A Hurricane Risk Assessment for Chatham County, Georgia

by

Alyson Marie Cederholm

A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science in Geography

Auburn, Alabama
August 2, 2014

Keywords: Risk Assessment, Hurricane, Vulnerability,
Resilience, Social Vulnerability

Approved by

Philip Chaney, Chair, Department of Geology and Geography
Luke Marzen, Department of Geology and Geography
Chandana Mitra, Department of Geology and Geography

Abstract

In 2010, Savannah, GA. was ranked 4th in The Weather Channel's Top 5 Hurricane Vulnerable and Overdue Cities. Savannah is located in Chatham County, GA., which has not been impacted by a land-falling hurricane since Hurricane David in 1979. Given its growing population and historical tourist destinations, Chatham County could potentially suffer excessive damage from a land-falling hurricane. A hurricane risk assessment is being conducted to evaluate the potential extent of damage. This risk assessment documents historical hurricane activity in the region, social vulnerability, building and infrastructure vulnerability, and storm surge potential. These factors were used to compute potential loss estimates for a worst-case scenario and a most probable scenario for the county. The worst-case scenario is the potential for a hurricane to produce the maximum amount of damage, in this case a category 5 hurricane. The most probable case scenario is the amount of loss that is most likely to occur. The determination of the worst-case scenario and most probable scenario will allow the community to make decisions and develop policies for future tropical cyclone hazards. This project focuses on hurricanes that make landfall within 150 miles south of the county and 100 miles north of the county. Four socio-economic groups; buildings; and roads and telecommunication towers will be assessed. SLOSH model data was utilized to assess storm surge potential for each hurricane category. The end result will provide Chatham County with a comprehensive, updated hurricane risk assessment.

Acknowledgments

First and foremost I would like to offer my most sincere gratitude to my advisor, Dr. Philip Chaney. The knowledge I gained while working with Dr. Chaney helped shape me academically as well as professionally. Without the support and guidance of Dr. Chaney, I would not have been able to complete this thesis.

I would also like to thank my other committee members, Dr. Luke Marzen and Dr. Chandana Mitra, for their expertise and added support throughout my thesis research and writing process. I sincerely value the knowledge I gained in remote sensing and GIS from both Dr. Marzen and Dr. Mitra during my time at Auburn University.

I would like to thank Savannah Area GIS for allowing my access to their data. The data they provided greatly aided in the completion of this thesis research.

Lastly, I would like to thank my parents, Rick and Annette Cederholm, my brother, Erik Cederholm, and my boyfriend, Chris Vargas for their love and support throughout my academic endeavors. Without them this journey would have been impossible.

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

Natural hazards research is a part of geography that allows for the study of the interaction between humans and the environment (Paul 2011). Natural hazards research is an important aspect of human-environment interaction and interest in the topic has grown over the last several decades. One of the first notable researchers investigating human-environment interaction and natural hazard research was Gilbert White. White observed the relationship between human activity and physical processes and concluded that human behavior, such as people living in high risk areas, was a major contributing factor in natural hazards and disasters (Burton et al 1993). Natural hazards researchers have developed two main concepts relative to this problem: vulnerability and resilience. The way humans interact with the environment can have an impact on a community's vulnerability or a community's resilience in the face of a natural disaster. Turner et al (2003) defines vulnerability as "the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor." It is difficult to assess the vulnerability of a location without also assessing the sustainability and resilience of that location. Tobin (1999) defines sustainability and vulnerability as "societies which are structurally organized to minimize the effects of disasters, and, at the same time, have the ability to recover quickly by restoring the socio-economic vitality of the community."

Major hurricane disasters in recent past have brought much attention to this question about the role of humans. There are five major components to hurricane hazards: wind, tornadoes, storm surge, inland flooding, and coastal erosion. Of those five components, storm surge accounts for the majority of damage and loss (Burton 1993). Hurricanes, such as Ivan in 2004, Katrina in 2005, and Sandy in 2012, have caused death and devastation across the Gulf of Mexico coast and up the U.S. Atlantic Coast in the last decade. Hurricane Ivan was responsible for 92 deaths, 25 of which were in the United States, and approximately $14.2 billion in damages and losses (Stewart 2005). Hurricane Katrina was responsible for approximately 1833 deaths, both directly or indirectly. Katrina also caused roughly $108 billion in damages and losses making it the costliest storms in U.S. history (Knabb et al 2005). Hurricane Sandy's death toll is estimated at 147, 87 of which indirectly related to Sandy (hypothermia, carbon monoxide poisoning, and cleanup effort accidents) (Blake et al 2013). The estimated damages and losses for Sandy were estimated to be around $50 billion, which is second in costliest storms behind Hurricane Katrina (Porter 2013). Naturally, coastal cities are extremely vulnerable when it comes to hurricanes, particularly in light of their high population densities. If a community is aware of its vulnerable locations, steps can be taken and policies can be put in place to help reduce the vulnerability and build resilience in the community.

