreline stabilization. Beach nourishment or restoration is termed the soft alternative to the armored or hard alternative for shore protection.

Traditional hard armoring includes seawalls, bulkheads, and protective revetments for cliffs and dikes. The cost of hard armoring may be justified when flooding and wave damage would threaten substantial human investments. If a recreational beach is present, periodic beach nourishment would be anticipated to retain the width of the buffer strip between the armored shoreline and the sea. Shoreline stabilization takes the form of headland and nearshore breakwaters, groins, sills and reefs, and wetlands. These structures could moderate the coastal sediment transport processes to reduce the

Table 5.1 Recommended Shore Protection Options

		Geometry	Materials
HARD ARMORING	Seawall	Vertical, Curved	Concrete, Rock
	Bulkhead	Crib, Stepped	Concrete, Steel, Timber, Aluminum
	Dike/ Revetment	Sloped	Earth, Rock, Geotextiles, Gabions
STABILIZATION	Breakwaters Groins		Concrete, Rock, Steel, Timber, Geotextile Bags
SOFT PROTECTION	Beach Nourishment	Underwater Berms	Dredged Materials, Artificial (crushes
	Sand Passing	Bypassing Bankpassing	Downdrift Material Returned Updrift
	Vegetation		Vegetation, Mangrove
	Sills		Sills

local erosion rate. They should be considered where chronic erosion is a problem due to diminished sediment supply. They can be used to slow the loss of placed sand, instead of trapping sands and creating more problems elsewhere. Beach nourishment is a measure to place loose sediment material on the subaerial beach, as underwater mounds, across the subaqueous profile, or as dunes to rebuild the dunes. The soft alternative solution for shore protection is gaining popularity as a more common alternative to hard armoring. (Laboratory, 2008)

The selection and engineering design of the shore protection structures is constrained by nature, costs, concerns of environmental impact, institutional, social, legal issues and possibly by aesthetics. The functional design details for the first three alternatives are shown in Table 5.1.

Hard Armoring

Seawalls and Dikes

A seawall is a massive structure that is designed primarily to resist wave action along high value coastal property. Seawalls may be either gravity- or pile-supported structures. The seaward face may be stepped, vertical, or recurved. Common construction materials are either concrete or stone. The primary purpose of a seawall and dike is to prevent inland flooding from major storm events accompanied by large, powerful waves. Dikes are typically earth structures, such as dams, that keep elevated water levels from flooding interior lowlands. If they are designed with a sloping surface or bubble mound, they could absorb some wave energy. The front face may also be curved or stepped in order to deflect wave run-up.

Using seawalls and dikes should recognize special concerns about environmental consequences. Seawalls can increase the rate of erosion in front of the seawall due to wave reflection and at the ends of the structure caused by wave focusing. When all available beaches have been removed in front of the wall, down drift areas will no longer receive sediment and erosion may be accelerated as a result of building the wall. (Ltd, 2010) An example of concrete seawall for Galveston Sea Wall West is shown in Figure 5.1

Bulkheads

Bulkheads are vertical retaining walls whose primary purpose is to hold or prevent backfill from sliding while providing protection against light-to-moderate wave action. They are used to protect

Table 5.2- Costs for 100 Linear Feet of Bulkhead Options

	Site Preparation $	Construction $	Initial Total $	Annual Maintenance $
Steel Sheet-Piling	900	418,600	419,500	37,020
Railroad Ties and Steel H-Piles	900	364,550	365,450	46,860
Gabions	900	151,475	152,375	19,540

Table 5.3- Costs for 100 Linear Feet of Revetment Options

	Site Preparation $	Construction $	Initial Total $	Annual Maintenance $
Quarrystone	10,475	285,100	295,575	26,225
Concrete Blocks	10,475	154,570	165,045	21,260
Gabions	10475%	154775%	165250%	21,190
Soil Cement	9,225	80,680	89,905	20,520

eroding bluffs by retaining soil at the toe. Bulkheads are either cantilevered or anchored sheet piles or gravity structures such as rock-filled timber cribs and gabions. An example picture of concrete bulkhead, which is taken from TJ's Marine Construction Inc's website is shown in Figure 5.1.

A cost analysis of bulkheads per 100 linear feet is shown in Table 5.2.

Revetments

Revetments are a cover of facing of erosion resistant material, such as stone or concrete, and are built to protect a scarp, embankment, or other shoreline feature against erosion. They are usually placed directly on an existing slope, embankment or dike. Since revetments rely on the land behind it for structural support, it is less costly than sea walls. A typical revetment is composed of the armor layer, filter, and toe. A sloping revetment will have a reduced effect on the erosion rate by dissipating the wave energy. However, they also lock up the shoreline sediments as sea walls and will cause down drift erosion problems. (Ltd, 2010) An example picture of concrete revetment, which is taken from ASP Enterprise's website is shown in Figure 5.1.

A cost analysis of revetments per 100 linear feet is shown in Table 5.3.

Shoreline Stabilization

Headland Breakwaters

Natural sandy beaches between rocky headlands are verified to hold static equilibrium and the creation of artificial headland breakwaters can be used as a shore protection structure. Normal wave conditions with a predominant swell direction produce a maximum indentation between two fixed points and a fully equilibrated, planeform shape. Man can mimic nature by building the headland breakwaters and letting nature sculpture the beach with a limiting indentation. A photo for headland breakwaters at the Luter Project (James River) 1999 is shown in Figure 5.1.

Nearshore Breakwaters

Nearshore breakwaters are detached, generally shore-parallel structures that reduce the amount of wave energy reaching a protected area. The reduction in wave energy would slow the littoral drift, produce sediment deposition and a shoreline bulge or salient feature in the sheltered area behind the breakwater. Nearshore breakwater system can be applied to increase the fill life of a beach nourishment project, provide protection to upland areas from storm damage, provide a wide beach for recreation, and create or stabilize wetlands areas. A photo for nearshore breakwaters at the Presque Island, Pennsylvania 1994 is shown in Figure 5.1.

Groins

Groins are constructed to maintain a minimum dry beach width for storm damage reduction or to control the amount of sand moving alongshore. They are usually perpendicular to the shoreline and relatively short. Over some time interval, accretion causes a positive increase in beach width updrift of the groin. However, conservation of sand mass would produce erosion and a decrease in beach width on the downdrift side of the groin. Groins can be made of rubble, timber, timber-steel, pre-stressed-concrete, or cellular-steel.

Reefs, Sills, and Wetlands

Reefs, sills, and wetlands can reduce the wave energy striking the shoreline. Reefs are massive calcareous rock structures built up to a strict elevation in relation to low tide. Natural reefs require high wave energy to survive and form wide platforms that cause waves to break across the reef. Wetlands are coastal salt or freshwater marshes that are low-lying meadows of herbaceous plants subject to periodic, water level inundations. Wetlands are fragile and only survive in low wave energy environments. Sill is used for wave attenuation in the lee of the structure. It may take the form of a submerged, continuous, nearshore dike to hold sand moving offshore from a nourished beach or of a perched beach.

Soft Protection

Beach Nourishment

Beach nourishment involves the artificial placement of sandy material along the shore to establish and subsequently maintain a desired beach width and

Figure 5.1 Shore Protection Options

Groins, breakwaters photos: Coastal & Hydraulic Laboratory, Coastal Engineering Manual, http://chl.erdc.usace.army.mil/, 2008

Sea wall photo: Anthony Marino, http://www.austinareaphoto.com/2010/03/21/galveston-trip-spring-2010/, 2010

Revetment photo: ASP Enterpise, http://aspent.com/channels-and-streambanks/, 2010

bulkhead photo: TJ's Marine Incorporation, http://www.tjsmarineweb.com/services.html, 2012

shore position to dissipate wave energy and enhance beaches, particularly for recreational and aesthetic purposes. Beach nourishment can also enhance the natural environment by widening beaches and reducing the potential for new, tidal inlet formation during storms. Recreational beaches often require periodic beach nourishment. It can provide a natural buffer between the erosion hazard and the asset in long term. Loose sediment material can be placed on the sub-aerial beach, as underwater mounds, across the subaqueous profile, or as dunes to rebuild the dunes. Once the initial design life is exceeded further nourishment is likely to be required and the design life is dependent on the rate of erosion at the site and the volume of material added.

Dune Building

Sand dunes are formed by wind rather than moving waters. They provide a coastal defense system and vegetation is vital for the maintenance of dunes because their root systems bind sediment and facilitate the build-up of dune sediment via wind baffle. With sand fences, mesh matting, and vegetation planting, dunes could successfully regenerate dunes via sediment entrapment and vegetation colonization.

Coastal Revegetation

The presence of vegetation in coastal areas improves slope stability, consolidates sediment and reduces wave energy moving onshore. This method may be successful in estuarine conditions (low energy environment), but not on the open coast (high energy environment).

Impact Analysis for Hard Armoring

Effect on People

Hard armoring protection structures change the appearance of the coastline. They are likely to have less aesthetic value than the original environment. The structure should be sited to avoid known archaeological or other cultural sites and it should be designed to be aesthetically pleasing. Land use patterns will often change as a result of construction of hard armoring. Local scour or flanking erosion at the ends of shoreline armoring structures can affect the existing structures or adjacent property. The high water line will continue to migrate landward on either side of the armoring.

With beach width narrowed, lateral access is diminished and ultimately lost, unless long-term beach nourishment is feasible. Beach losses could impair recreation (Dronkers, et al., 1990).

Effect on Place

Once a hard structure has been built along a shoreline, the land behind it will no longer be vulnerable to erosion, and the contribution of littoral material to the system will be diminished along the affected shoreline. It would stabilize the upland and protect infrastructure and properties. However, the contribution formerly made by the area must now be supplied by the adjoining areas. Some vertical structures such as bulkheads may cause increased wave reflection and turbulence with a subsequent loss of fronting beach. The building of hard structures could possibly degrade water quality by increasing suspended solids during construction and altering circulation. Transportation of material, preparation and construction using heavy equipment, and back filling and grading during construction will cause temporary dust and noise pollution close to the site as well. Placement of coastal shore protection structures requires an initial disturbance of benthic substrate. Moreover, vertical structures may accelerate erosion of the foreshore and create unsuitable habitat for many bottom species in front of the structure as the result of increased turbulence and scour from reflected wave energy. But it results in the formation of a new substrate composed of structural material and stability of the sediments adjacent to the structure. The design using rubble toe protection or a riprap revetment with a sloping angle will help dissipate wave energy and will provide reef habitat for many species. Bulkhead and revetments can reduce the area of intertidal zone and eliminate the important beach or marshland between the aquatic and upland environment.

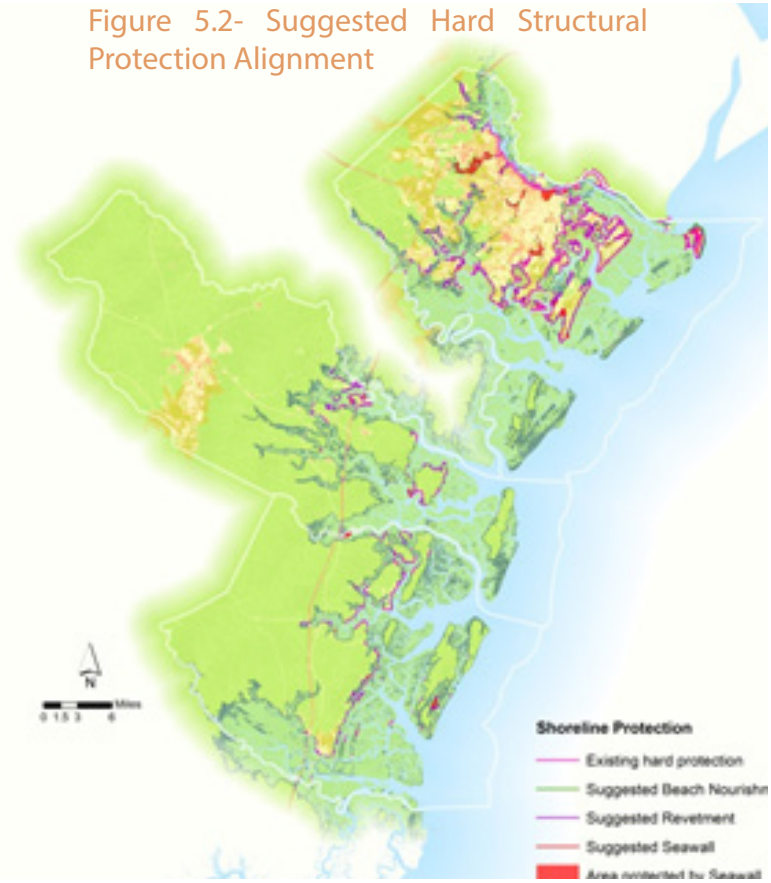
Along a shoreline undergoing long-term erosion, the high water line will continuously migrate landward. In response to sea level rise, the shoreline will continue to migrate landward until it reaches a hardened surface. The loss of dry beach results with high water forced against the structure.

Effect on Economy

The building of hard armoring could prevent physical damage to property and prevent loss of economic production and income. It can also prevent land and natural habitat loss during erosion. The benefits should be evaluated with the costs of initial building and maintenance. Cost estimates in different parts of the country can vary significantly depending on the availability of materials and transportation charges. The following cost estimates developed for 1,000 lin ft of protection is shown as an illustration (Engineers, 1995).

The presence of hard armoring structures could encourage development in high-risk areas. And the risks of inundation and flooding can never be fully eliminated by protective structures. As sea level continues to rise, efforts to prevent overtopping coast wide might ultimately be futile. It should also be noted that these structures have limited life spans, lasting only a few decades, and attempts to maintain them in the face of sea level rise will be costly. Economists have identified and recommended elimination of perverse tax breaks to homeowners of coastal developments, and to infrastructure in coastal zones as a stimulant that encourages development in high-risk locations, and the national government has yet to fully grapple with the very substantial costs of repairing the damage from Hurricane Katrina and Sandy, so the fiscal consequences of coastal development could well change in the future (Force, 2010).

Figure 5.2- Suggested Hard Structural Protection Alignment



Preliminary Impact Analysis for Beach Nourishment

Effect on People

With improvement of beach environment with beach nourishment, more residents and visitors would be attracted to the coastal region, leading to increased development and congestion. Beach nourishment may potentially increase the burden on local public infrastructure because of increased activity. On the other side, increased storm damage reduction and erosion can potentially increase liability for society in the future because of the large development incentives resulting from the beach nourishments. Over-development may occur on properties that will be inundated decades later (Board, 1995). When the costs for beach nourishment are paid by the taxpaying public, rather than those property owners that benefit most directly, the opinion gap between proponents and critics increases (ScienceJrank, 2012).

Effect on Place

The immediate result from beach nourishment is the reduced erosion by modifying the slope of the shore and by diminishing wave energy. Restoration of beach profile and dunes can benefit endangered and threatened species such as turtles, birds, and plants. Ecological benefits that provide improved and increased nesting opportunities for endangered species might arise from beach nourishment. Benefits may accrue downstream if the sand shifts to another location and provides benefits there (Board, 1995).

However, it should also be noted that beach nourishment could generate other negative impacts.

If the sand used for beach nourishment is removed from a site where it contributes ecological or other benefits, the removal of the sand would generate a negative effect at the borrow pit. Vegetation and place of activity for animals may be buried by the sand replacement. The difference in the grain size of new sand and old one may harm local organism as well.

Effect on Economy

Beach nourishment could elongate the life of properties that would otherwise be destroyed sooner. The maintenance of high quality beach also results in amenity values in local real estate. Private property owners near attractive shorelines can gain from an increase in beach amenity value. Beach nourishment keeps the high quality of coastal natural resources that benefit both visitors and local folks. Tourists are attracted with an increased consumer willingness to pay.

The cost for beach nourishment includes the labor, capital, energy, and material used in the construction of a project. The effect of beach nourishment is at the mercy of natural forces. And renourishment is needed when uncertain storm events occur (Board, 1995). However, the continued rise of sea level may make beach nourishment untenable. The initial and maintenance cost for Georgia beach nourishment is obtained by using the average of Florida-Northeast estimation references and South Carolina estimation references. The expected life cycle would be 4.5 years, the cost per mile would be $2,132,875, and annual maintenance cost would be $478,525 in the first ten years (USACE, 2005).

County Planning for Shoreline Protection

Chatham County is home to many communities and the beaches of Tybee Island along its eastern border are a major tourist attraction. Sloping sea walls are allowed under the Shore Protection Act, but not vertical sea walls, because they do not dissipate wave energy and they increase shoreline erosion. Nourishment is allowed under the act, but is generally conducted only as a private enterprise in Georgia. An application for funding or permit of a seawall triggers a consultation to determine the effects of the construction on affected species. The metropolitan area surrounding Savannah will almost certainly be protected. Currently, Savannah Historic District is not marked for protection by local ordinance, but county staff anticipates constructing dikes along the Savannah River, where it abuts the city. Protection is also likely for developed portions of Tybee and Skidaway Islands, Dutch Island, Isle of Hope, and Modena. Given the value of developed property in coastal Georgia, the county believes that privately funded protection of these lands is likely (Concannon, Hussain, Hudgens, & Titus, 2010).

In Liberty, the most heavily developed portion of the county is the town of Hinesville and the surrounding Fort Stewart area. As previously stated, Hinewsville is so far inland that it will be largely unaffected by

Figure 5.3- Hard Structural Protection Alignment for Tybee Island, Potential

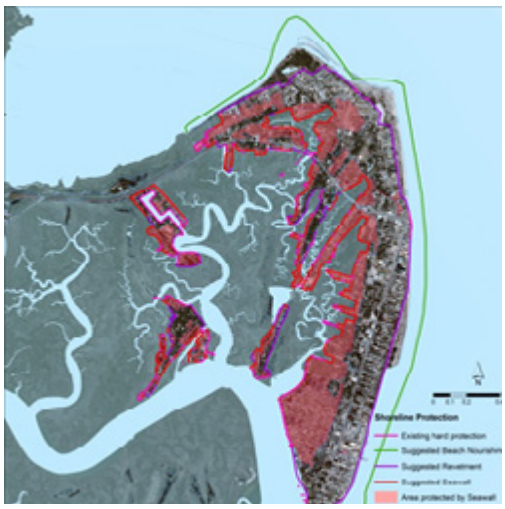


Figure 5.4- Hard Structural Protection Alignment for Wilmington Island, Potential

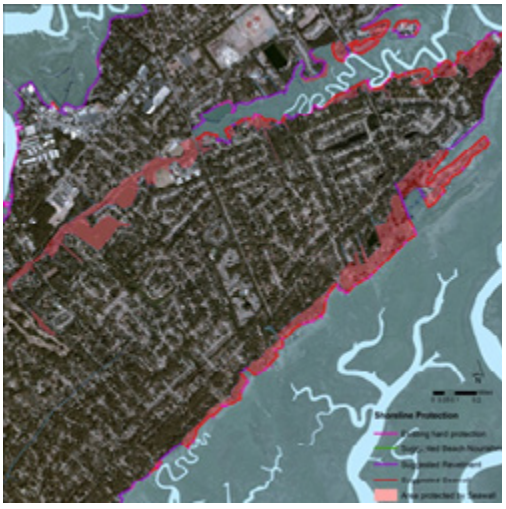
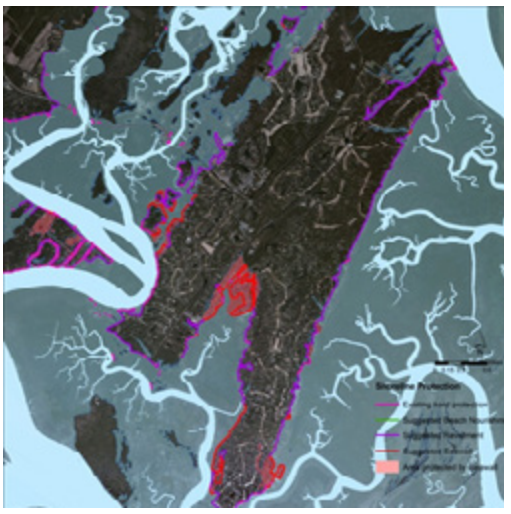


Figure 5.5- Hard Structural Protection Alignment for Skidaway Island, Potential



a sea level rise. Protection is likely for the residential areas of Riceboro and Midway (Concannon, Hussain, Hudgens, & Titus, 2010).

Points of interest in McIntosh County include the City of Darien, the Fort King George Museum, and Sapelo Island. The developed portion of Townsend is considered certain to be protected, while developed areas such as Richmond Hill, Shellman Bluff, Crescent, Meridian, and portions of Sapelo Island are likely to be protected. City of Darien is mostly located above the 20-foot elevation contour and therefore is not considered to require future shore protection (Concannon, Hussain, Hudgens, & Titus, 2010).

Shore Protection Planning

In the investigation of hard structural protection, the data used includes the 2006 land cover gird of 30 meter resolution and the sea level rise model. The existing hard protection is considered as well. The accurate boundary for properties and communities

Table 5.4- Summary of Potential for Hard Structural Protection

	Chatham	Liberty	McIntosh	Total
Existing hard structure (ft)	341,825	28,774	43,963	414,562
Suggested revetment (ft)	817,426	131,047	138,084	1,086,557
Suggested Sea wall (ft)	177,024	21,036	22,423	220,483
Area protected by sea wall (sqmi)	5.877	0.134	0.304	6.315
Buildings protected by sea wall	1,522	48	55	1,625
Suggested beach nourishment (ft)	24,822	-	-	24,822

Source: Bathtub SLR, Google Earth 2012

Table 5.5- Summary of Potential for Hard Structural Protection: Tybee Island, Isle of Hope, and Skidaway Island

	Tybee Island	Wilmington Island	Skidaway Island
Existing hard structure (ft)	29,785	32,788	46,611
Suggested revetment (ft)	37,351	80,780	182,390
Suggested Sea wall (ft)	49,662	29,733	74,339
Area protected by sea wall (sqmi)	0.586	0.316	0.739
Buildings protected by sea wall	948	146	255
Suggested beach nourishment (ft)	24,822	-	-

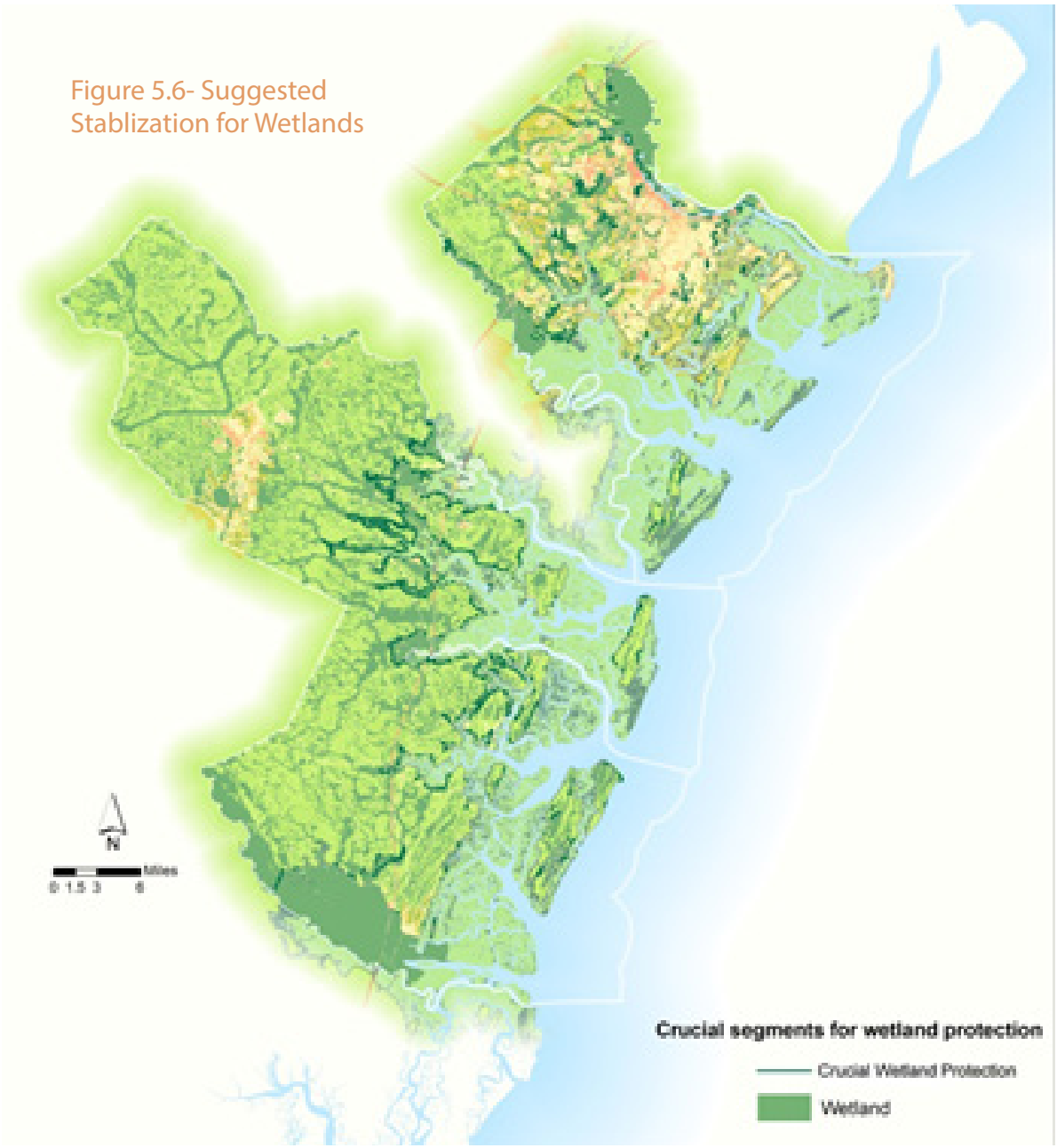
Source: Bathtub SLR, Google Earth 2012

Table 5.6- Summary of Wetland Stabilization Lengths

	Chatham	Liberty	McIntosh	Total
Suggested segments for wetland protection (ft)	416,783	587,057	352,725	1,356,565
Wetland Area Impacted (sqmi)	20.689	28.036	37.306	86.031

Source: Bathtub SLR, Seamless National Wetlands Inventory 2009

Figure 5.6- Suggested Stablization for Wetlands



are identified on the Google satellite maps. The boundary segments that intersect with the sea level rise surface are highlighted as potential sites for sea walls and the boundary segments that border the sea level rise surface are highlighted as potential sites for revetment and bulkheads. The developed area under sea wall protection, the buildings, and wetlands have been taken into account.

In the recommendation for attention for wetland protection, the existing wetland that will be severely impacted by sea level rise is shown. This data is adapted from the 2009 Seamless National Wetlands Inventory maps of Georgia.

Potential Hard Structural Protection

This section of the report identifies potential locations for hard structures and potential points of interest for wetland stabilization. Identification as a possible site for hard structural protection is based on the location of existing properties. The result of the investigation is consistent with the planned county shoreline protection described above. The rise in sea level would affect the developed regions in two ways. Primarily, sea level rise would directly inundate some portion of residential properties, commercial buildings, and industrial sites within the study region if no additional protection is made. For the portion of potentially inundated land, sea walls could be considered for protection of this property. It should also be known that many communities in the study region are located and bounded within the "highland" area above sea level rise. Although

the rising sea will not immediately inundate those community, but the sea has circled its boundary. When erosion occurs, the property in the community will also be threatened. Hard structures, such as bulkhead and revetment, are potential solutions for community borders along the shore. The total shoreline with the potential for hardscaping is lengthy, and it would be infeasible to implement this solution along its entirety.

The potential for hardscape protection in the study region is shown in Figure 5.2. The total length of shoreline suitable for hardscaping is outlined in table 5.4,

As a look at specific locations, the protective alignment for Tybee Island, Wilmington Island, and Skidaway Island are magnified in Figures 5.3 through 5.5. The summary for the hardscaping options for those communities are outlined in table 5.5.

Potential Wetlands Stabilization

Sea level rise will also threaten the survival of wetlands. The wetlands projected to be impacted by sea level rise are outlined in table 5.6. Policymakers should consider measures such as stabilization and soft protections for those sensitive borders. Hard structural protection should be strictly controlled near those wetlands to allow natural migration.

Wetlands threatened by sea level rise are shown in Figure 5.6. When the border of the wetlands is faced with the sea level rise border or the sea level rise leads to part of inundation of the wetlands, special attention for wetlands protection is recommended. The total length suggested for stabilization is summarized in table 5.6.

Infrastructure Adaptation

The term infrastructure is used by urban planners, architects and engineers to "describe essential facilities, services, and organizational structures for cities and communities" (Craven, 2012). The term includes, but is not limited to roads; rail lines; bridges; airports; telephone lines; water treatment facilities; ports; and municipal buildings. Within the

Figure 5.7 – Inundated Rail Lines near the Port of Savannah

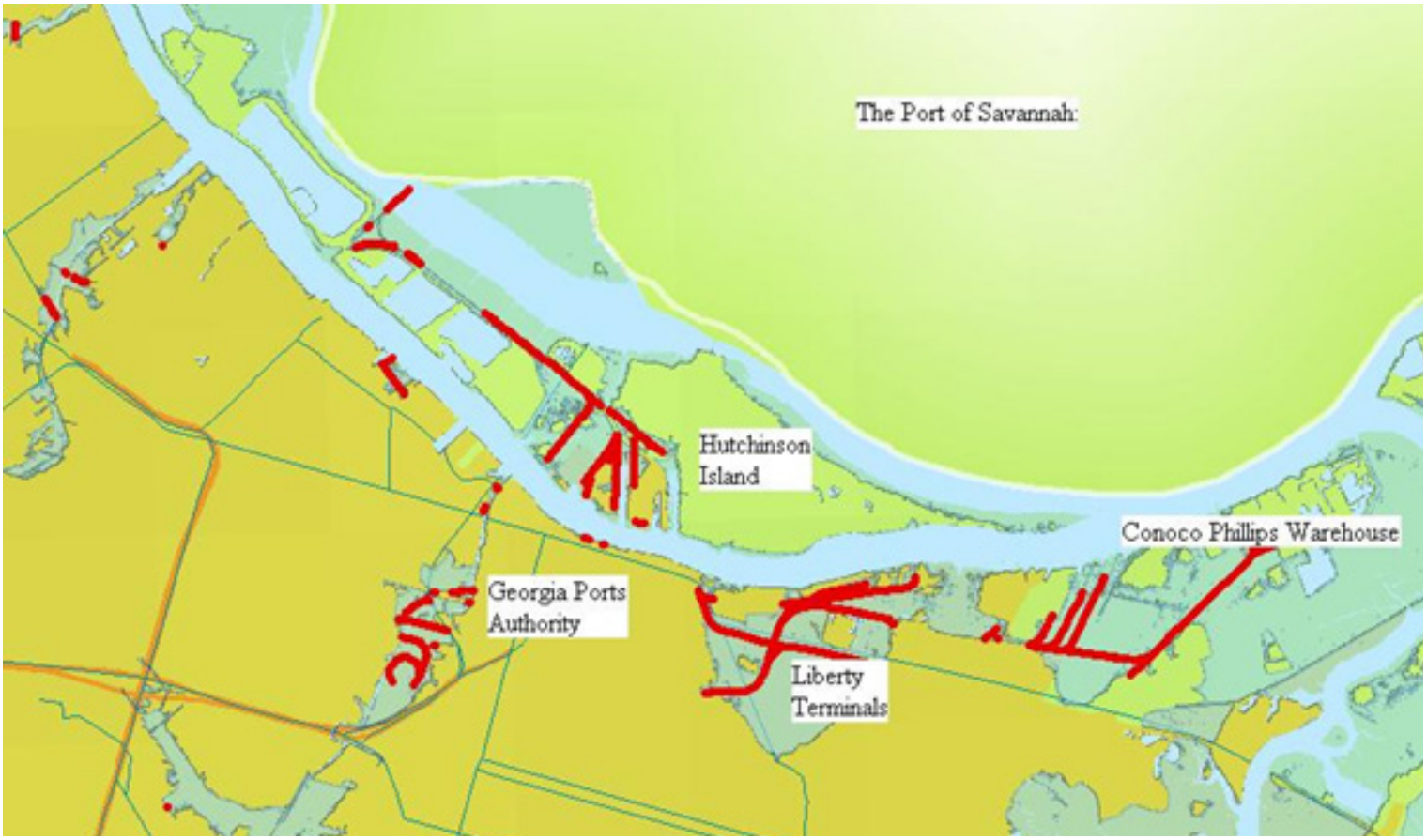
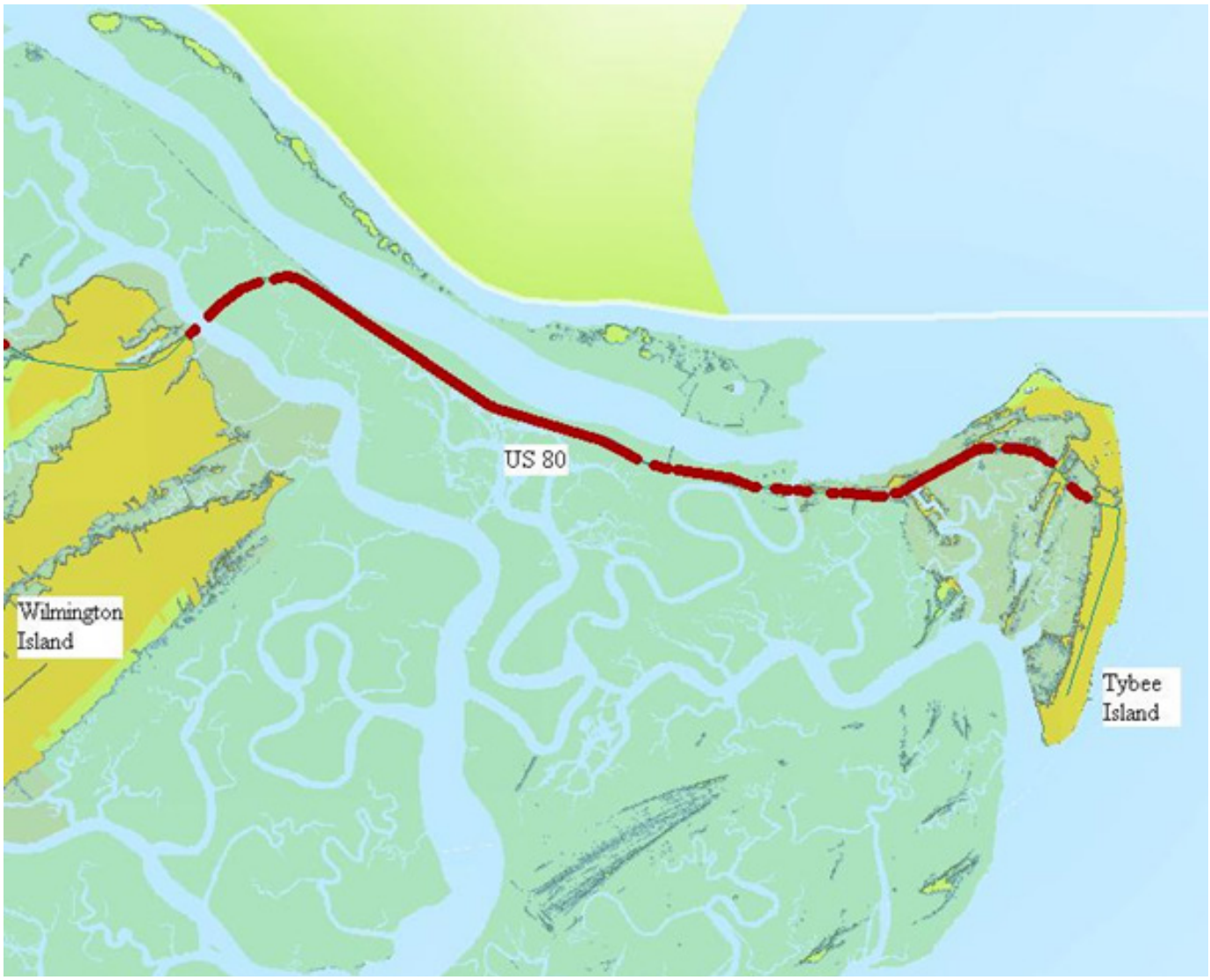


Figure 5.8 – Sections of US 80 Projected to be Inundated by Sea Level Rise.



three counties, there are hundreds of miles and units of infrastructure that are vital for the health, safety and livelihood of residents. Therefore, it is important to devise strategies for adaptation of the valuable infrastructure within Chatham, Liberty, and McIntosh Counties, and to establish plans for future growth and development of the area that considers the possible negative effects of sea level rise in the future.

Transportation

Mao (2011) suggests: "planning new routes [that] could be the evacuation routes of existing routes; reinforcement and ongoing maintenance, increased height of sea walls, landslide and dike fencing and monitoring; raising the elevation of routes; or abandonment" (Mao, 2011, p. 56 and 57). Also according to Mao (2011), based on a report from the Wilmington, Delaware Area Planning Council: "elevating streets, bridges, runways and rail lines; relocating sections of roads and rails inland; strengthening and heightening levees, seawalls and dikes to protect existing development; [and] restricting further development of vulnerable coastal areas" are ways in which sea level rise adaptation strategies for transportation infrastructure can be implemented (Mao, 2011, p. 19).

One option for rail adaptation is elevating existing rail links that may be in-danger of future inundation. Another option for rail adaptation may simply be hardscaping to prevent inundation, and this can come in many forms, such as rock or concrete walls, or other types of barriers. Based on the aerial view, and the analyses performed in this report, many people will be

Figure 5.9 – Sections of I-95 in McIntosh County Projected to be Inundated by Sea Level Rise.

affected by the inundation of the Port of Savannah. Methods such as installing a tidal gate are not recommended because many communities, habitats and historic sites are located adjacent, or within close proximity to, the Port.

Several, short rail links within the Port of Savannah will be inundated by sea level rise. CSX, Norfolk Southern, and Georgia Central own the rail lines within the Port. However, the terminal links that connect to the Port are used by all the lines as transfer and storage links. Therefore, these rail links are essential for maintaining the transportation network that carries goods from the Port to other locations throughout the State of Georgia and the region. The rail links will need to be adapted, either by elevating or by the construction of barriers to prevent inundation. Although relocation is conceptually an option, the rail links must remain in the Port in order to connect with ships carrying goods, and the property within the Port for relocating the lines may be difficult to obtain (Figure 5.7).

In terms of strategies for adapting highways, such as an approximately 6.2 miles long segment of I-95 in southern McIntosh County, elevating segments that are at-risk of becoming inundated or relocation of highways inland, are two viable options that engineers and planners can consider
(Figure 5.8).

However, the approximately 5.5 miles long segment of US 80 connecting Tybee Island to Savannah that is expected to become inundated, and is the only means by which Tybee Island residents and visitors can reach the island (Figure 5.8). Due to the fact that the Savannah River and portions of streams leading to Wassaw Sound flank US 80, relocation inland is not possible. Elevating the entire segment of the highway that runs along marshland and intercoastal

waterways to bridge status is the only potential strategy.

As for Interstate 95 in southern McIntosh County, based on the aerial image (Figure 5.9), it appears that the inundation will take place where inland streams connect to the Altamaha River and the Altamaha Sound. This area is low-lying, and numerous segments of Interstate 95 are already elevated by bridges. This portion of Interstate 95 may require a complete upgrade to bridge status for the approximately 6.2 miles of Interstate 95 affected by the inundation.

Effects on People, Place, and Economy

There are both positive and negative implications for adapting US 80 to Tybee Island, the segment of Interstate 95 in southern McIntosh County, and the rail links within the Port of Savannah. Any construction projects, such as elevation, relocation, or hardscaping will inevitably cause distress for local residents, by possibly limiting access to nearby communities or attractions, or possibly relocating homes. However, these projects are necessary for maintaining the local and State highway and rail networks, which ultimately ensures the access and safety of all residents and visitors to the area. During construction, planners will need to keep residents informed of all current projects and maintain a protocol that ensures the safety of residents during construction projects.

For Tybee Island residents and visitors, the construction of a bridge above the existing portion of US 80 will cause delays in travel on and off of the island. The stretch of Interstate 95 in McIntosh County will also experience severe congestion during construction. Consequently, these projects will need to be done in manageable small components, resulting in a longer, and more costly construction period.

As for the rail links within the Port of Savannah, construction projects involving elevating rail links or hardscaping around the Port to prevent inundation of rail has the potential of polluting local waters during construction and limiting local road access for residents or business owners. Elevating or hardscaping around rail links also has the potential for harming vulnerable wildlife, including wetlands and marsh areas adjacent to the Port of Savannah. Also, the costs incurred by elevating rail links or constructing barriers for hardscaping will be expensive and will require an extended period of time to complete. However, preserving the valuable rail links within the Port of Savannah is essential to ensure that the multi-modal terminal located at the Port continues to operate.