Many people question if our current approach to coastal development is sustainable. Human perception of natural hazards impacts the way in which they interact with their environment. Human solution to controlling hazards is through technical engineering (Burton et al. 1964). By building highly engineered infrastructures, humans believe they will be less vulnerable in the face of a natural hazard. Natural hazard history has suggested otherwise.

Hazards managers address vulnerability and resilience through a process known as risk assessment. Through technological advances such as GIS, remote sensing, and radar, hazards mapping and risk assessment techniques have greatly improved (Montz et al 2003, 29). This process helps county and government officials to better plan for and prepare their community for hazard events. Because risk can vary temporally and spatially, risk assessments of particular locales are something that should be conducted continuously. This allows for mitigation efforts to stay current with the changing dynamics of a community.

Events such as Hurricane Katrina demonstrate why risk assessment and mitigation efforts are important key elements within a community. Hurricanes have proven to be deadly and costly storms that can devastate an area. From the early 1990's through 2007, hurricanes and tropical cyclones were responsible for 69% of losses due to hazards along the Atlantic Coast (Cutter et al. 2007). The hurricane coasts in the United States have seen an increase in vulnerability in recent decades. Factors contributing to this increase in vulnerability to natural hazards include an increase in population along the hurricane coast, high density coastal development, and aging infrastructure (Cutter et al. 2007).

The National Oceanic and Atmospheric Administration predicted a busy 2013 Atlantic hurricane season. They expected 13-20 named storms, 7-11 hurricanes, and 3-6 major hurricanes (National Oceanic and Atmospheric Administration 2014). The 2013 Atlantic hurricane season was active in the sense that it produced 14 storms, however, of those 14 storms only two made it to hurricane strength. This was the first Atlantic hurricane season since 1994 in which no hurricanes made it to the status of a major hurricane. The first named storm of the season, Tropical Storm Andrea, was the only storm that made landfall in the United States during the 2013 hurricane season (Blake 2014). The National Oceanic and Atmospheric Administration released their 2014 hurricane season predictions for the Atlantic Basin in late May 2014. They are predicting either a near-normal or below-normal hurricane season. The predictions are 8-13 named storms, 3-6 hurricanes, and 1-2 major hurricanes (National Oceanic and Atmospheric Administration 2014).

The future of hurricane activity and its impact on the United States is one of the many debated topics when it comes to climate change. In 2012, the Intergovernmental Panel on Climate Change (IPCC) released the Special Report for Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaption. This report stated that it was likely that tropical cyclone frequencies will remain the same or decrease in the coming years. However, they believe that the intensity (the mean maximum wind speed) of tropical cyclones will increase. This means more than likely most ocean basins will experience a higher frequency of intense tropical cyclones (Intergovernmental Panel on Climate Change 2012). Along with the increased intensity, it is suggested that the paths these hurricanes take will be more difficult to forecast (Knuston et al 2004). This could potentially lead to major hurricane impacts on areas that are not used to such events.

This thesis conducts a risk assessment for Chatham County, Georgia, which given its coastal location, is susceptible to tropical cyclone impacts. Muller et al (2001) conducted a study on tropical cyclone strikes on the United States. They found that some coastal areas, such as southeastern Louisiana, southern Florida, and eastern North Carolina, experience a higher frequency of tropical cyclones (14-17 in 100 years), while other coastal areas, such as the Sea Islands of Georgia, have a low frequency of tropical cyclones (1 in 100 years). Keim et al (2007) conducted a study on the spatiotemporal patterns and return periods of tropical cyclones in the United States from Texas to the Northeast. The time frame for this study was from 1901 through