Water Treatment and Water Supply

According to an article by Rosenweig et al. (2007) on sea level rise adaptation strategies for existing water treatment and water supply infrastructure: "managing risk by adapting long-lived infrastructure to the effects of climate change must become a regular part of planning for water supply, sewer, wastewater treatment, and other urban infrastructure during this century" (Rosenzweig, et al, 2007). Rosenzweig, et al (2007) also states that agencies can "incorporate adaptations to the risks of climate change into their management, investment, and policy decisions over the long term as a regular part of their planning activities" (Rosenzweig, et al, 2007).

According to the results from the analyses presented in this report, there is one wastewater treatment facility in Chatham County that is at-risk of becoming inundated by sea level rise. The wastewater treatment facility at-risk of inundation is the President Street Water Quality Control Facility, located adjacent to the Savannah River and the Savannah Hills Golf Club. This wastewater treatment plant also treats water discharged from the Windsor, Georgetown, and Travis Field municipal treatment plants.

Because our assignment stopped short of investigating steps that agencies responsible for vulnerable facilities might have taken to protect those facilities, the President Street plant may have begun adaptive protection strategies. Our analysis shows that these kinds of strategies are necessary. The specific options include the construction of barriers along the north side of the facility property, adjacent to the Savannah River. Another option is elevating portions of existing facilities that are in-danger, although this option would be costly. If preventative measures are not taken on the current facility, engineers and planners may opt for abandonment and relocate the facility elsewhere but this is typically a last resort.

The President Street plant is located on property adjacent to the Savannah River. Although the main facilities at the plant can likely be protected through barriers along the Savannah River, the remainder of the facilities, located to the north, alongside the River, will likely need to be relocated due to their close proximity to the River.

Effects on People, Place, and Economy

Adaptation strategies for the President Street wastewater treatment plant will have both positive and negative impacts on the surrounding communities, environment and local businesses. Although preserving the existing facility will extend its life, to continue construction of barriers and elevating techniques could impact local communities by temporarily delaying service. However, adapting the current facility will obviously not require abandoning the site, possibly introducing a Superfund project. Also, preserving the current location will prevent seeking a location for a new plant that would be difficult and costly.

Other Infrastructure

Other than road, rail, the ports, and water treatment and supply facilities, there are many other types of infrastructure within Chatham, Liberty, and McIntosh Counties. Some of these other facilities include airports; government facilities; medical facilities; schools; and hurricane shelters. Adaptation strategies for guarding various types of infrastructure against the negative effects of sea level rise, as suggested by Nicholls and Mimura (1998) include: "information measures, including studies to predict future changes and their impacts; [and] technical measures, in terms of coastal planning and engineering" (Nicholls and Mimura, 1998, p. 14). These strategies are also necessary for devising plans for future development; however, physical adaptation strategies must be implemented to protect and preserve currently existing infrastructure.

Based on the results from the analyses presented in this report, the two airports in Chatham and Liberty Counties: Savannah/Hilton Head International Airport in Chatham County, and Midway Regional Airport in Liberty County, will not be inundated by sea level rise. A small segment of peripheral land at the Savannah/Hilton Head Airport will be affected, but it is so remote that it will not affect airport operations. Also based on the analyses, none of the medical facilities in the three counties will be inundated. There are no hurricane shelters in Chatham, Liberty and McIntosh Counties, thus, there is no risk of inundation. None of the 35 elementary schools, 13 middle schools, 12 high schools, nine k-12 schools, or seven public colleges will be inundated. However, the results from the analyses show that nine fire stations in Chatham County, and two jails on Tybee Island will be inundated.

The construction of barriers to protect vulnerable fire and jail facilities will likely to be necessary. Elevating portions of existing facilities that are in danger may also be another option. Planners and engineers will need to determine if sea level rise adaptation can effectively take place, otherwise, relocation of the Chatham County fire stations farther inland, and the demolition, reuse, or sale of the Tybee Island jails and shared use with Chatham County may be options.

Effects on People, Place, and Economy

Adaptation strategies for other infrastructure will inevitably have both positive and negative implications for the residents, environment and the local economy surrounding the infrastructure that is vulnerable to sea level rise. In this case, the nine fire stations located in Chatham County and the two jails on Tybee Island will need to be adapted, and the adaptation strategies used will have both positive and negative effects on the local communities. Relocation of facilities, especially fire stations, will have negative impacts on some communities in Chatham County by removing proximate facilities. Relocating a fire station to another area may jeopardize the safety of residents residing in the previous location by delaying the response time of safety and fire personnel possibly increasing insurance rates. Also, construction of barriers may not be the best option. Elevation of some facilities, such as the city jail on Tybee Island, located at the police department adjacent to 2nd Avenue, may be a viable option, by maintaining the current facility location providing safety services to residents and detention facilities for local offenders.

Adapting the fire stations in Chatham County and the jail facilities on Tybee Island will have effects on the environment, both the natural environment and

local communities. Elevating current facilities will require construction, but the elevation process will likely not impact the local environment as much as relocating and rebuilding new facilities. Elevating currently existing facilities could potentially impact the environment by potentially harming local wildlife or marshland near construction project sites.

Adapting the fire stations in Chatham County and the jails on Tybee Island will have impacts on the local economies. Preserving the existing facilities will be costly, although the costs will likely be less than those involved in relocating to an entirely new location. Depending on the size of the buildings, elevating the buildings only a couple of feet will be very costly, and these costs will be incurred by taxpayers. Relocating will be very costly and will require the need to acquire land in locations within close proximity to the current locations, and these properties may be unavailable for building purposes.

Hazardous Sites

There are numerous facilities and locations within the region that contain hazardous materials, or perform functions that would result in harm to people and wildlife living within close proximity if the byproducts and pollutants of these facilities were to infiltrate the water table. Nicholls (2011) states: "there are potential indirect impacts such as adverse effects on human health, for example, the release of toxins from eroded land fills and waste sites" (e.g., Flynn et al., 1984). Furthermore:

> "These indirect impacts are little researched, but will have economic consequences in terms of the damages caused (and/or the diversion of investment to fund the adaptation to avoid them). Thus, sea level rise has the potential to trigger a cascade of direct and indirect human impacts" (Nicholls, 2011, p. 148).

Some of these sites within Chatham, Liberty, and McIntosh Counties include: power production facilities and landfills. Flynn et al (1984) stated that:

> "[T]he need for anticipating sea level rise and reconsidering the adequacy of existing regulations varies according to the operating status of hazardous waste sites. Owners and operators of proposed facilities should consider whether the prospect of increased flooding justifies changing the planned location. Proposed facilities may minimize flood mitigation investments in the long run by designing for the flood levels to be experienced over the project's lifetime rather than those currently to be expected".

Based on the results from the analyses presented in this report, there are no power facilities at-risk of becoming inundated by sea level rise. However, the facilities that are located within Chatham, Liberty and McIntosh Counties still require monitoring. These facilities require fresh water for cooling purposes; thus, saltwater intrusion in nearby water sources could pose a threat to the functioning and general maintenance of these facilities. Therefore, measures will need to be taken to ensure that these facilities are not at-risk of the negative effects of sea level rise by monitoring nearby freshwater sources.

There are 43 landfills within the region: 28 in Chatham; 13 in Liberty; and two in McIntosh County. Based on our analyses, only one landfill will be inundated by sea level rise: the Dean Forest Road Municipal Solid Waste Reclamation and Disposal Facility, located in Savannah

Based on this analyses and the aerial views of the location, it is evident that inundation of the Dean Forest landfill will pose a threat to nearby residents, as it appears that several neighborhoods are located adjacent to the landfill property. The landfill will require close monitoring, and preventative measures will need to be taken to prevent runoff from the landfill from infiltrating the water supply. It may be necessary for the landfill to become a Superfund site, in order for the eventual abandonment of the facility to take place and to make clean-up a priority. "The Superfund cleanup process is complex. It involves the steps taken to assess sites, place them on the National Priorities List, and establish and implement appropriate cleanup plans. This is the long-term cleanup process" (Environmental Protection Agency, 2012).

Effects on People, Place, and Economy

The Dean Forest landfill is located off of Interstate 16, near the Savannah-Hilton Head International Airport, adjacent to the Southbridge community

Figure 5.10- Tidal Wetland in Georgia's Coastal Area

Source: GDNR (Division)

and RV park. The landfill provides waste disposal services for many residents and businesses within Chatham County. Because the landfill is adjacent to communities and businesses, inundation of the site would jeopardize the health and safety of many people. Adapting the landfill to sea level rise will be difficult. Although barriers can be constructed, it is unlikely that these barriers will completely prevent runoff of contaminants from the landfill and prevent pollutants from infiltrating the water table.

Decommissioning the landfill and relocating its functions to another area within Chatham County would have direct, negative impacts by jeopardizing the health and safety of residents and the environment. If the facility is relocated, measures will need to be taken to secure funding to make the original location a Superfund site. Planners will need to begin cleanup of the site well before the effects of sea level rise occur because this will likely take many years to complete. Another location, farther inland, away from low-lying lands and inland streams, will need to be acquired, and this will also be difficult and costly to obtain.

Adaptation Strategies for Wetlands

Georgia's coastal wetlands (figure 5.10) are among the most valuable ecological areas in the world (Division, n.d.). They provide a nursery for commercially and recreationally important species that link directly to

Table 5.7- Types of Wetlands and Coping Capacities

Wetlands type	Inundated area (acres)	Percent inundated (%)	G-ranked* inundated area (acres)	Percent G-ranked inundated (%)
Barrier island freshwater and ponds	601	0%	531	2%
Bayheads and titi swamps	104	0%	42	0%
Brackish marsh and salt marsh	204,254	88%	1,115	5%
Coastal scrub-shrub wetlands	1,519	1%	1,519	7%
Forested depressional wetlands	1,496	1%	1,441	6%
Swamps	3,316	1%	2,558	11%
Freshwater tidal marsh	21,683	9%	16,007	69%
Total	**232,973**	**100%**	**23,213**	**100%**

**G-ranked wetlands include only G1 (Critically imperiled), G2 (Imperiled) and G3 (Rare or uncommon) habitats. For the definition of wetlands, swamp, marsh and forested depressional wetlands, please refer to Appendix*

the region and the state's economies. In addition, they also provide other important ecological functions such as wildlife habitat, nutrient transformation, carbon sequestration, pollutant dissemination and shoreline stabilization (Tiner, 2011).

Table 5.8 below, following the case studies, outlines the adaptation strategies for wetlands.

The assessment of sea level rise's impact on wetlands (see Chapter 3: Physical Impacts) reports that over three-quarters of the three county study region wetlands to be completely inundated (Figure 5.11). This effect is most severe in Chatham County, where almost 90% of wetlands will be under sea level (Figure 5.11). The impact of sea level rise on wetlands is further exacerbated by the concentration of globally ranked habitats (G1, G2 and G3) in inundated areas. Overall, almost a one-third of all G-ranked habitats in the three county study region are present in these wetlands (figure 5.12).

There are seven types of wetlands in three county study region. Among them, freshwater tidal marshes which locate along major rivers such as Altamaha River, brackish and salt marshes, which locate along the coast, are most affected by sea level rise. Over 200,000 acres of brackish and salt marsh will be inundated, accounting for 88% of all inundated wetlands in three counties (Table 5.7). Although only 21,683 acres of freshwater tidal marshes will be inundated, accounting for 9% of all impacted wetlands, they contain 69% of G-ranked habitats that will be threatened by Sea level rise. In contrast, brackish and salt marshes contain only 5% of G-ranked habitats, less then forested depressional wetlands (6%), coastal scrub-shrub wetlands (7%), swamps (11%) and freshwater marshes (69%). Although containing a small amount of critical habitat, brackish and salt marshes are no less important than other wetlands due to their strategic function as buffers to protect inland communities and habitats from saltwater intrusion and storm surges (Alkaff, 1997).

Each type of wetlands has different coping capacity to sea level rise, as seen in figure 5.13. Salt marshes usually have lower vertical accretion rates compared to brackish and freshwater ones (Craft et al., 2008). Freshwater tidal marshes which receive sediments from major streams, have the highest vertical accretion rate among the three (Craft et al., 2008).

Figure 5.11- Threatened Wetlands

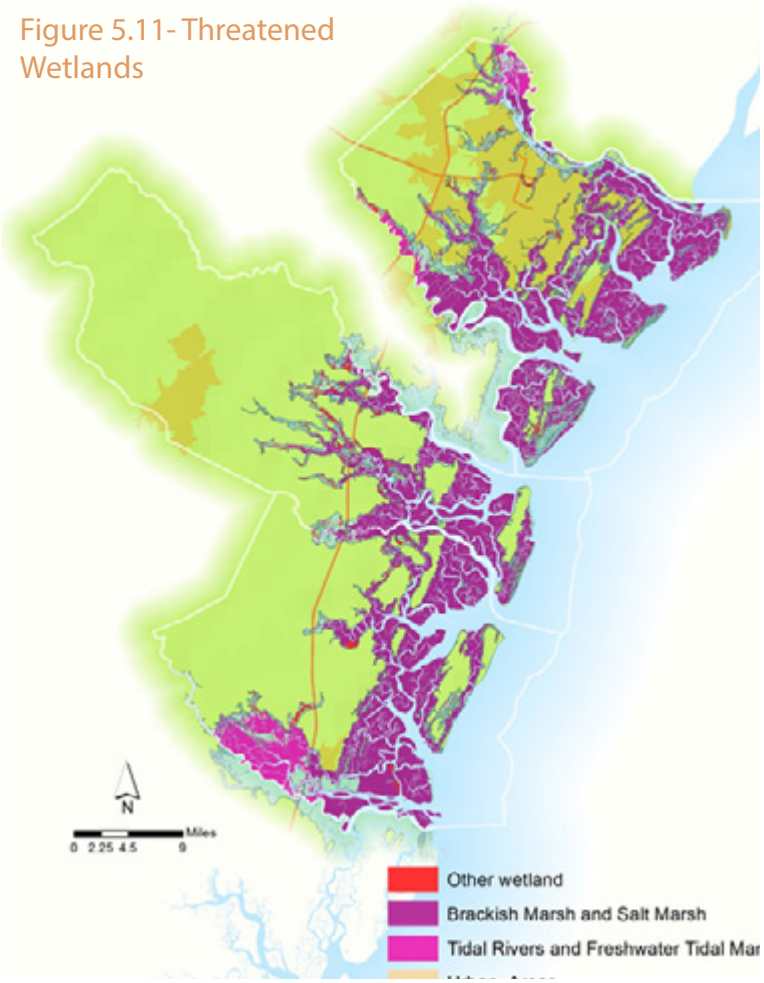
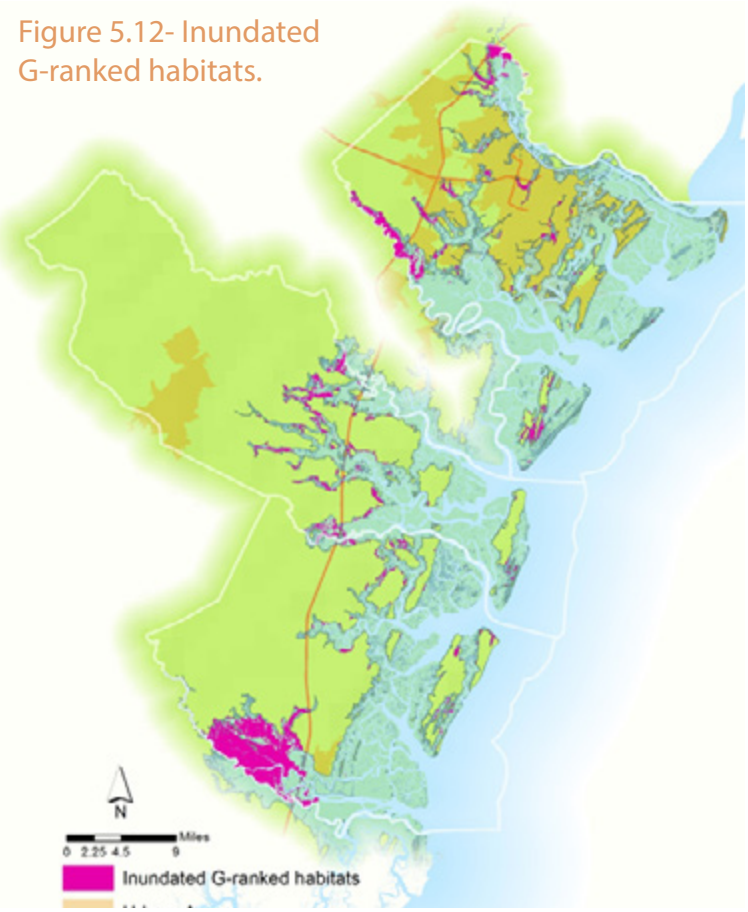


Figure 5.12- Inundated G-ranked habitats.

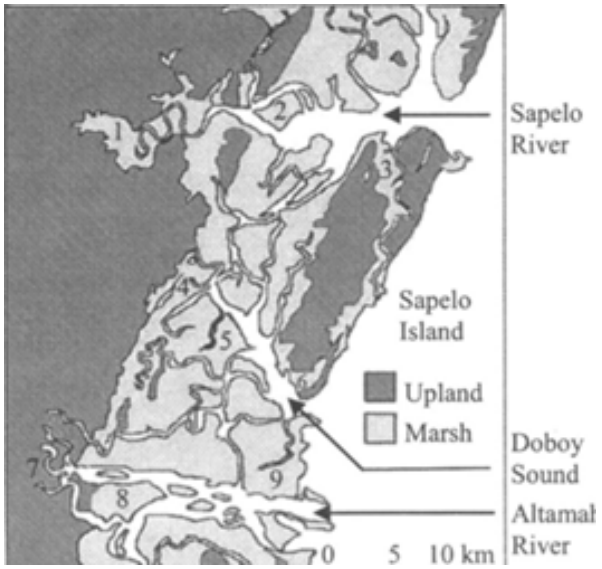


For example, freshwater wetlands of Altamaha River has an accretion rate of 14+- 4 mm per year, which is approximately equal to sea level rise rate we are considering. In contrast, nearby marshes of the marina-dominated Doboy Sound and Sapelo River accrete only 4+-10 mm per year. Another study by Letzsch (Alkaff, 1997) estimates the accretion rate of the salt marshes in Sapelo Island is only 2 mm per year, which is far less than the sea level rise. Freshwater marshes, which contain most of critical habitats, are more capable than saltwater marshes to adapt themselves to sea level rise. However, freshwater marshes' adaptation capacity is only realized when they have preserved space to migrate inland. On the other hand, other wetlands with low accretion rates will need different approach to sustain them through sea level rise.

To develop a comprehensive and successful plan for wetlands adaptation, we will need extensive data on sediment supply, erosive force of ocean waves and soil characteristics, etc. at site level which are not available at this moment. Here, we assume that at current conditions, freshwater marshes are able to mitigate to higher land while salt marshes are not.

How do we protect Georgia's coastal wetlands?
Based on the understanding of Georgia's coastal wetlands, their vulnerability to sea level rise and general adaptation schemes developed by EPA (Agency, 2009) in a synthesis of adaptation options for coastal areas, four major strategies are suggested for the three county study region:

Figure 5.13- Three Tidal marshes Studied by Craft et al 2008



Allow Wetlands to Migrate Through Land Preservation

This adaptation strategy for maintaining wetlands focuses on facilitating wetlands migration through modifications in legislations and regulations and land purchase of areas adjacent to wetlands. Possible legislation and regulation changes include zoning amendment (i.e. setback enlargement) and rolling easement. This strategy also has other positive effects on wetlands such as pollution prevention, wildlife habitat protection. Excepting the land purchase option, this strategy has low costs of implementation since it requires no physical intervention. This strategy, however, may fail to implement in highly developed coastal areas such as Tybee Island and the City of Savannah due to limited land availability and high land value. On the other hand, this strategy is irrelevant to wetlands with low accretion rates and/or fast-paced sea level rise. In these situations, wetlands cannot successfully migrate since their vertical accretion rates are too low to keep pace with the rising sea level.

Impacts on People, Place, and Economy

This strategy will have no direct negative impact on people. However, people's lands adjacent to existing wetlands will be restricted in terms of the developable area. This means their current property values can be reduced due to new setback and boundary regulations.

This strategy will enhance biological condition of the coastal area since it protects wetlands and prevents pollution to flow over the water courses. This strategy will also maintain the landscape of coastal wetlands in the areas it is implemented.

On one hand, this strategy will help the fishing and recreation industries by protecting commercially and biologically significant habitats. On the other hand, this strategy will likely have fiscal impact by reducing property values and thus tax collected in the preservation areas.

Case Study: Worcester County (MD) Implements Conservation Easement Strategy

Worcester County, Maryland, created a plan in 1997

Figure 5.14- Worcester County (MD) Implements Conservation Easement Strategy

http://co.worcester.md.us

to protect ecologically-sensitive undeveloped land fronting Chincoteague Bay. The plan calls for a combination of conservation easements and land purchases to protect 15,400 acres of waterfront land and 16 miles of undeveloped shoreline from future development. The County also recognized the value of protecting the shoreline from development and hardening to allow for the natural migration of wetlands. As of 2005, the county purchased conservation easements for 6,000 acres of land (representing eight miles of shoreline). The county continues to work with land owners within the Coastal Bays Rural Legacy Area to encourage others to place conservation easements on their property as well (Administration, n.d.).

Figure 5.14 shows a scene from the Worcester County implementation conservation easement strategy.

Promote Wetlands Accretion by Supplying Sediment

Since wetlands' accretion rates depend on the

Figure 5.15- Mississippi River Delta Management Plan

The Coastal Protection and Restoration Authority (Louisiana) (2007);

Figure 5.16- Living Shoreline, Virginia Beach, Virginia

SOURCE: LYNNHAVEN RIVER NOW PROGRAM (2012);

amount of sediment received, one strategy to enable them to accrete at a rate consistent with sea level rise is transport extra sediment to the critical habitats. This strategy includes either trapping sediment that would otherwise migrate or reintroducing sediment into the target area. In three county study region, beside sediment supplied by major rivers, another source is dredged sediment from Savannah River. This strategy requires a careful implementation to avoid sudden changes to the living habitats, periodic maintenance and a large budget to import outside materials if they are locally unavailable. This strategy makes minimal intervention into ecosystems, maintains wetlands where they are, and thus continues to protect inland communities and habitats from storm surges. Since there is a limited amount of sediment available while wetlands are dispersed throughout the three county study region, it is recommended to develop a regional Sediment Management Plan (SMP) to manage sediment from source to sink and prioritize supply to critical habitat areas. Such a plan will help to reduce engineering problems and costs while efficiently supporting wetlands migration.

Impacts on People, Place, and Economy

The primary impacts on people will be the time and social effort to organize a comprehensive response to an unfamiliar threat and the fiscal costs of the alternatives selected.

Without importing sediment from outside, redistribution of this resource in the region to support wetlands migration in some areas might expedite the inundation process of wetlands in other places. Therefore this strategy will modify current landscape and could put some wetlands in at risk. Thus, a regional Sediment Management Plan is needed to manage and minimize negative externalities of this strategy.

Case Study: Mississippi River Delta Management Plan

Historically, the Mississippi River was re-channelized for navigation and flood control without understanding the consequences for the wetlands system. About 22 million cubic yards of sand and mud are dredged to make way for shipping and then dumped as waste into the deep water off the Gulf's continental shelf while the region is losing wetlands - its first protection against hurricanes. Based on a more complete understanding of environmental dynamics, the new Mississippi River Delta Management Plan aims to redistribute sediment into fragmented marsh and shallow water to create new delta lobes and nourish existing wetlands (The Coastal Protection and Restoration Authority, 2007).

The Mississppi River Delta Management Plan is illustrated in figure 5.15.

Prohibit Hard Shorelines and Utilize "Soft" Measures

This adaptation strategy is a complement to the first two strategies. Shoreline hardening may protect human settlements and infrastructure, but has adverse impacts on wetlands by preventing sediment transport which is essential to those ecosystems. Therefore, removing and prohibiting hard shoreline protection in particular areas is the precondition to allow wetlands migration and sediment deposit. However, different from the first strategy, this strategy is not merely regulation-based but includes physical interventions. After removing hard structure, the new shoreline will need to be protected against erosion and storm surge. "Soft" measures such as marsh creation and planting submerged aquatic vegetation in some instances can prevent erosion (Agency, 2009). "Soft" measures have lower costs of construction than "hard" ones while preserving habitats for wildlife and maintaining sediment transport. However, these measures may not reliable and sustainable for long-term. They have lower level of protection for waterfront properties and their protection capacity varies seasonally due to vegetation change. A combination of "soft" and "hard" measures can alleviate these weaknesses.

Impacts on People, Place and Economy

While this strategy is very friendly to the ecosystem, it may permit destruction to shoreline properties. Therefore it should be considered only in undeveloped or after careful analysis.

On one hand, this strategy will allow wetlands and species to migrate inland and enhance ecological sustainability of coastal areas. On the other hand, this strategy provides a lower level of immediate protection than "hard" measures.

The impact of this strategy on local economy is difficult to determine in the abstract. In undeveloped areas, this strategy will protect wetlands and vulnerable species and thus support fishing and recreation industries. In developed areas, careful analysis should precede application.

Case Study: Living shoreline, Virginia Beach, Virginia

Living Shoreline is a program initiated in the city of Virginia Beach, VA, to restore lost habitats such as oyster reefs, salt marshes and other ecological buffers that can filter polluted run-off and protect the river and its marine life. Living shorelines provide long-term protection, restoration or enhancement of tidal wetlands through the strategic regarding and placement of plants, sand fill, stone support and other structural and/or organic materials such as biologs. One the main focuses of the program is to recreate tidal wetlands to replace hard structures along the shorelines. The program prefers tidal wetlands to hard protection along the shoreline because they can provide dual role of limiting erosion and providing environmental benefits such as preserving the important natural connections between the marine and upland ecosystems. The Commonwealth of Virginia has identified living shoreline as the preferred shoreline treatment and together with municipalities offers a simpler permit process for living shoreline projects (Lynnhaven River Now Project, 2012).

The Virginia Beach Living Shoreline project is shown in figure 5.16.

Protect Existing or Create New Artificial Barrier Islands

Coastal barrier islands play a critical role in ameliorating the destructive force of ocean waves on wetlands. These forces will increase as sea level rises and can subsequently destroy wetlands, particularly during storm events. The protection of barrier islands will have a positive impact on preserving the wetlands located behind them. In three county study region, most of barrier islands are undeveloped and can be heightened and strengthened with both "hard" and "soft" protection to protect habitats and inland communities behind them. Artificial barrier islands can be created to provide further protection from hurricanes and storm surges for important settlements and critical facilities like the city of Savannah and its port system. In the long-term, to tackle sea level rise beyond 100 year time-frame, a system of levee and tidal gates could be integrated with existing barrier islands to form an offshore protection ring protect both habitats and communities from threats from the sea. This type of protection will be very expensive and only feasible

Figure 5.17- Restoration of Pelican Island off the Coast of Louisiana.

OEROPHOTO (2012)

for very critical areas such as Savannah metropolitan area.

Impacts on People, Place, and Economy

This strategy provides an extensive protection for the wetlands, communities and people. There is no direct adverse impact of this strategy on people's health and wellness since the construction will be conducted offshore. The indirect negative impacts derive from costs and increased taxes.

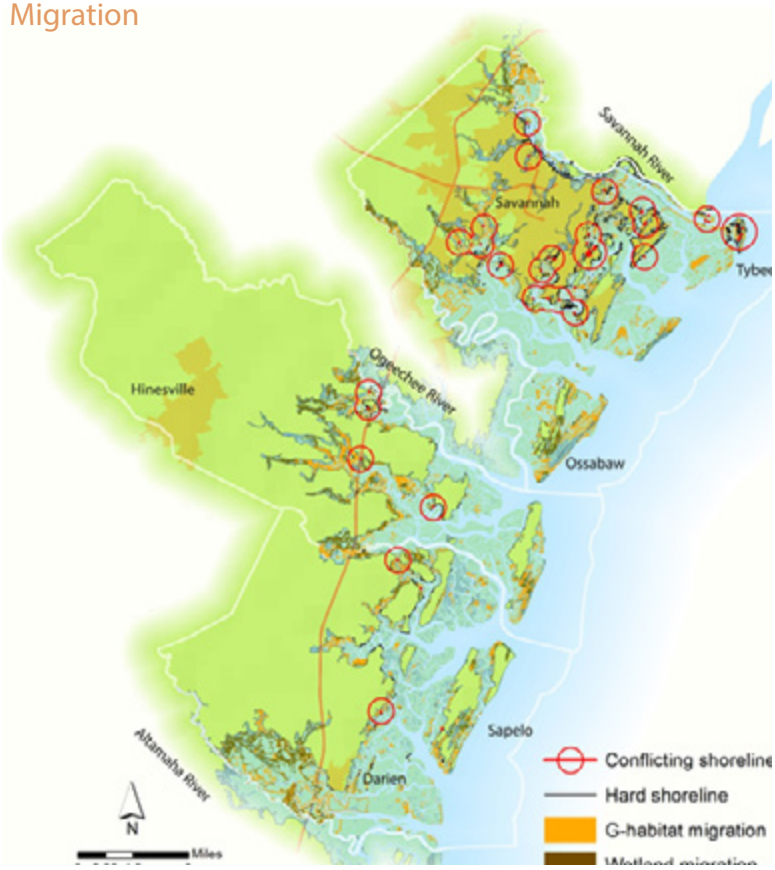
This strategy, if implemented properly, will help to restore and protect fisheries and wildlife habitats as well as human settlements and their infrastructure systems from storm surges, hurricanes and sea level rise. An integrated coastal defense system with barrier islands as key elements can further reduce the need for hard shorelines and thus enhance the habitats along the coastal area.

Constructed barrier islands would require an enormous public investment. Due to their scale, this kind of intervention should be considered at state and national level with a long-term vision and management plan.

Case Study: Restoration of Pelican Island, Louisiana

Pelican Island is a key barrier island inside the

Figure 5.18- Potential Location for Wetlands Migration



Barataria island chain. The restoration project will provide in excess of 580 acres and nearly 3 miles of new dunes and marshland within the original island footprint. Pelican Island is considered crucial for the protection against storm-surge intrusion into southeast Louisiana and for the restoring of fisheries and wetlands. The $50M price tag marks Pelican Island as the largest and most aggressive coastal restoration project for Louisiana (NOAA Habitat Restoration http://www.habitat.noaa.gov).

Figure 5.17 depicts the Pelican Island restoration project.

Initial Land Preservation for Wetlands Migration

To allow local governments to take early actions on wetlands protection against sea level rise, land areas, where wetlands in general and G-ranked habitat in particular might migrate in the near future should be identified. This is particularly important for three county study region since most G-ranked habitats in the region are freshwater wetlands and can migrate relatively unassisted.

Potential locations for wetland migration is seen in

Table 5.8- Four Strategies for Wetlands Adaptation

Adaptation strategies	***Benefits***	***Constraints***	***Actions required***	***Examples***
Allow wetlands to migrate through land preservation	*Maintain species habitat and the protection for inland ecosystems; Minimal intervention on wetlands;*	*May be not feasible in highly developed areas; - Less effective with fast-paced SLR;*	*Amend construction setback requirement to allow wetlands to migrate; Land purchases; Rolling easements;*	*Buzzards Bay Action Plan: Planning for a Shifting Shoreline;*
Promote wetlands accretion by supplying sediment	*Maintain wetlands location and protect coastal land from storms*	*Costly Requires continual management Depends on local wetlands' sediment ranges*	*Trapping and redirect sediment flows; Remove levee and prohibit channelization that prevent sediment from entering wetlands;*	*Louisiana Comprehensive Plan for a Sustainable Coast*
Prohibit hard shoreline and Utilize "soft" measures;	*Maintain sediment transport and allow shoreline migration Low construction cost Mitigate erosion force of SLR - Protect habitat*	*Costly to implement; Difficult to implement due to property loss;*	*Remove hard protection; Plant dune grasses and submerged aquatic vegetation; Restore oyster reef along coastline*	*Living Shoreline Stewardship Initiative (Chesapeake Bay) South Carolina Oyster Restoration and Enhancement*
Protect existing barrier islands; or Create artificial barrier islands;	*Protect both wetlands and inland developments for a long period;*	*Very costly to implement; May change the ecological condition of protected wetlands*	*Determine critical locations to implement this strategy; Construction works*	*Louisiana Barrier Island Restoration*

figure 5.18.

In this examination, there are many variables that affect the migration of wetlands. We take into account three factors: 200-foot buffers around existing wetlands and G-ranked habitats, terrain slope, and land availability.

- Buffers: Buffers are drawn around inundated wetlands and G-ranked habitats to identify the area they may migrate. Both general wetlands and critical G-ranked habitats are considered to reflect two different levels of ecological importance. Current regulations in the state of Georgia use 100-foot and 150-foot buffers to protect riparian corridors and water-supply watersheds respectively. We use the 200-foot distance to further explore the interaction between wetlands and other land uses.
- Slope: the average slope of wetlands in three county study region is 1.6%. Since wetlands migration is a slow process at the rate of few millimeters per year, it will require land with continuously gentle slope. Thus, we assume that suitable land will have average slope equal to or below 1.6%.
- Land availability: land suitable for wetlands migration process is undeveloped land where there is no man-made structure that might prevent the process. Using land cover data, we can indentify undeveloped land in the three county study region.

In summary, suitable areas for wetlands migration are undeveloped lands located within a 200-foot buffer from current wetlands and having 1.6% or lower slope. The first two buffer layers are overlaid to get a new layer of wetlands-adjacent zones. This new layer is then intersected with slope layer and land availability layer to get the final result (Figure 5.18).

The result shows two major areas for wetlands migration. The first is riparian corridors along major rivers: Altamaha, Ogeechee and Savannah Rivers. The second is small habitats located on barrier islands. The riparian corridors, which make up almost 70% of all G-ranked habitats, are already protected by current state and local regulations by 100-foot buffers. The government would need to expand these zones further to allow freshwater wetlands migration in the next 100 years. Barrier island migration areas which include both freshwater wetlands and salt marshes need further interventions beyond land preservation. They will need extra sediment supply and protection from ocean waves.

We don't see many migration areas along the edge of salt marshes. The main reason is that these marshes are located along the coast where their migration is blocked by abrupt changes in elevation. Salt marsh migration is also particularly difficult in nature due to small accretion rate. To protect these wetlands, we may have to opt for building offshore levee rings which link all barrier islands together to form a complete protection system.

Lastly, we overlay hard shoreline over the migration areas to identify conflicts in location between shoreline protection and wetlands migration. Most of these conflicting locations are in the Savannah region where there is substantial hardscaping along the coast. While many of these structures have to stay to protect inland communities from flooding and storm surges, their protection capabilities need to be re-assessed in the new context of sea level rise and wetlands migration. Some hard shoreline protection may need to be removed and replaced by "soft" measures to allow wetlands migration.

Sea level rise is slow in terms of time but complicated and threatening spatially. To protect wetlands in general and rare habitats in particular from sea level rise caused inundation, we should act early and act with a group of strategies, not just a single one. In fact, all four strategies listed above are related to each other. To help wetlands to adapt to sea level rise, we will need to maintain and even increase sediment supply, remove some hard shorelines and protect barrier islands. On the other hand, migrated wetlands can function as the new "soft" measures to stabilize the shoreline and protect inland communities. While strengthen existing barrier islands and/or building new ones can "hold the sea", their capital costs and environmental costs are unknown and need further research.

Sea level rise will affect wetlands at a slow almost imperceptible pace. However, addressing this problem is urgent because the longer we wait to react, the more costly and difficult the measurements will be. To help local governments taking early action, we have identified potential migration areas for wetlands. These areas are concentrated mostly along

riparian corridors and barrier islands. To protect these river corridors, local governments will need to consider further expansion of existing protection buffers along major rivers. Transfer of Development Rights, which is discussed earlier in this chapter, can be applied to protect wetlands migration areas. To protect wetlands in barrier islands and salt marshes, a comprehensive plan and an extensive implementation effort will be needed to preserve future migration areas, increase sediment supply, and/or build a complete offshore protection system.

Lastly, we also identify conflicting locations between hard shoreline protection and wetlands migration. While some of these structures will not be able to protect communities from sea level rise and other threats from the ocean, they prevent wetlands from migration inland. Local governments will need to conduct assessments of these structures as part of their comprehensive plans for responding to sea level rise. These assessments will help to determine which structures will need to stay and be strengthened and which ones will need to be removed to help wetlands to adapt to a new environment.

Education, Outreach, Community Input, and Social Vulnerability Resources

The third part of the adaptation approach offers avenues to generate knowledge about the impacts of sea level rise, how to use this knowledge to reach out citizens in general and especially to socially vulnerable citizens, and viable housing options to help resettle vulnerable populations as a result of sea level rise. One challenge to generating knowledge and educating residents about sea level rise is when and how to start the education process and the medium through which this information is conveyed. It is critical that the disseminated information is comprehensible and accessible to everyone, and not only to those who are well-educated. A second challenge is relaying the message about sea level rise so that it becomes personal to the individual. This will spark greater interest in how sea level rise affects all citizens. The third challenge relates to providing knowledge about available resources as it pertains assistance citizens can access to help them respond and adapt.

Education

It is important to start knowledge generation and education at schools as early as possible; a similar approach can be used for those who are socially vulnerable, particularly the Gullah-Geechee community. An approach similar to this one is credited with successfully incorporating the benefits of recycling (Schlindwein). Providing education about environmental changes to Georgia's coast can alleviate reticence that citizens have about sea level rise. One benefit of this approach is that citizens may be more receptive to strategies and policies that are designed to prepare for sea level rise, and educating students at a young age also promotes creative-thinking that may result in technological innovations to combat the effects of sea level rise. Lastly, tailoring information on the effects sea level rise to residents' places of employment that will face partial or direct inundation is critical. Although a person's home may not be inundated, his or her place of employment or route to employment may be inundated. This makes going to work a difficult or impossible task, in turn, affecting how residents earn income.

Effects on People

Casting the widest net for generating knowledge on the impacts of sea level rise can be done within the dimensions of educating school-age children by incorporating sea level rise into the school curriculum. Several grant and funding opportunities are available via the National Science Foundation (NSF), Environmental Education in Georgia, Grants.gov (Federal grant searching website), and National Oceanic and Atmospheric Administration (NOAA). An example is the 'Sidewalks to the Sea' grant at Thunderbolt Elementary Marine Science School (TEMSS) in Thunderbolt in Chatham County. 'Sidewalks to the Sea' is a three-year grant program to encourage school children to embrace the sea and to promote responsible stewardship (Environmental Education in Georgia, 2012).

Effects on Place

Continuing education through high school and later integrating it into the curriculum at the university and college level further reinforces the lessons learned. Two of the many local institutions that are already integrating marine studies into their curriculum are Savannah State University and the Skidaway Institute

of Oceanography. Savannah State University's Marine Science program is dedicated to:

> "research, education, and outreach programs which contribute to a vital, technically qualified, intellectually thoughtful, and ethnically diverse community of individuals capable of creatively solving problems and answering questions related to coastal and ocean ecosystem health, environmental quality, and fisheries sustainability" (Savannah State University Marine Science Department, 2011).

The Skidaway Institute of Oceanography's goals are to :

> "further understanding of marine and environmental sciences, conduct leading edge research on marine and coastal systems, and train tomorrow's scientists. The Institute also strives to create a more knowledgeable citizen capable of promoting sound utilization of natural coastal and marine resources while capitalizing on coastal economic opportunities" (Skidaway Institute of Oceanography, 2012).

By using these and other local research and higher education institutions, the three-county area can further explore and teach about the changing environment related to sea level rise.

Effects on Economy

A conversation with local business leaders, civic leaders, and residents is needed to educate how sea level rise will impact the local economy. Places of employment will be threatened due to inundation; therefore, a discussion about how the local economy will function is necessary. Questions exist regarding how jobs dependent on the coast, such as local fisheries, will adjust to sea level rise. This response is contingent upon multiple factors, such as how the oyster and fish populations are affected. Distribution centers and paper and chemical industries located near the Savannah River, the Wilmington River, and the Port of Savannah are vulnerable to the effects of sea level rise because they depend on the water for transportation or use water as a key component to produce and manufacture goods. These industries are prime candidates for protection such as hardscaping because of their dependence on water, and these industries also employ a large number of people, so any negative consequence to these industries can negatively affect the local economy.

Outreach and Community Input

Outreach is a vital component in communicating an effective, efficient, and comprehensive, plan to the community. The primary objectives of outreach efforts should focus on disseminating information as it relates to sea level rise and eliciting participation. Concentrated outreach efforts need to be on those who are difficult to locate and those who have specials needs. In addition to locating vulnerable populations, outreach efforts must convey information that has been gathered and include input from the community regarding protection and prioritization adaptation strategies.

Effects on People

Information about the disabled population was suppressed in the 2010 U.S. Census; no detailed geographic analysis could be done on the effects of sea level rise on this vulnerable population. Particular disabled populations have differential capacities to respond to natural disasters. For the millions of people with disabilities, surviving a disaster can be just the beginning of a longer term struggle to adapt to a new reality (Disabledworld.com). Outreach efforts should focus on locating disabled populations and formulating a plan that addresses the specific complications they encounter. A possible solution to assist in the evacuation process is the registration and documentation of disabled citizens. This data can be used to plan ahead for evacuations due to sea level rise or increased storm surges. A shuttle can be used to pick-up registered members and take them to specified safety facilities; this process can be extended for other citizens, such as those who do not drive. This shuttle service can also bring disabled and elderly citizens to town hall meetings or charrettes because they need to be involved in the decision-making process for sea level rise.

Effects on Place

Sea level rise will partially inundate infrastructure in the three-county area, including roads, historic sites, and public facilities. Community input can be

used to contact citizens and to allow them to voice their concerns about the roads or sites they would like to see protected. Outreach efforts should prioritize protection strategies for infrastructure and include input from stakeholders and members of the community. Effective outreach can also address two issues: (1) mitigate difficulties associated with prioritizing and allocating tax dollars by taking into account the sites citizens would like to see protected and (2) inform residents about potential steps being taken in preparation to sea level rise. This would be especially beneficial when attempting to alert citizens to road construction and detours along major roads and thoroughfares. One potential course of action would be to start a website or newsletter that specifically discusses what sea level rise is, what effect it will have on the community, and what can be done to mitigate its effects. This document is similar to a community newsletter because it addresses effects in the immediate area; however, this document differs from a traditional newsletter because the area of focus is much larger.

Effects on Economy

Several of the industries located near the coast stand to potentially lose all functionality if steps are not taken to protect the businesses. Outreach must be used to identify these businesses and to inform them of the impacts of sea level rise. Outreach can include recommendations on potential relocation facilities and best practices to protect businesses from sea level rise. Companies can also use outreach to communicate potential employment opportunities and job training events that help improve job skills.

Social Vulnerable Resources

Sea level rise poses heightened challenges for the socially vulnerable population. Two of these challenges are job placement and training and housing options. Job placement and training opportunities and housing options are already limited for socially vulnerable citizens, but sea level rise adds another burden for many. There is also a needed discussion for how disabled citizens, public transportation dependent citizens, and those who may not be in inundated areas but are socially vulnerable because of age (children under age 5 and senior citizens over age 65) will be affected by sea level rise.

Effects on People

Sea level rise is projected to impact industries and top employers in the three-county area. These impacts may affect many employees because their employment may be interrupted or, in extreme cases, lost. Hourly employers and employees without protections for annual leave, sick leave and/or personal leave will be affected immediately by loss of income, and depending on the severity of damaging events amplified by sea level rise, may face extended periods without income. Emergency assistance programs should anticipate that many employees in retail, tourism dependent jobs, other services, and construction will need support over extended periods.

A broad range of socially vulnerable people will require attention to protect them from gradual increases in sea levels. The present analysis has identified the number and locations of some of these citizens: children under 5 years, older men and women (over 64 years), single parents families, impoverished individuals and families, and under-educated people (lacking a high school diploma and older than 25 years). Many others could only be identified in general terms and not by location: disabled people (of many different types, noted below), high rise and other types of assisted housing residents, homeless people, long term unemployed people, people dependent on medications of multiple and various types, and others.

Referring to the many different types of disable people, this research was not able to discern the particular types of disabilities affecting people, but there are a broad range of disabling conditions that limit people's activities and capacities to respond to changed circumstances. Each requires particularized categories of assistance.

Government and voluntary agencies' capacities to respond to the diverse needs of socially vulnerable people present will require knowledge and resources that do not presently exist. Some agencies, notably Centers for Independent Living, have some knowledge of the locations of some of the people who will require assistance, and they know the incidence of some of the particular disabilities and conditions that will require particular types of aid.

But, they do not know all of the locations or all of the particular disabilities/conditions. Prior to the onset of debilitating sea level rise and prior to the increased risks of the amplification of more threatening hurricanes and/or Nor'easter storm surges by sea level rise, governments and voluntary social service agencies need to collaborate on developing both more extensive knowledge of where particular socially vulnerable people are and on expanding the types of assistance they are equipped to provide.

Effects on Place

Some of the more noticeable jobs that could be lost are those along the coast and those dependent on the environment, like fisheries and tourism jobs. Because of the changing environment caused by sea level rise, there will be a change in the way fisheries and coastal jobs operate. For fisheries and industries that depend on fisheries, the impact of sea level rise may mean a decrease in the game fish stock near the coast as fish gravitate to cooler waters found farther away from the coast or fish population is declining because their food chain is also changing and declining with the rise of water temperature. As game fish stock move farther away from the coast or is declining in population, for those dependent on fishery industry, it may be necessary to change business and employment practices.

Effects on Economy

A major economic impact will depend on how successfully Tybee Island adapts to increasing sea levels. As the primary coastal recreational resource, Tybee Island will undoubtedly expand efforts in sea level rise mitigation per preserving as much of the resource as feasible and by maintaining access across the marshes. There are both physical/environmental and fiscal issues that these efforts will and are confronting. On the physical/environmental front, is construction of new dunes in the ocean east of the present coast and periodically renourished beach technically and financially feasible? On the fiscal side, who will pay the substantial sums that elevation/ replacement of US 80 across miles of marsh will require?

The Gullah-Geechee Community

Sea level rise will intrude on the lives of the Gullah-Geechee, but these effects can be at least partially mitigated through emphasis on three important elements: education, community outreach, and the economy. Education can be defined in a two ways. In the literal sense, education means to teach residents about the effects and the actions one can take in response to sea level rise; this is essential in assessing how sea level rise will affect their quality of life. Education also needs to promote the idea of creating cultural hubs as a means to identify and preserve sites, historical data and artifacts associated with the Gullah as laid out in the Gullah-Geechee Heritage Corridor Management Plan.

The second critical element that should be included in adaptation approaches for the Gullah-Geechee is a plan on how to relay the message of sea level rise to the community. A form of outreach is needed to identify both those who need or who can provide assistance, as well as those who seek input during the decision-making process. One final aspect that needs to be addressed is the effect of sea level rise on the economy. In preparation for sea level rise, the Gullah-Geechee need an adaptation plan that addresses the services needed to find jobs and promote workforce development. Creating a plan that includes these elements decreases the likelihood of encountering obstacles related to education, outreach, or job services from hindering the adaptation process.

Effects on People

The Gullah-Geechee have a close relationship with the water in both proximity and oneness. This relationship has benefits, but also has made the Gullah-Geechee vulnerable to the effects of sea level rise. The impact on the Gullah-Geechee is concentrated in three areas: Sandfly, Pinpoint, and Hog Hammock. These three areas will experience at least partial inundation. Most of the population in Sandfly and Pinpoint will not directly affected by sea level rise; however many of the major access roads will face inundation. Sea level rise will affect Hog Hammock by inundating essentially all of the land where people live. Close to 95% of the population will be forced to relocate if plan for protection is not implemented. Losing these areas to sea level rise will not only erase the culture, it will erase a large part

of Gullah-Geechee history. Although, no Gullah-Geechee historic sites listed in the Gullah-Geechee Heritage Corridor Management Plan will be affected directly by inundation, there are many historical sites that are not publicly indentified for security reasons and which are likely threatened by seal level rise. These sites have been inventoried at the behest of the Georgia Department of Natural Resources, so the first step of preserving or contending in a culturally responsible way with sea level rise has been taken.

On the mainland, roads that lead to Gullah-Geechee historical sites will face inundation. Protecting these roads is critical to implementing a strategy that could assist the Gullah-Geechee preserve their history. Geechee Kunda, in Riceboro, Georgia will not be inundated and has the foundation to embrace and promote the Gullah-Geechee culture.

Both Geeche Kunda nd the Pinpoint Museum can potentially be central resources for educating Gullah-Geechee and the larger society regarding Gullah-Geechee culture and preserving the culture in meaningful ways. To serve these roles, both will need to expand their resource bases, and both will need to undertake a range of outreach and cultural preservation programs.

Effects on Place

Sandfly, Pinpoint, and Hog Hammock will be affected by sea level rise in different ways and at different magnitudes. Although no residences in Pinpoint will be directly affected by sea level rise, Sandfly and Hog Hammock will face inundation. Most of the residences in Sandfly are located east of Harry Truman Parkway, this area does project to be directly affected by sea level rise, but areas west of Harry Truman Parkway will be affected. The road leading to the Georgia Regional Hospital at Savannah will need to raised to combat the effects of sea level rise. Chatham Aquatic Center is also projected to completely inundated if no protection strategies are put in place.

Behavior Cemetery, which is located 1.25 miles from the Hog Hammock Historic District, faces inundation. Over 90 percent of the residences in Hog Hammock will be inundated absent adaptation or protective strategies. Careful and deliberate planning fully engaged with the residents should precede decisions regarding responses to the threat of inundation. Extreme care should also be taken to develop strategies to preserve Gullah-Geechee historic resources presently on Sapelo Island. The Georgia Department of Natural Resources has studied the specific character and the geographic distribution of these resources. Neither of the dimensions of these valuable connections to Gullah-Geechee history and culture are public for security reasons. Plans for responding to sea level rise on Sapelo should devise methods to further analyze how these resources will be treated and access to them enhanced.

In the interim, a concentrated effort should be launched to preserve Gullah-Geechee residences in Hog Hammock and block the sales that are being driven by increased property taxes. Because the market for property sales in and around Hog Hammock is very small and much of the island is not available for sale, the few sales that have taken place represent an extremely distorted market. Using the few sales that have taken place as the basis for tax assessments in Hog Hammock will drive the remaining Gullah-Geechee off the island if a mechanism to protect their interests and halt the distorted assessments does not exist.

Effects on Economy

Information related to employment in Pinpoint and Hog Hammock does not reveal specific instances where sea level rise will directly affect employment. No building in Pinpoint will be directly affected and no jobs were shown in the Hog Hammock community. In Sandfly, roads leading to Georgia Regional Hospital at Savannah will be inundated, which directly affects employment in this area. Chatham Aquatic Center will face direct inundation if a strategy for protection is not adopted. These two are major sources of employment in Sandfly that would need to be protected or relocated in response to sea level rise. Furthermore, emphasis on creating access to jobs to replace or supplement other jobs that will be lost is critical to sustaining economic viability in this area. The Gullah-Geechee seek additional employment opportunities, adequate job training programs, and education opportunities (Gullah-Geechee Corridor Management Plan). However, the focus needs to be on providing adequate job opportunities that do not marginalize a person's position within society. Sea level rise will have a substantial effect on the areas

where the Gullah-Geechee are located, but proper planning can create opportunities for employment elsewhere.

Sea level rise complicates many aspects of life for those who live in the Chatham, Liberty, and McIntosh counties. This effect will be magnified for the Gullah-Geechee because they live in isolated area and do not represent a large percentage of the population. This makes it very difficult educate the Gullah-Geechee on the effects of sea level rise, where the educational and cultural hubs will be located and where to find employment opportunities. Proper planning should seek to preserve the Gullah-Geechee culture, create cultural and educational hubs and provide services that will assist the culture in mitigating the effects of sea level rise.

Under the Umbrella of Community Development

Block Grants (CDBGs), three housing programs that could be possible choices are the Entitlement Communities, the Section 108 Loan Guarantee Program, and the Neighborhood Stabilization Program. Based on a determined formula for an annual grant given to entitled cities and counties, the Entitlement Communities grant program provides "decent housing and a suitable living environment…principally for low- and moderate-income persons" (U.S. Department of Housing and Urban Development, 2012). Since this program encompasses more than just providing housing for low- and moderate-income residents---the program strives to allow grantees to revitalize neighborhoods, engage in economic development, and improve community facilities and services---this program may be a good fit for the three county area since it meets the eligibility requirements (principal cities in a Metropolitan Statistical Area, other metropolitan cities with a population of at least 50,000, or qualified urban counties with a population of at least 200,000) and the CDBG monies may be used for activities that are better suited to assist the area, like rehabilitating residential and non-residential structures that may be future housing or allowing the acquisition of real property.

A second option is the Selection 108 Loan Grant Guarantee Program. Similar to the Entitlement Community grant program in its assistance to entitled local governments, this loan program is for non-entitled local governments---"all units of government of general local government that do not meet the definition and qualifications for an entitlement community...and any incorporated units in urban counties who have opted not to participate in the county's entitlement CDBG program" (U.S. Department of Housing and Urban Development, 2012). The strength of Section 108 resides in its power to allow non-entitled communities "to transform a small portion of their CDBG funds into federally guaranteed loans large enough to pursue physical and economic revitalization projects that can renew entire neighborhoods" (U.S. Department of Housing and Urban Development, 2012). Because this is a loan, not a grant, it is more forgiving as to how communities can use monies to revitalize areas that are more important to them to house the community residents, but it is also riskier because the local governments must have monies to cover the amount of the loan as security for the loan. This may not be financially feasible for those communities that are expected to be impacted by sea level rise.

The third option is the Neighborhood Stabilization Program (NSP), which is to stabilize those "communities that have suffered from foreclosures and abandonment"; the goal of this program is to purchase and redevelop these residential properties through a determined grant formula (U.S. Department of Housing and Urban Development, 2012). A component of this program is that grantees are given the liberty to orchestrate their own program and funding priorities but must do so using at least 25 percent of the funds to purchase and redevelop foreclosed or abandoned homes or other residential properties that can function as homes for individuals or families whose incomes are less than 50 percent of the area median income (U.S. Department of Housing and Urban Development, 2012). This program may be a good fit for the vulnerable communities since the program must benefit low- and moderate-income persons and meet one of the following national objectives: (1) providing or improving permanent residential housing for individuals whose income is at or below 120 percent of the area median income; (2) benefiting individuals or families in a primary residential area in which at least 51 percent of the residents have incomes at or below 120 percent of the area median income; and (3) serving a limited clientele whose incomes are at or below 120 percent of the area median income.

Under the Affordable Housing umbrella, two options are Low-income Housing Tax Credit (LIHTC) and Housing Choice Voucher Program (Section 8). Low-income Housing Tax Credit allows low-income individuals or families to have affordable rental housing options. The Housing Choice Voucher Program also affords low-income individuals and families with rent subsidies, freedom of housing options, and the opportunity to integrate into mainstream society (Georgia Department of Cultural Affairs, 2012). Because of the effectiveness and popularity of both affordable housing programs, either is a top option to expand within the vulnerable communities. And because of the Fair Housing Act (FHAct), seniors and disabled citizens will be allowed to have affordable housing options.

The second resource to affect the livelihood and people is employment. The full economic impact of sea level rise goes beyond damaged buildings and amenities. Earlier studies have included potential costs as a result of the magnified effects of direct damage as critical variables are used in evaluating indirect loss, such as production, job losses, reconstruction duration, and the benefits of investment in reinforced sea defenses (Hallegatte, Ranger, Mestre, Dumas, Corfee-Morlot, Herweijer, & Muir Wood, 2011). It is also suggested to take special notice of indirect loss of the local economy - key industries, major employers, commercial centers, or tourist attractions. However, these losses are still less studied and are more difficult to measure than the direct loss (New York State Department of Environmental Conservation, 2010). Due to the constraints of availability of accessible data and the economic characteristics of the tri-county study region, this report focuses on the loss of general employment due to sea level rise at the census block level. This information is especially useful for national and local decision makers who are faced with the choice to restrict development or investing in efforts to protect a threatened resource (Cooper, Burke, & Bood, 2008).

FURTHER ACTION

Sea level rise will have a real effect on the coastal region of Georgia by the year 2110. However, the consequences of SLR will occur incrementally, allowing time for responsible, informed planning and preparation. Our central findings regarding the impacts and implications of sea level rise are presented below.

Physical Vulnerability: Impacts and Response

Of the 1,378 square miles in the study region, 418.92 square miles, or 30.45 percent of the land, is at risk for some level of inundation by 2110. More than three-quarters of the study area's wetlands will be completely inundated, including globally-ranked habitats (G-1, G-2, and G-3), causing a loss of one-third of the rare habitats in the study area. Chatham has the highest percentage of land expected to experience inundation, at almost 50 percent. While only 5 percent of the urbanized area in Chatham will be inundated, these include major facilities and hazardous sites as well as densely populated areas.

Wetlands

The land uses most at risk for disruption caused by sea level rise are those which are near the coast and along the region's rivers. It follows that within the natural environment, wetlands, which exist in low-lying areas near open water, are the most at risk. While 88 percent of the wetlands most susceptible to inundation are generally brackish and salt marshes with a low accretion rate, the most globally significant wetlands have a high chance of survival through inland migration. This survival is dependent on the preservation of accessible land for that migration.

The Built Environment

One of the most important effects of sea level rise will be damage to homes and buildings due to flooding. Our analysis shows that highly developed areas in low-lying regions near the ocean and rivers are in most danger of damage. Some of the places in which this is especially true are the more populous islands, the city of Darien, and the portions of Savannah near the Savannah River.

The greatest building loss due to inundation will occur in Chatham County. Though the majority of the historic district of Savannah will be spared from inundation, the commercial district adjacent to the Savannah River (River Street) and the region of the city outside of the historic boundaries will experience significant impacts.

Darien, Tybee Island, and Wilmington Island will experience the greatest inundation of residential buildings. Overall, approximately 40 percent of the existing buildings on Tybee Island will be affected by sea level rise. One-third of the land area in Darien will become inundated, with most of this inundation occurring in parks, recreation, and conservation lands. Nearly 20 percent of Darien's residential buildings are threatened by inundation, especially in the areas adjacent to the Darien River.

There are ten nationally-designated historic places, one state-designated historic place, and three cemeteries that are projected to become inundated. Without planning and protection, it is likely that some of them will be lost due to damage caused by flooding.

Facilities

Though many of the facilities that stand within the three-county region will not be touched directly by sea level rise, many will be isolated due to the inundation of the roads that lead to these sites. However, there are ten environmentally-sensitive facilities that will be affected by a one-meter rise in sea level. These facilities include sewer treatment plants, hazardous sites, and landfills. Half of the facilities are concentrated in a single block-group located to the north of downtown Savannah.

Because of their function as major municipal facilities that contain hazardous materials, the inundation of facilities such as the Dean Forest Landfill and President Street Water Control Facility will be detrimental to the health of the surrounding environment and population.

Transportation

The travel routes in the coastal region are crucial to the local economy and the safety of residents in need of evacuation in the event of hazardous events. Approximately thirteen miles of Interstate 95 and US 80 are threatened by inundation. The endangered section of US 80, from the intersection with Johnny Mercer Boulevard, in Savannah, to the intersection with Campbell Avenue, on Tybee Island, is especially noteworthy because flooding of this route will prevent residents and visitors to Tybee Island from accessing

and leaving the island. Although it would be costly, the portions of Interstate 95 and US 80 threatened by inundation could be elevated to bridge status in order to maintain safe routes away from the coast as well as access to Tybee Island.

Approximately eleven miles of the CSX Norfolk Southern rail that links the Port of Savannah are projected to be exposed to inundation. Most of the threatened rail links are on Hutchinson Island and the Liberty Terminals property adjacent to East President Street. This lack of connection with the rail network will create difficulties in the transportation of goods from the Port of Savannah to the rail and highway networks, which will negatively impact the local and State economy. Elevation or shielding will need to be instituted to maintain these facilities.

A few of the actions that can facilitate informed future development and growth are outlined below.

- Sea level rise should be incorporated into local comprehensive planning processes. Communities should shape their future land use vision to account for sea level rise and prepare for it. Zoning, building codes, and the cost of investing in new infrastructure should be considered.
- Local communities should participate in the National Flood Insurance Program to protect property owners from damage caused by flooding. Areas vulnerable to flooding include the areas that will be inundated by sea level rise. Local communities should adopt policies that encourage residents and business owners to obtain flood insurance whether they own or rent their property. Flood plain maps must be kept up to date since flood zones will change as sea level rise advances. Action will also need to be taken at the national level to adjust the NFIP so that it no longer encourages development in the floodplain. The Coastal Barrier Resources System provides an avenue for discouraging this development.
- Communities within the study area should consider creating a Transfer of Development Rights program for both undeveloped and developed properties within the sea level rise impact zone as a mechanism for compensating these landowners for their properties that will cease to be viable at some point within the next one hundred years.
- Sea level rise adaptation strategies should be implemented in order to maintain a connection with Tybee Island. US 80 is the only transportation connection with Tybee Island. Elevating the six miles of highway at-risk of becoming inundated, in order to maintain that connection.

Social Vulnerabilities: Impacts and Response

As is the case with the physical landscape, populations closer to the coast, marshes and rivers are more likely to experience the effects of sea level rise. Areas near water with higher population densities, including many segments of Savannah, Riceboro, Darien, and Tybee Island, will have more people whose residences will be directly affected by sea level rise These areas, with the exception of Tybee Island, are also more likely to contain higher populations of people who fall within our definition of "vulnerable." Much of the population affected by sea level rise on Tybee Island is not considered vulnerable due to their relative wealth and expected resilience level.

At the most precise level of analysis available, we identified a high number of inundated commercial buildings and homes in block-groups west and south of Savannah. Areas of particular concern are manufactured home communities located in southwest Savannah and central McIntosh County are projected to become

Tidal Gates on Tybee Island

inundated. Not only is the ability of these structures to withstand the water damage associated with sea level rise diminished by their construction standards, but the limited incomes of some of the residents in these communities may bind their ability to avoid or react to that damage.

To plan for the protection and well-being of the population of coastal Georgia over the next century, municipalities must know where other socially vulnerable populations are located and what resources they will need to cope with the effects of sea level rise. There is a need for the development of local metrics to more accurately track indicators that identify populations as more vulnerable to the damaging consequences of sea level rise, including the cost burden of housing on local families, disabilities, transportation needs, homeless people, single parent families, elderly people, and low income households. We were able to identify and locate some of these populations but too little is known about others. Measurement tools should be developed and utilized to create a better understanding of the people for which these communities are planning.

A primary step in preparing coastal communities for the challenges ahead is sharing information about sea level rise and the implications that this trend will have over time. The sooner knowledge generation and education around the topic of sea level rise begins, the more vibrant and vigorous the planning will be.

Further Action

This analysis has enabled us to highlight three major action steps that, if enacted in the near future, may help mediate the long-term negative effects of sea level rise.

Continue to Conduct Research Investigating Sea Level Rise and its Effects

Start with Local Conditions

The present analysis was conducted primarily at a regional scale. To most effectively begin the process of planning for sea level rise, communities must take

Dune protection at Fort Pulaski Tide Station

a more locally defined, in-depth look at the threats associated with sea level rise. The results of these studies should be reviewed often to ensure that needs are included in present planning efforts.

Develop More Precise Metrics

To conduct more local analyses, measurements of key social indicators at a neighborhood scale are necessary. Local communities should consider investigating what key indicators are not yet measured, especially as they relate to more potentially vulnerable populations, and determining how tools might be developed to track these indicators properly.

Land Use Analysis

An additional analysis of the land use variable should be performed that combines a land use data set with the HAZUS data set in order to refine and improve the estimation of the number of buildings that will be inundated by sea level rise. For example, instead of assuming that all residential buildings are evenly distributed throughout an entire census block as we did in our analysis, we suggest using a land use data set to gain a more accurate understanding of where the residential buildings are located within each census block. This will allow a better estimate to be made of how many of those residential buildings will actually be inundated by sea level rise. A land use data set will need to be obtained or created that aligns well with the HAZUS data set. Additionally, this new analysis should incorporate the more recent HAZUS data rather than the year 2000 data available to this analysis.

Incorporate Planning for Sea Level Rise into Local Policy

Sea level rise is a slow process, but local governments must take early action to reduce the costs and difficulties of responding appropriately. If communities move now to shape their land-use and development policies to encourage growth in areas that will not be directly affected by sea level rise and discourage growth in affected areas, they can reduce the potential damage of destruction associated with delaying these actions to ten, twenty, and fifty years from now. It is important that sea level rise be incorporated into local comprehensive planning processes. Communities can shape their future land use to account for sea level rise and prepare for it through modifying zoning, building codes, and the location and function of new infrastructure based on projections for future inundation.

Take Steps to Protect the Wetlands

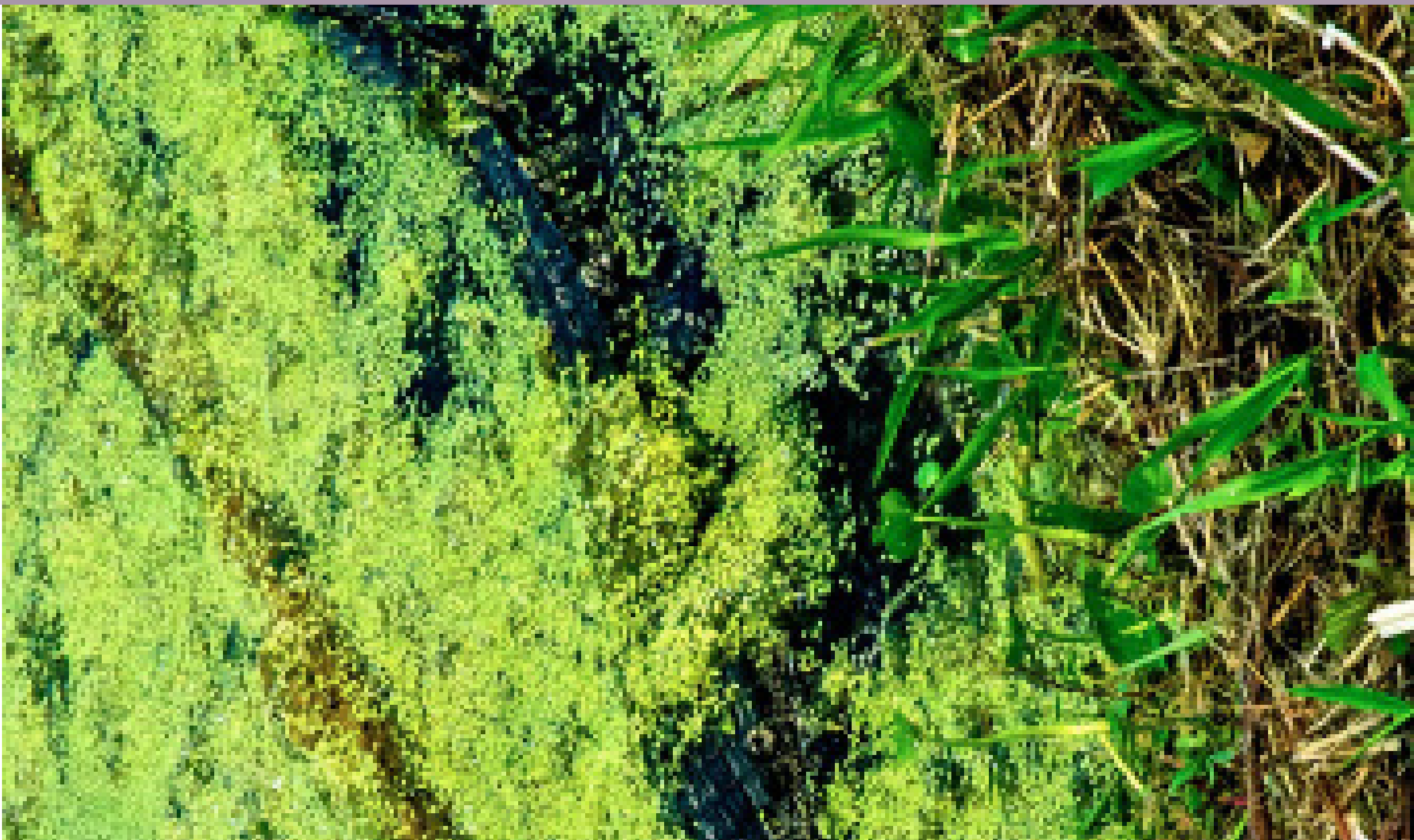
Generally, there are four major strategies that may be utilize to protect wetlands from sea level rise:

- Utilize "soft" shoreline alternatives to allow wetland migration;
- Conserve land for wetland migration;
- Contribute additional supplies of sediment material to promote wetland accretion rate; and
- Institute an offshore protection system by building and enhancing barrier islands.

These four strategies are complementary to one another and should be considered inclusively in any adaptation plan for wetlands. Hardscaping shorelines has been a popular method for mitigating damage caused by changing water levels; however, this method causes significant disruption in wetland migration. We recommend that municipalities consider removing some of the hardscaping currently in place to create more area for wetland movement.

This study is an effort to lay a foundation for the type of research that should take place to understand sea level rise and the effects that this phenomenon will have on the inhabitants of coastal regions. In the end, we should seek to preserve the rich history and culture of the Georgia coast, remembering that just as we are all products of our histories, so will the well-being of the generation of coastal inhabitants in the year 2110 be shaped by the actions that we take today. Thorough investigation and responsible planning for the consequences of sea level rise are the fundamental steps in preserving the quality of coastal life for future generations.

REFERENCES



African American History Month: FeaturedProperties, 2012, from http://www.nps.gov/nr/feature/afam/2001/nr_properties.htm.

"City of Darien, GA ", 2012, from http://www.cityofdarienga.com/visitor_guide_sapelo_island_darien.php.

(2010). "Geechee and Gullah Culture." 2012, from http://www.georgiaencyclopedia.org/nge/Article.jsp?id=h-1063.

(2012). "Geechee Kunda: Honoring, Teaching, Remebering the Culture of the Gullah Geechee People." 2012, from http://geecheekunda.com/.

(2012). Gullah Geechee Cultural Heritage Corridor Management Plan, National Park Service, Denver Service Center.

Administration, N. O. a. A. (n.d.). Case studies: Worcester County, Maryland Implements Conservation Easement Strategy to Protect Coastal Property. Retrieved 11/20, 2012, from http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_easements.html#1

Alberti, M., J. M. Marzluff, E. Shulenberger, G. Bradley, C. Ryan and C. Zumbrunnen (2003). "Integrating humans into ecology: opportunities and challenges for studying urban ecosystems." BioScience 53(12): 1169-1179.

Alkaff, H. F. (1997). Climate Change, Rising Sea Level and the Fate of Coastal Wetlands. Paper presented at the Proceedings of the 1997 Georgia Water Resources Conference, KJ Hatcher (Editor). The University of Georgia, Athens, Georgia.

Bamberger, M. (1991). "The importance of community participation." Public Administration and Development 11(3): 281-284.

Board, M. (1995). Beach Nourishment and Protection. The National Academies Press.

Botes, L. and D. Van Rensburg (2000). "Community participation in development: nine plagues and twelve commandments." Community Development Journal 35(1): 41-58.

Bowers, P. (2012). Gullah Geechee Corridor takes a big step forward Charleston City Paper.

Bowers, P. (2012). Gullah Geechee Corridor takes a big step forward. Charleston City Paper.

Bracht, N. and A. Tsouros (1990). "Principles and strategies of effective community participation." Health promotion international 5(3): 199-208.

Butler, M. (2011). Georgia Laws and Rules: Regulating Employment of Children. G. D. o. Labor. Atlanta, Georgia Department of Labor.

Carpini, M. X. D., F. L. Cook and L. R. Jacobs (2004). "Public deliberation, discursive participation, and citizen engagement: A review of the empirical literature." Annu. Rev. Polit. Sci. 7: 315-344.

Concannon, T., Hussain, M., Hudgens, D., & Titus, J. G. (2010). Georgia. Washington, D.C.: The Likelihood of Shore Protection along the Atlantic Coast of the United States. vol2: New England and the Southeast. Report to U.S. EPA.

Clark, G. E., S. C. Moser, S. J. Ratick, K. Dow, W. B. Meyer, S. Emani, W. Jin, J. X. Kasperson, R. E. Kasperson and H. E. Schwarz (1998). "Assessing the vulnerability of coastal communities to extreme storms: the case of Revere, MA., USA." Mitigation and Adaptation Strategies for Global Change 3(1): 59-82.

Cooper, E., Burke, L., & Bood, N. World Resources Institute, (2008). Coastal capital: The economic contribution of Belize's coral reefs and mangroves

Craven, Jackie. 2012. "What is Infrastructure?" Retrieved from: http://architecture.about.com/od/engineeringconstruction/g/infrastructure.htm. Accessed: November 9, 2012.

Cutter, S. L., Boruff, Bryan J. & Shirley, W. Lynn (2003). "Social Vulnerability to Environmental Hazards." Social Science Quarterly 84(2): 242-261.

de Oliveira Mendes, J. M. (2009). "Social vulnerability indexes as planning tools: beyond the preparedness paradigm." Journal of Risk Research 12(1): 43-58.

Division, G. D. o. N. R.-C. R. (n.d.). Wetlands. Retrieved November 12th 2012, from http://coastalgadnr.org/cm/wet

DOT Center for Climate Change and Environmental Forecasting. (2002). The potential impacts of climate change on transportation. Federal Research

Partnership Workshop. Retrieved from http://2climate.dot.gov/documents/workshop1002/workshop.pdf

Dronkers, J., Gilbert, J., L.W. Butler, J. C., Campbell, j., James, E., McKenzie, C., . . . Dadelszen, J. v. (1990). Strategies for Adaptation to Sea Level Rise. Geneva: Intergovernmental Panel on Climate Change: Report of the IPCC Coastal Zone Management Subgroup: Intergovernmental panel on Climate Change.

Encylopedia, T. N. G. (2012). "Geechee and Gullah Culture."

Engineers, U. A. (1995). Design of Coastal Revetments, Seawalls, and Bulkheads. Washington, DC: Department of the Army U.S. Army Corps of Engineers.

Environmental Education in Georgia. (2012). Sidewalks to the Sea. Retrieved from http://eeingeorgia.org/core/default.aspx?s=0.0.0.4863

Environmental Protection Agency. 2012. Superfund: Cleaning Up the Nation's Hazardous Waste Sites. http://www.epa.gov/superfund/index.htm Accessed: November 12, 2012.

Florida Department of Health (2012). Local Vulnerable Population Assessment Tool. F. D. o. Health, Florida Department of Health: 1-23.

Force, N. Y. (2010). New York State Sea Level Risk Task Force Report to the Legislature. Albany: Department of Environmental Conservation, New York State.

Flynn, T., Walesh, S., Titus, J., & Michael, B. (1984). Implications of sea level rise for hazardous waste sites in coastal floodplains. Retrieved from www.papers.risingsea.net

Georgia Department of Cultural Affairs. (2012). Housing Finance Division (HFD). Retrieved from http://www.dca.state.ga.us/main/quickmenuListing.asp?mnuitem=PROG

Government, C. C. (2012). "Rural Land Stewardship Area (RLSA) Overlay Program." Retrieved November 26, 2012, from http://www.colliergov.net/Index.aspx?page=1515.

Gullah Geechee Cultural Heritage Corridor. (2012). Retrieved from http://www.gullahgeecheecorridor.org/

Hallegatte, S., Ranger, N., Mestre, O., Dumas, P., Corfee-Morlot, J., Herweijer, C., & Muir Wood, R. (2011). Assessing climate change impacts, sea level rise and storm surge risk in port cities: A case study on Copenhagen. Climate Change, 104(1), 113-137.

Henry, V. (2009, 7/17/2009). Geology of the Georgia Coast. Retrieved 11/20, 2012, from http://www.georgiaencyclopedia.org/nge/Article.jsp?id=h-2777

Hobbs, M. "Improving Sea Level Rise Adaptation in Rhode Island: Seeking Insight from Other States to Better Prepare the Coast."

International journal of community research & engagement. Broadway, NSW, University of Technology.

Jason Hanly-Forde, e. a. "Transfer of Development Rights Programs." 2012, from http://government.cce.cornell.edu/doc/html/Transfer%20of%20Development%20Rights%20Programs.htm.

Keating, L. and M. Mailloux (2010). Improving Access: An Analysis of Impediments to Fair Housing in Savannah. Savannah, GA, City of Savannah, GA.

Kelly, P. M. and W. N. Adger (2000). "Theory and practice in assessing vulnerability to climate change andFacilitating adaptation." Climatic Change 47(4): 325-352.

Knotts, H. G. (2006). "Sticks, bricks, and social capital: the challenge of community development corporations in the American Deep South." Community Development Journal 41(1): 37-49.

Ltd, B. I. (2010). Shoreline Protection Guidelines. Government of Kiribati.

Mao, Weifeng. 2011. "The Impacts of Sea-Level Rise on I-95 Corridor in Delaware." University of Delaware. Newark, Delaware.

Matthew Heberger, H. C., Pablo Herrera, Peter H. Gleick, and Eli Moore of the Pacific Institute (2009). The Impacts of Sea-Level Rise on the California Coast, California Climate Change Center.

Nicholls, R. (2011). Planning for the impacts of sea

level rise. Oceanography, 24(2), 144-157.

Nicholls, R., & Mimura, N. (1998). Regional issues raised by sea-level rise and their policy implications. Climate Research, 11, 5-18.

NOAA. (2012). "Sea Level Trends." Tides & Currents Retrieved October, 2012, from http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml.

Oliver-Smith, A. (2009). "Sea Level Rise and the Vulnerability of Coastal Peoples." Responding to the Local Challenges of Global Climate Change in the 21st Century. Publication Series of UNU-EHS 7.

OnTheMap. (2010). U.S. Census Bureau. Retrieved from http://onthemap.ces.census.gov/

New York State Department of Environmental Conservation, (2010). Sea Level Rise Task Force. Report to the legistation. Retrieved from http://www.dec.ny.gov/docs/administration_pdf/slrtffinalrep.pdf

River Basin Center. (2011). "Sea Level Rise on Georgia's Coast: Year Two." Retrieved October, 2012, from http://www.rivercenter.uga.edu/research/climate/slr_2.htm.

Robinson, M. H., C. R. Alexander, C. W. Jackson, C. P. McCabe and D. Crass (2010). "Threatened archaeological, historic, and cultural resources of the Georgia Coast: Identification, prioritization and management using GIS technology." Geoarchaeology 25(3): 312-326.

Rosenzweig, C., Major, D., Demong, K., Stanton, C., Horton, R., & Stults, M. (2007). Managing climate change risks in New York City's water system: assessment and adaptation planning. Mitigation and Adaptation Strategies for Global Change, 12(8), 1391-1409.

Rygel, L., D. O'sullivan and B. Yarnal (2006). "A method for constructing a social vulnerability index: an application to hurricane storm surges in a developed country." Mitigation and Adaptation Strategies for Global Change 11(3): 741-764.

Savannah State University Marine Science Department. (2011). Retrieved from http://www.savannahstate.edu/cost/nat-science/marine-sci.shtml

Schmidtlein, M. C., R. C. Deutsch, W. W. Piegorsch and S. L. Cutter (2008). "A Sensitivity Analysis of the Social Vulnerability Index." Risk Analysis 28(4): 1099-1114.

ScienceJrank. (2012). Beach Nourishment. Retrieved from Science encyclopedia: "http://science.jrank.org/pages/780/Beach-Nourishment.html"

Severson, K. (2012). Taxes Threaten an Island Culture in Georgia. The New York Times, The New York Times Company.

Shepard, C., V. Agostini, B. Gilmer, T. Allen, J. Stone, W. Brooks and M. Beck (2012). "Assessing future risk: quantifying the effects of sea level rise on storm surge risk for the southern shores of Long Island, New York." Natural Hazards 60(2): 727-745.

Skidaway Institute of Oceanography. (2012). Retrieved from http://www.skio.usg.edu.

Social Security Administration. (2012, October 17, 2012). "Social Security: The Official Website of the U. S. Social Security Administration." Retirement Planner: Benefits By Year of Birth Retrieved October 19, 2012, 2012, from http://www.socialsecurity.gov/retire2/agereduction.htm.

State, U. S. D. o. (2010). U.S. Climate Action Report 2010. Washington, DC: Global Publishing Services.

Tiner, W. (2011). Predicting Wetland Functions at the Landscape Level for Coastal Georgia Using NWIPlus Data. Retrieved from http://coastalgadnr.org/sites/uploads/crd/CORRELATION%20REPORT%20Georgia_FINAL_September-20-2011.pdf.

U.S. Census Bureau (2008). A Compass for Understanding and Using American Community Survey Data. Washington, D.C., U.S. Census Bureau.

U.S. Census Bureau (2010). 2010 American Community Survey/Puerto Rico Community Survey Group Quarters Definitions.

U.S. Census Bureau (2010). OnTheMap: Data Overview (LODES Version 6). U. C. Bureau. Washington, D.C., U.S. Census Bureau.

U.S. Bureau of Labor and Statistics. (2011). Retrieved from http://data.bls.gov/location_quotient/ControllerServlet

U.S. Department of Housing and Urban

Development. (2012). Housing Programs. Retrieved from http://portal.hud.gov/hudportal/HUD?src=/program_offices

U.S. Department of Housing and Urban Development. (2010). Low-Income Housing Tax Credit Database. Retrieved from http://lihtc.huduser.org/

U. S. Department of Labor (2010). Child Labor Provisions for Nonagricultural Occupations Under the Fair Labor Standards. U. S. D. o. L. W. a. H. Division, U. S. Department of Labor. Child Labor Bulletin 101: 1-26.

U.S. Department of Labor, Education and Training Administration. (2012). Retrieved from http://www.doleta.gov/

USACE. (2005). Beach Nourishment Experience. Retrieved from US Army Corps of Engineers Environmental Laboratory: http://el.erdc.usace.army.mil/workshops/05feb-dots/session4-pilkey.pdf

University of Technology Sydney. Shopfront. and Loyola University of Chicago. Center for Urban Research and Learning. Gateways

Virginia Department of Transportation. (2012). Assessing vulnerability and risk of climate change effects

on transportation infrastructure. Federal Highway Administration. Retrieved from http://www.virginia.edu/crmes/fhwa_climate/files/finalReport.pdf

Walcott, S. (2002) "Unique Gullah/Geechee culture at risk." CNN.

Wilder, M. (2001). Race, ethnicity and class: facing the limits of community-based development. Danish Building and Urban Research/EURA Conference (presented paper) Copenhagen, http://www. sbi. dk/eura/workshops/papers/worksho p4/wilder. htm.

APPENDIX I. Physical Impacts

Appendix I.1 - Assessing Physical Vulnerability

For the purpose of this report, physical vulnerability is defined as the exposure and sensitivity of infrastructure and the natural environment to hazardous events and inundation caused by sea level rise. Exposure refers to the extent to which these systems are at risk for sea level rise while sensitivity refers to the extent to which exposure could harm those communities (adapted from San Francisco Bay Conservation and Development Commission, 2012). The measurement of physical vulnerability conducted here merely describes the exposure of those systems to sea level rise, i.e., how much infrastructure or how many facilities will be inundated due to sea level rise and what are the percentages of infrastructure and/or facilities that will be impacted? The physical vulnerabilities this report will discuss are:

(1) Land Cover and Endangered Habitats
(2) Land Use
(3) Transportation
(4) Environmentally-sensitive Facilities
(5) Facilities
(6) Historic Sites

Considering the scope of data that was readily available, a land cover analysis was conducted for Chatham, Liberty, and McIntosh counties that took into account both general land cover as well as threatened ecosystems. We extracted several unique characteristics of the three study counties through the process, including the way in which the alignment of a county to the ocean affected the general impact of sea level rise. Overall, we found that the majority of areas currently characterized by wetlands are in locations that are projected to be inundated within the next century. We also concluded that many (G)-Ranked habitats would be in inundated areas, especially in Chatham County. The presence of Savannah, the primary economic hub of the region, poses additional problems as more greenfields across Chatham can be expected to develop, which would further marginalize these threatened ecosystems.

The analysis undertaken is a worst-case scenario of sea level rise and its impact on Georgia's coastal habitats. Due to the absence of several key variables as well as the presence of inconsistent data, it was not feasible to engage in even an elementary land cover change analysis. As such, much of the discussion focused on gaps in data that may be used to project land cover into the future. If such an effort were executed, a more thorough illustration of the study area's physical would be possible. In lieu of that prospect, there are several simple endeavors that can be accomplished to enhance the data analysis, such as developing weights for the (G)-Ranks or dividing the data into more discrete geographic units. In spite of the myriad flaws of this undertaking, it provides a thorough dataset on the possible, albeit worst-case scenario, impacts of one meter of sea level rise.

Throughout the course of the analysis, it became increasingly evident that the differing geography between the three counties would affect the extent to which each

will be impacted by rising sea levels; indeed, it appears that both the shape and relation to the coast of each county influence the amount of land inundated therein. This is apparent in the case of Liberty County, which is oriented horizontally to the coast and extends far inland. Chatham and McIntosh counties, conversely, are positioned in a manner that maximizes their coastlines. This geographic reality had a direct effect on the comparison of land cover change between the three counties; while the average amount of dry land that is to be inundated was 32.28%, only 17.28% of Liberty County's dry land was predicted to be inundated. This is especially relevant if this figured compared to the portion of area submerged in Chatham and McIntosh counties, which is 44.67% and 37.74%, respectively. It is difficult to quantify the degree to which coast frontage affects inundation impact, but it would certainly add a rich dimension to the data analysis.

As a part of the land cover analysis, useful information concerning the contrast between the characteristics of the three counties was gleaned. Chatham County was by far the most urbanized of the three counties, having over a quarter (25.93%) of its land characterized as developed. On the other hand, Liberty County had a balance of land cover classes distributed throughout its borders, including grass (6.29%), developed (9.79%), and wetland (26.69%), though it was foremost covered by forest (55.85%). Such a balance, especially its above-average share of grasslands, is possibly indicative of a more rural nature. Finally, McIntosh County was almost entirely classified as vegetation, composed of forest (48.39%) and wetland (42.70%). Further, developed land in McIntosh only covered 5.72%, which suggests that it could be characterized as the least disturbed of the counties.

While this classification system (Chatham as the urban county, Liberty as the rural, and McIntosh as the natural) allows one to understand each county in very general terms, some interesting exemptions emerged when conducting the (G)-Rank analysis. Despite being such an underdeveloped county, McIntosh had the fewest G1-ranked habitats. Furthermore, Chatham County had the most inundation of (G)-Ranked land. A possible explanation for this occurrence is that development pressures have pushed the brunt of critical habitats to the marginal lands of Chatham: areas that are most vulnerable to sea level rise. Based on the forecasted extents of land cover classes with inundation factored in, developed land in Chatham is projected to compose 44.71% of the total land area. If one were to project development patterns into the future, it is almost certain that the urbanization of Chatham County will continue an upward trend, which would further threaten the remaining (G)-Rank habitats in the area not directly impacted by inundation. In addition to the outright displacement of these endangered ecosystems, continued development may prevent migration, both of (G)-Ranked places as well as wetlands.

Appendix I.2 - Physical Vulnerability Methods

Rail

Using ArcGIS, the rail network dataset was added to a database containing layers of the study area, current water level and the sea level rise shapefile. Performing a clip function in ArcGIS, it was found that approximately 13 miles of rail will become inundated, based on the projected one-meter rise in sea level. Although this is only a small portion of the overall rail network, this is crucial for the rail network within the study area, and within the State of Georgia.

Roads

An analysis in ArcGIS was performed using AADT data from 2010 created by GDOT and accessed from the Georgia GIS Clearinghouse website. The top 25% of all roads within Chatham, Liberty and McIntosh counties with the highest AADT values were selected and analyzed in order to examine roads (other than interstate highways) that have heavy traffic volumes compared to other roads in the general vicinity. These roads were then analyzed with respect to the projected one-meter rise in sea level.

Evacuation Routes

An analysis using ArcGIS was performed to examine the locations of GEMA evacuation routes within the study area that may become inundated due to the projected one-meter rise in sea level. A dataset showing the evacuation route locations in the study area was obtained from GEMA. In ArcGIS the clip function was used with the evacuation routes shapefile and the SLR shapefile to find the total miles of inundated GEMA evacuation routes that are located within the study area.

Hazardous Materials

The metric for this variable was the number of inundated sites and their hazardous categories and comparing the number of vulnerable sites under sea level rise impacts. This information was found on the Georgia Environmental Department's inventory of hazardous sites.

Wastewater Treatment Plant

The metric for this variable is the number of sites and its capacity of millions of gallons per day. This information was gathered at EPA's Enforcement and Compliance History Online website.

Landfills

We acquired the geospatial data of landfill sites from Georgia GIS Clearinghouse. We overlaid this data with the one-meter sea level rise layer to learn which places are become inundated. Since the locations of landfills are presented in point-form, which is not able to visualize the aerial impact of sea level rise on landfills, we created 500-meter buffers surrounding landfill location points and overlaid these buffers with sea level rise to investigate which ones have the potential to be impacted

by sea level rise. Then we studied the boundary of each landfill area to determine whether they will be inundated or not. For the purpose of this assessment, we assume that if a portion of a landfill is inundated then the entire landfill is considered to be impacted by sea level rise. The metric for this variable was the number of sites that would be impacted by sea level rise.

Power Plants

We acquired geospatial data of power generation facilities, which included boilers, generators, and plants from the Environmental Protection Agency (EPA)'s Emission and Generation Resource Integrated Database (eGRID)[1]. We overlaid this data with the one-meter sea level rise layer to learn which facilities are projected to become inundated. Since the locations of power facilities are presented in point-form, which is not able to visualize the aerial impact of sea level rise on facilities, we created 500-meter buffers surrounding location points of the facilities and overlaid these buffers with sea level rise to investigate which ones have the potential to be impacted by sea level rise. Then we studied the boundary of each facility area to determine whether or not it will be become inundated.

Historic Sites

We acquired geospatial data of historic places in the *kml* format from the National Register of Historic Places Program website[1]. This database covers both national and state register systems. After converting the data from the *kml* format to *shapefiles*, we overlaid it with the one-meter sea level rise layer to learn which places are projected to become inundated. Since the locations of historic places are presented in point-form, which is not able to visualize the aerial impact of sea level rise on districts, we studied the boundary of each designated district to determine whether or not it will become inundated. For the purpose of this assessment, we assume that if a portion of a district is inundated then the entire district is considered to be impacted by sea level rise.

Building Inundation

The HAZUS data set was developed by FEMA's Mitigation Division by the National Institute of Building Sciences and provides information on the number of existing buildings and an estimate of their replacement values. HAZUS data from year 2000 was used in the analysis of the land use variable as a supplement to the land use data sets and as a tool to look more specifically at the existing land uses. The HAZUS data set divides buildings into seven broad land use categories: residential, commercial, industrial, agricultural, religious, education, and government. Within each land use category, the data set provides the number of existing buildings and an estimation of their replacement value. The HAZUS data is available at the census block level for each of the three counties in the study area.

Using the HAZUS data set and the sea level rise shapefile, a GIS analysis was performed to estimate the number of buildings that will be affected by sea level rise and the approximate replacement value of those buildings. The first step in the analysis was to use ArcGIS tools to find the percentage of each census block that will become inundated by sea level rise. Next, this inundated land percentage for each census block

was multiplied by the corresponding HAZUS data for each census block. This step of the analysis was made simple by assuming that the land use infrastructure was evenly distributed across each of the census blocks. For example, if 50% of a census block will be inundated by sea level rise, and there are 100 residential buildings in that census block, we assumed that 50 residential units would be affected by sea level rise. Additionally, the results of this analysis were also aggregated to the county level to investigate overall trends. The exact analysis steps performed in ArcGIS can be found in the appendix under the title "Inundated Building Number/Replacement Value Analysis Steps."

The census block level analysis of buildings affected by sea level rise was again aggregated up to a higher level – the census block group level. This step was necessary so that the land use variable could be compared with other important variables that did not have data available at as fine a grain as the census block level.

Non Environmentally Sensitive Facilities

To further delve into the physical facilities that are projected to be impacted by the one-meter sea level rise, a closer look at the specific locations of where people work, live, and learn is needed in the study of vulnerable places. Using the U.S. Census, HAZUS data, the Georgia GIS Clearinghouse, and information provided by government agencies, calculations were made to get the total number of the eight facilities and then the number of these facilities that are projected to be impacted by the one-meter sea level rise within a 500-meter buffer.

The seven categories of physical facilities that were reviewed are:

(1) Airports (includes airfields, airstrips, and airparks)
(2) Government (city hall, police and sheriff departments, fire stations, and jails)
(3) Medical (hospitals, clinics, dentists, other places that can provide medical attention)
(4) Schools
(5) Hurricane Shelters
(6) Churches
(7) Cemeteries
(8) Major Industries and Top Employers

Appendix I.3 - Non-Environmentally Sensitive Facilities Analysis

The extent of expected inundation on non-environmentally sensitive facilities is outlined in Table I.4.1. Some key non-environmentally sensitive facility locations that will be impacted are:

Chatham County

Hodges Airpark in Savannah near Chevis Road and Beaufort Road
Savannah City Hall on East Bay Street

Thunderbolt Town Hall on Russell Street
Tybee Island City Hall on Butler Street
Gun Hill Cemetery near the town of Ogeechee Farms
Waldburgh Cemetery near the town of Grubbs
Bonaventure Cemetery in Savannah on Bonventure Road
Chatham Steel Corporation in Savannah on West Boundary Street
Derst Baking Company in Savannah on Mills B Lane Boulevard
Diamond Crystal Brands in Savannah on Tremont Road
Georgia-Pacific Gypsum Corporation in Savannah on Wahlstrom Road
IKEA Savannah Distribution Center in Port Wentworth on Little Hearst Parkway
Savannah State University in Savannah
Savannah College of Art and Design in Savannah
Weyerhaeuser Company in Port Wentworth on Appleby Road

Liberty County

Midway City Hall on East Olgethorpe Highway
Midway Cemetery on Ocean Highway near the Midway Museum
Floquip Engineering in Riceboro on Chemical Plant Road
Interstate Paper Company in Riceboro on Interstate Highway Papermill
SNF Holding Company in Riceboro on Chemical Plant Road
Woodland Healthcare in Midway on Ocean Highway

McIntosh County

Patterson Island Airport in Darien
Barbour Island Airport in Shellman Bluff
Sapelo Island Airport on the southern western tip of the island
Darien City Hall on Washington Street
Gould Cemetery in Harris Neck National Wildlife Refuge
Old Sailors Burial Ground on the Doboy Sound
Behavior Cemetery in Sapelo Island
Crescent Equipment Company in Townsend on Johnson Road

Table I.4.1: Non-Environmentally Sensitive Facilities

		Chatham	Liberty	McIntosh	Three County Study Region
Airports	Inundated	2	2	6	10
	Total	3	3	16	22
	% Inundated	67%	67%	38%	45%
Governmental	Inundated	32	8	8	48
	Total	66	24	13	103
	% Inundated	48%	33%	62%	47%
Medical	Inundated	6	0	0	6
	Total	678	61	9	748
	% Inundated	1%	0%	0%	1%
Schools	Inundated	22	1	2	25
	Total	51	13	4	68
	% Inundated	43%	8%	50%	37%
Shelters	Inundated	0	0	0	0
	Total	0	0	0	0
	% Inundated	-	-	-	-
Churches	Inundated	123	13	20	156
	Total	327	80	50	457
	% Inundated	38%	16%	40%	34%
Cemeteries	Inundated	20	4	18	42
	Total	29	21	31	81
	% Inundated	69%	19%	58%	52%

Appendix I.4 - Physical Vulnerability Data Limitations

Migration

Based on the simple projections used during the data analysis, it would appear that by 2110 wetlands would be nearly decimated from the Georgia coast. Using the data available, however, it was impossible to accurately project the future extent of each land cover class across the study area. The measures that were used assume land cover remains the same over the entire period, but the gradual pace of change means that ecologically significant habitats (including those (G)-Ranked) should have an opportunity to migrate over space and time.

In order to accurately project the extents of each class into the future, a projection of future land cover must also be accomplished in tandem with an evaluation of several other factors. For example, many of the areas classified as forest in the future extent are likely to shift to wetlands as soils adjacent to the coast become saline with sea level rise. Additionally, the existence of tides means that many lands classified as dry land in the projection would instead be inundated part of the time, providing an ideal habitat for wetland species. As such, the loss of wetland and other critical habitats is most likely not going to be as severe as is indicated by the analysis.

HAZUS Data

For the HAZUS data analysis it is important to point out the limitations associated with the data itself and with the analysis methods used to process the data. There are inherent limitations in the replacement value portion of the HAZUS data that come from the way the data is produced by the National Institute of Building Sciences. The HAZUS replacement value data comes from a database called the General Building Stock Inventory, which bases the replacement values on national-average construction costs. The difference between the replacement value and the actual market value of a home can be large due to the added values associated with land value, neighborhood, school district, and several other factors (Heberger 2009). For this reason, it is important to note that the replacement value often underestimates the actual costs associated with replacing those buildings.

Another important limitation associated with the processing of the HAZUS data is that we assumed in our analysis that the buildings were evenly distributed throughout the census blocks. This is a major assumption and significantly increases the variability in our results for the number of inundated buildings and their associated replacement values. In a later section of this report called “Suggestions for Further Land Use Analysis” we suggest a method to improve the results by combining the land use data and the HAZUS data, so that you do not have to assume and even distribution of buildings throughout entire census blocks.

A complicating factor in this census block group aggregation was that the census block HAZUS data was only available from year 2000, but the other variable analyses were conducted using the more recent 2010 census block group shapes. The year 2000 census blocks did not fit neatly inside the year 2010 census block groups because there was a significant change in the number and shape of the census blocks between the year 2000 census and the year 2010 census. To overcome this issue, a GIS tool was used to assign the year 2000 census blocks to the 2010 census block group containing their centroid and then aggregate the 2000 census block data to the 2010 block group level. The exact steps performed in ArcGIS in this portion of the analysis are listed in the appendix in the section titled “Inundated Building Number/Replacement Value Aggregation to Block Group Steps.”

Data Inconsistencies

After initially evaluating the data associated with (G)-Ranked habitats, it was important to gain a more thorough understanding of the specific elements associated with each (G)-Rank emerged. Once this was accomplished, it became evident that (G)-Ranks are not ranked on a linear scale; for example, critically imperiled (G1) habitats require much more immediate attention than imperiled (G2), as extinction is an imminent possibility in the former and not the latter (CITE). As such, a loss of five square miles of a G1-ranked is exponentially more ecologically devastating than loss of five square miles of G2 territory. In order to rectify this data inconsistency and develop a better quantitative scale, it would perhaps be productive to weight (G)-Ranks based on some established means, though relevant literature must first be identified.

Through GIS analysis we found that neither of our land use data sets matched up well with the HAZUS data set. The data sets do not classify land uses in a consistent manner and there is a discrepancy between the locations where the two data sets display various land uses. In order to overcome this issue we recommend that a new land use data source be obtained that is more consistent with the land uses presented in the HAZUS data set.

This combined analysis would involve calculating the percentage of each land use within each census block that will become inundated for the new land use data set in the same way that we previously did this calculation for our land use data sets. You would then multiply those percentages by the corresponding number of buildings and total replacement value from the HAZUS data for each census block and land use combination. The steps carried out in ArcGIS for the first part of this analysis are exactly the same as those that were used previously in our land use data analysis and can be found in the “Inundated Land Use Percentage Analysis Steps” section of the appendix. A suggestion of the ArcGIS analysis steps for the second part of this analysis are outlined in the “Additional Data Analysis Steps Necessary for the Combined Data Analysis” section of the appendix.

Ocean Dynamics

Because the model used to quantify sea level rise was a simple bathtub type, ocean dynamics such as storm surges and tidal ranges were not taken into account in the analysis. It is theorized that storm surges will be intensified as the sea rises, so it would be important to take this factor into account in order to identify particularly vulnerable areas.

APPENDIX II. Social Impacts

Appendix II.1 - Inundation of Socially Vulnerable Groups

Table II.1.1 shows the expected impact on socially vulnerable groups within each county as a proportion of the total vulnerable population within the three county region.

		INUNDATION TOTALS				% OF THE THREE COUNTY COUNTY TOTAL			
		Chatham	Liberty	McIntosh	Three County Study Region	Chatham	Liberty	McIntosh	Three County Study Region
POPULATION AND HOUSEHOLD DENSITY	Population	42,623	3,377	4,059	50,059	13%	1%	1%	15%
	Households	17,187	1,311	1,581	20,079	13%	1%	1%	16%
AGE	Under 5 Years	2,711	171	271	3,153	11%	1%	1%	13%
	5-14 Years	4,798	341	456	5,595	11%	1%	1%	13%
	Above 64 Years	6,377	464	587	7,428	17%	1%	2%	20%
RACE AND ETHNICITY	Nonwhite	12,669	1,037	1,405	15,111	8%	1%	1%	10%
	Hispanic	1,791	41	64	1,896	10%	0%	0%	10%
GENDER AND FAMILY STATUS	Female Population	21,697	1,742	2,141	25,580	13%	1%	1%	15%
	Families	11,333	908	1,107	13,348	14%	1%	1%	16%
	Single Parent Families	1,752	125	167	2,044	9%	1%	1%	11%
EDUCATION	Over 25 Years with Less than High School Education or Equivalent	2,541	419	556	3,516	9%	2%	2%	13%
OCCUPATION AND EMPLOYMENT	Employed Population	19,607	1,498	1,852	22,957	14%	1%	1%	16%
	Service-Sector Employees	11,227	755	1,046	13,028	13%	1%	1%	16%
INCOME AND POVERTY	Median Income	Inundation cannot be measured.							
	Families in Poverty	728	81	102	911	7%	1%	1%	9%
	Single Parent Families in Poverty	438	36	60	534	7%	1%	1%	8%
	Single Mother Families in Poverty	415	28	51	494	7%	0%	1%	8%
HOMELESS	Sheltered	Inundation cannot be measured.							
	Unsheltered								
	Total								
HOUSING AND THE BUILT ENVIRONMENT	All Housing Units	19,807	1,574	2,577	23,958	13%	1%	2%	16%
	Owner-Occupied Housing Units	11,742	975	1,128	13,845	16%	1%	2%	19%
	Renter-Occupied Housing Units	5,447	338	453	6,238	10%	1%	1%	12%
	Vacant Housing Units	2,624	263	995	3,882	12%	1%	4%	17%
	Median Home Value	Inundation cannot be measured.							
	Median Monthly Rent								
	Manufactured Housing	1,466	470	730	2,634	11%	4%	5%	20%
MODE OF TRANSPORTATION	Households with No Vehicle Access: Home Owners	Inundation cannot be measured.							
	Households with No Vehicle Access: Renters								
	Total of Households with No Vehicle Access								
DISABILITY		This variable is difficult to measure quantitatively.							
SITE SPECIFIC		This variable is difficult to measure quantitatively.							
SOCIAL CAPITAL		This variable is difficult to measure quantitatively.							

Appendix II.2 - Assessing Population Impacted by SLR

We started by identifying the area of land in the three counties that is not part of the coastal marshland. Not only do less people live in the wetlands compared to the rest of the counties' areas, but the wetlands are going to be almost entirely inundated. So, we wanted to look at the non-coastal-wetland land to determine the impact of sea level rise on the population.

First, we looked at the wetlands separately to see what population density is actually like. In total, there is 323 square miles of coastal-wetlands in Chatham, Liberty,

and McIntosh counties. Of all of this square mileage, only 3.1 square miles are not going to be directly affected by sea level rise. That is less than one percent of the total coastal-marshland land. Within the coastal-marshland, 134 square miles has a residential population, which is 41.4% of the total coastal-marshland area. Conversely, 189 square miles, or 58.6%, of the coastal-marshland area has no residential population.

Without the wetlands, the total area of the three counties is 1,056 square miles. Of that square mileage, 125 square miles are directly affected by sea level rise, meaning there is 931 square miles of non-coastal-marshland land that is not directly affected by sea level rise. In other words, 11.8% of the three counties' land will be inundated by sea level rise while 88.2% will not be inundated.

Next, we showed the block groups that are directly affected by sea level rise. A vast majority of the demographic data we have is from the Census Bureau, which uses block groups as the lowest level of designation. Total, there are 245 block groups in the non-coastal-marshland land of the three counties. Of the 245 block groups, 141 are directly affected by sea level rise. This is 57.6% of the total number of block groups in non-coastal-marshland land.

Even though most of our demographic data is at the block group level, we wanted to look at population at the block level for a more precise illustration of population density. In total, there are 11,262 blocks in the three counties that are non-coastal-marshland land. Of these blocks, 2,288 are directly affected by sea level rise. This is 20.3% of the total number of blocks in the non-coastal-marshland land. This decreased percentage from the block group level informs us that the block level has higher precision. However, as previously stated, a vast majority of our demographic data can only be found at the block group level.

Methodology

1. First, we show the population density per block level and block group level. We want to show the block level density because it's more accurate that the block group level. However, we are using the block group level for our analysis because of our demographic data.

-Block level: Shapefile, quantities, population summation

-Block group level: Shapefile, quantities, population summation

2. To take into account that the wetlands area will have a much less dense population, we are merging the block group shapefile with the wetlands land cover shapefile to get an accurate account of population density there. We show that because of the little amount of people residing there, the wetlands should not be included in our demographic analysis.

-ArcGIS merge

3. Erase the wetlands data from the block group shapefile. After that, we use the non-wetland land as our base of analysis

-ArcGIS erase

4. We now account for the 1-meter sea level rise and what block groups it directly affects.

-ArcGIS overlay

-ArcGIS intersection

5. By looking at the area of the block groups that will be inundated and compare it to the area of the block groups as a total, we can come up with specific ratios to interpolate the percentage of the population that will be directly affected.

-Area inundated/block group total area= affected population percentage

6. We apply this affected population percentage to all demographic analysis to get a more accurate idea of the actual amount of people being touched by a 1-meter sea level rise.

Appendix II.3 - Subsidized Housing

Figure II.3.1 and Figure II.3.2 map subsidized housing in the study region.

Figure II.3.1 – Subsidized Housing in Chatham, Liberty, and McIntosh Counties

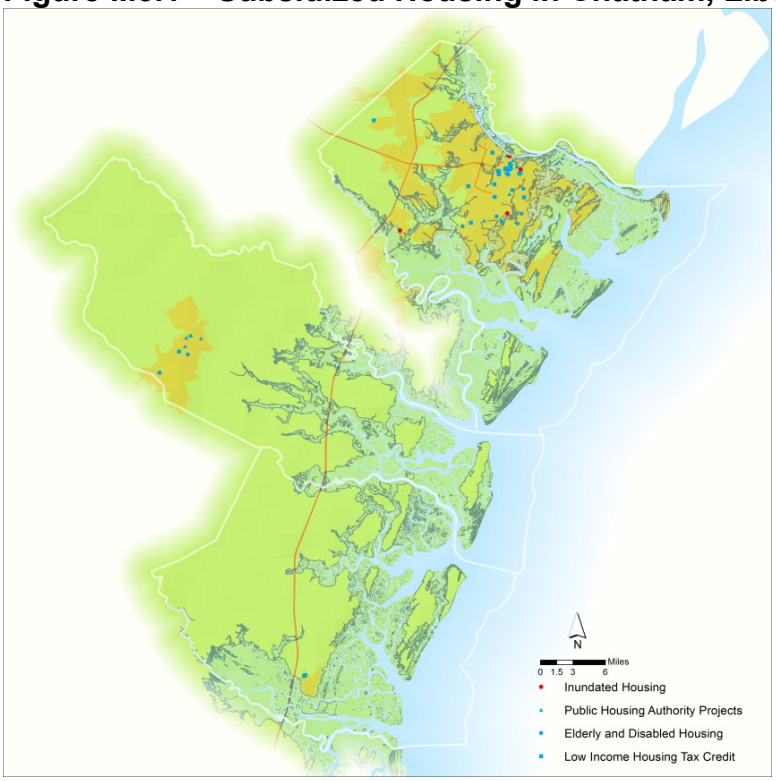
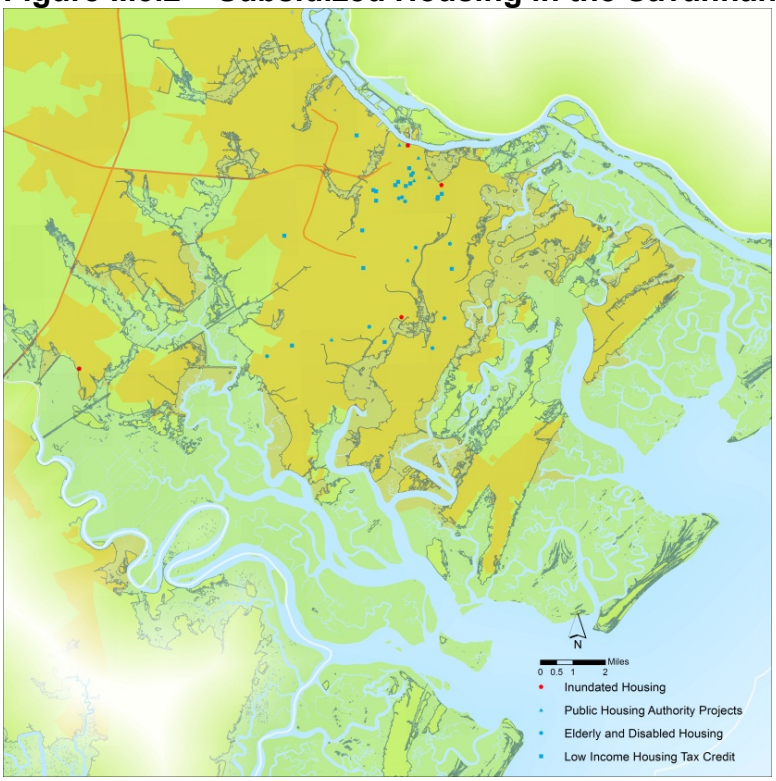


Figure II.3.2 – Subsidized Housing in the Savannah Region



Appendix II.4 - Employment Analysis: Data Source & Methodology

Data Source

The general economic pattern and employment loss are derived from LEHD Origin-Destination Employment Statistics (LODES) dataset (OnTheMap, 2010). This dataset is released as part of the OnTheMap application and in raw form as CSV text files. The most recent published data is in 2010 and the block is defined by the Census Bureau TIGER file 2010. For each state, there are three groups of files: Origin-Destination data (OD), residence area characteristic data (RAC), and workplace area characteristic (WAC) data based on census block level. The WAC provides information about the total of job opportunity in blocks defined as “working based”. The RAC provide information about the total of employed in blocks defined as “residence based”. The OD data provides the directional work flow between “working based” and “residence based” block pairs. These data also provide detailed categorical information by grouping employments according to age, earning, education level, race, and NAIC sectors.

This project is supported by the Employment and Training Administration (ETA) at the U.S. Department of Labor. The employment data with LODES comes from several sources: Unemployment Insurance (UI) Wage Records reported by employers and maintained by each state for the purpopose of unemployment insurance system, the Office of Personnel Management (OPM), and the Quarterly Census for Employment and Wages (QCEW) collected by each state under an agreement with the Bueau of Labor Statistics (BLS). Age, earnings, and industry profiles are compiled by the Census

Bureau from a state's records and are supplemented with other Census Bureau source data. And since final compilations are performed by the Census Bureau, LODES is consistent with the data provided by Census Bureau.

The recreational fishery data comes from the Marine Recreational Information Program (MRIP) conducted by National marine Fishery Service (NMFS). MRIP is the counting of National Oceanic and Atmospheric Administration (NOAA) Fishery for marine recreational catch and effort. It is a creel survey with information on fishing location, mode, target species, catch and harvest, and fishing time periods. The direct expenditure, indirect economic impact, employment created by recreational fishing and tax generated are estimated in the 2006 angler expenditure report. The intercepted survey data from MRFSS program bears the information based on county level and is carried out with random, so the distribution of the county with this data can be viewed as the general proportion of the anglers in each county.

Methods

The strategy to estimate the total loss of employment due to sea level rise is based on the assumption that the job opportunities are distributed uniformly within each "working-based" block. The "working-based" blocks are intersected with the 100-year sea level rise plane and the inundated area within each block is calculated. The loss of employment is in proportional to the percentage of land loss. So . The total job loss in the study region can be estimated by using WAC data. A combination of RAC data and OD data can match the workflow from "residence-based" blocks to "working-based" blocks. Thus, the unemployment caused by sea level rise can be summarized based on "residence-based" blocks by using the forementioned formula. This enables information on how many people lose jobs in different communities.

The exposed fishery industry in each county is calculated by using a quantity in unit of (fishing days*person), which is taken from the intercept survey conducted by MRFSS in 2010. This quantity is used to balance the expenditure estimation in the angler expenditure report of MRIP in 2006. The proportion is calculated to be (Chatham County: Liberty County: McInstosh County: Other GA counties=16360:1159:7714:29821). Since about 70% of the beach will be inundated with the SLR, all the beach resources can be viewed as in threat and the total industry is exposed to the danger of SLR.

Appendix II.5 - Recreational Fishing in Coastal Georgia

The second site specific variable involves the recreational fishing industry, which almost piggy-backs off of the Gullah-Geechee culture variable. According to the Geechee Kunda community center, the Gullah-Geechee have historically been fishermen. Regardless of the connection, fishing, whether for livelihood or recreational, is a part of Coastal Georgia now.

According to these results, the expenditure and the economic benefits brought by recreational fishing is summarized in Table II.5.1-II.5.3. If the sea level rise is not defended, the loss of the beach and the wetland resources will give rise to a huge loss in economy based on the great economic value carries by these natural resources. The

direct expenditure brought by recreational anglers is totaled as $82,261 thousand dollars as presented in Table II.5.1. This amount of expenditure has generated an indirect additional economic value in all related industries of $30,013 as shown in Table II.5.2. Table II.5.3 has revealed that the total employment created by the creational fishery industry is 722. The sea level rise will destroy the beach and natural wetlands, which provides the attraction for tourism in this region and lead to the loss in this part of revenue and employments.

Table II.5.1 - Direct Expenditure (Unit: thousand dollars)

	Chatham	Liberty	McIntosh
Private transportation	**1478**	**105**	**697**
Food from grocery	**345**	**24**	**163**
Food from restaurant	**80**	**6**	**38**
Lodging	**67**	**5**	**32**
Boat fuel and rental	**1132**	**80**	**534**
Access and parking	**23**	**2**	**11**
Bait and ice	**606**	**43**	**286**
Tackle, rod, reels, and other gears	**10915**	**773**	**5147**
Camping equipment	**108**	**8**	**51**
Clothing	**1,343**	**95**	**633**
Taxidermy	**14**	**1**	**6**
Magazine	**744**	**53**	**351**
Club	**209**	**15**	**98**
License	**1,099**	**78**	**518**
Boat purchase	**15,930**	**1,129**	**7,511**
Accessory purchase	**2,578**	**183**	**1,216**
Boat Registration, storage, insurance and maintenance	**9,076**	**643**	**4,279**
Vehicle purchase	**2,576**	**182**	**1,215**
Vehicle insurance and maintenance	**2,562**	**182**	**1,208**
Second home insurance and maintenance	**2,450**	**174**	**1,155**
Total	**53,335**	**3,778**	**25,148**

Table II.5.2 – Indirect Economic Impact (Unit: thousand dollars)

	Chatham	Liberty	McIntosh
Private transportation	**516**	**37**	**243**
Food from grocery	**100**	**7**	**47**
Food from restaurant	**46**	**3**	**22**
Lodging	**39**	**3**	**18**
Boat fuel and rental	**461**	**33**	**217**
Access and parking	**13**	**1**	**6**
Bait and ice	**150**	**11**	**71**
Tackle, rod, reels, and other gears	**3,393**	**240**	**1,600**
Camping equipment	**26**	**2**	**12**
Clothing	**358**	**25**	**169**
Taxidermy	**7**	**1**	**4**
Magazine	**162**	**11**	**76**
Club	**117**	**8**	**55**
License	**1,595**	**113**	**752**
Boat purchase	**3,286**	**233**	**1,550**
Accessory purchase	**1,143**	**81**	**539**
Boat Registration, storage, insurance and maintenance	**4,293**	**304**	**2,024**
Vehicle purchase	**849**	**60**	**400**
Vehicle insurance and maintenance	**1,469**	**104**	**692**
Second home insurance and maintenance	**1,436**	**102**	**677**
Total	**19,459**	**1,379**	**9,175**

Table II.5.3 Total Fishery Tourism-based Employment

	Chatham	Liberty	McIntosh
Private transportation	**12**	**1**	**6**
Food from grocery	**3**	**0**	**1**
Food from restaurant	**2**	**0**	**1**
Lodging	**1**	**0**	**1**
Boat fuel and rental	**13**	**1**	**6**
Access and parking	**1**	**0**	**0**
Bait and ice	**5**	**0**	**2**
Tackle, rod, reels, and other gears	**60**	**4**	**28**
Camping equipment	**1**	**0**	**0**
Clothing	**10**	**1**	**5**
Taxidermy	**0**	**0**	**0**
Magazine	**3**	**0**	**1**
Club	**4**	**0**	**2**
License	**33**	**2**	**16**
Boat purchase	**123**	**9**	**58**
Accessory purchase	**30**	**2**	**14**
Boat Registration, storage, insurance and maintenance	**84**	**6**	**40**
Vehicle purchase	**17**	**1**	**8**
Vehicle insurance and maintenance	**32**	**2**	**15**
Second home insurance and maintenance	**34**	**2**	**16**
Total	**468**	**33**	**221**

APPENDIX III. Temporal Analysis: Data and Methods

High-resolution, raster-based DEM data was acquired from the Skidaway Institute in order to create four new sea level rise vectors. Because the DEM was provided at an extremely high resolution of 4' by 4' grid cells, the data was simplified by a factor of four, resulting in a new raster with 16' by 16' grid cells. In order to convert the raster data to vector data, the map algebra was then calculated, which provided a series of GRIDCODE attribute values that estimated the z-value (elevation) at each grid cell in feet. The raster was then converted into a vector shapefile, and the GRIDCODE values were converted into meter units. A definition query was used to isolate values under one meter, and the fields under zero meters were merged, to represent current sea level. The resulting GRIDCODE values above zero meters included:

0.2 meters, representing sea level in 2040
0.4 meters, representing sea level in 2065
0.6 meters, representing sea level in 2085
0.8 meters, representing sea level in 2100

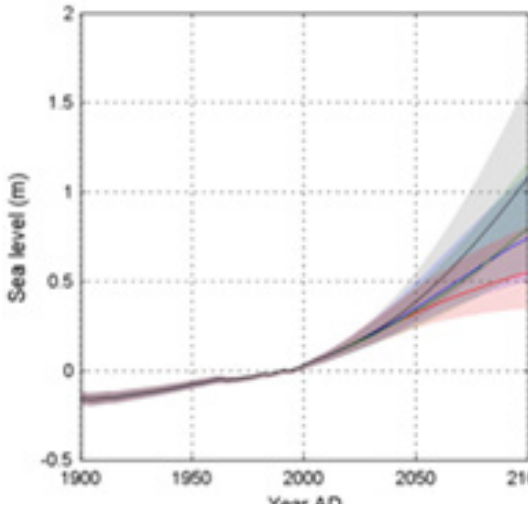
The approximate year represented by each GRIDCODE value was extrapolated from existing sea level rise projections, shown in Figure 4.1.

Once the four sea level rise values were established, the data were then intersected with the block group level data, which was first erased by the water shapefile to exclude the preexisting sea level. This intersection resulted in four separate vector shapefiles, which, following a recalculation of geometry, estimated inundation by block group (in acres). These four shapefiles, plus the original one-meter sea level rise vector, were then intersected with each of the factors examined in this temporal analysis, which included:

Primary Road Length (in miles)
Facilities (aggregation of historic, landfill, sewage, and hazardous sites)
Landcover (developed and wetland area, in acres)

Once all of this data was intersected and the geometry was recalculated, it was brought in Access, and through a series of queries, amassed with its corresponding block group. For ease of presentation in this report, the results were aggregated to the county level using totals queries. The results, presented at the county level, are presented below.

Figure III.1 – Projected Sea Level Rise Throughout the 21st Century



Source: Jevrejeva, Moore, and Grinsted, 2012

APPENDIX IV. Definitions

Wetland are areas where water covers the soil, or is present either at or near the surface of the soil all year or for varying periods of time during the year, including during the growing season.

Marshes are defined as wetlands frequently or continually inundated with water, characterized by emergent soft-stemmed vegetation adapted to saturated soil conditions. There are many different kinds of marshes, ranging from the prairie potholes to the Everglades, coastal to inland, freshwater to saltwater.

Non-tidal marshes are the most prevalent and widely distributed wetlands in North America. They are mostly freshwater marshes, although some are brackish or alkaline. They frequently occur along streams in poorly drained depressions, and in the shallow water along the boundaries of lakes, ponds, and rivers. Water levels in these wetlands generally vary from a few inches to two or three feet, and some marshes, like prairie potholes, may periodically dry out completely.

Tidal marshes can be found along protected coastlines in middle and high latitudes worldwide. They are most prevalent in the United States on the eastern coast from Maine to Florida and continuing on to Louisiana and Texas along the Gulf of Mexico. Some are freshwater marshes, others are brackish (somewhat salty), and still others are saline (salty), but they are all influenced by the motion of ocean tides. Tidal marshes are normally categorized into two distinct zones, the lower or intertidal marsh and the upper or high marsh.

Swamps are any wetland dominated by woody plants. There are many different kinds of swamps, ranging from the forested Red Maple, swamps of the Northeast, to the extensive bottomland hardwood forests found along the sluggish rivers of the Southeast. Swamps are characterized by saturated soils during the growing season, and standing water during certain times of the year.

Rolling easements are a type of easement placed along the shoreline to prevent property owners from holding back the sea but allow other types of use and activity on the land.