2005. They found three distinct areas of high activity: Galveston, TX to Panama City Beach, FL; south Florida from Marco Island on the Gulf of Mexico coast to Vero Beach on the Atlantic coast; and the outer banks of North Carolina from Wrightsville Beach to Nags Head. Areas from Apalachicola, FL to Cedar Key FL on the Gulf coast and northern Florida through the coast of Georgia on the Atlantic coast experience few tropical cyclone landfalls. The Northeast experienced the lowest number of tropical cyclone landfall events. The return period was calculated for 45 coastal areas throughout the study area. The return period was calculated for Tybee Island in this study. The return period was 4 years for all tropical storms and hurricanes, 21 years for all hurricanes, and 105+ years for major hurricanes (category 3 and stronger). Therefore, it is important for government officials and policy makers to be aware of the vulnerability of the area to better prepare for a tropical cyclone event in the future. This could potentially reduce the amount of damage and loss of life in the event of a tropical cyclone impact. This study consists of a detailed analysis of historical hurricane activity, a storm surge assessment, an assessment of social vulnerability, and a building and structural vulnerability assessment for Chatham County. Storm surge maps along with social vulnerability maps and building and infrastructure maps were produced to highlight the areas of highest vulnerability within the county.

Applied geography research helps solve problems and the results are used to inform decision and policy makers (Torrieri et al 2003, 34). This study follows in the tradition of applied geography research in contributing to the development of methods for conducting risk assessment for hurricane hazards to produce meaningful results for hazards management purposes and development of public policy on future management and coastal development issues.

Research Questions

- What is the history of hurricane activity in Chatham County, GA?
- How would hurricane-induced storm surge impact Chatham County, GA?
- Where are the socially vulnerable populations located in Chatham County, GA?
- Where are the vulnerable buildings and infrastructure in Chatham County, GA?
- What is the overall hurricane vulnerability for Chatham County, GA?

Thesis Outline

This thesis explores the historical hurricane data in the Atlantic Basin surrounding Chatham County, GA. It also examines the factors and variables that contribute to the county's social and building and infrastructure vulnerability. Chapter 2 reviews literature on how natural hazards research has evolved through examining the vulnerability of an area and focusing on building resilience. Chapter 3 provides background information and details about the study area. This will provide details about Chatham County that provide insight into why this study area was chosen for this thesis research. Chapter 4 details the methods used to complete the historical hurricane, social vulnerability, and building and infrastructure assessments as well as how these assessments were combined to complete the hurricane risk assessment for the county. The methods detailed in this section can be used to conduct risk assessments for the county in the future. These methods can also be utilized to conduct natural hazards risk assessments for other coastal areas. Chapter 5 presents the results from the assessments that were completed. The historical hurricane assessment will provide details about the past hurricane activity in and around Chatham County. The social vulnerability assessment and building and infrastructure assessment will produce maps to display the vulnerability throughout the county. Chapter 6 summarizes the findings and results of this thesis. It also answers the research questions that were stated in the introduction to this thesis.

Chapter 2

Literature Review

Human Vulnerability and Hazards of Place

Gilbert White was one of the pioneers in hazards research in the field of geography. His approach to hazards research was based on the behavioral approach, which led to the development of the human ecological model (Paul 2011). This model focuses on the relationship that connects humans to their environment by recognizing, with respect to hazards research, that they do not exist independent from each other. As such, vulnerability must be researched from both physical and social perspectives.

Hazards of Place (HoP) was first introduced by Cutter and Solecki (1989) as a concept applied to the topic of airborne toxins. Cutter (1996) introduced the Hazards of Place (HoP) model (Fig. 1) to hazards research. The purpose of this model was to create a tool that could contribute to a better understanding of the different factors that play a role in the vulnerability of places. The model examines the factors that contribute to biophysical vulnerability and social vulnerability as well as the factors that contribute to biophysical/technological hazards to determine the overall vulnerability of a place. Once the place vulnerability is determined, it loops back to mitigation and risk. Depending on how place vulnerability is perceived, it can either increase mitigation efforts and reduce risk or increase risk and reduce mitigation efforts. The model can be used for a specific place to examine either a single hazard or multiple hazards. Cutter et al. (2000) completed an applied study using the hazards of place model for Georgetown

County, SC. The study applied the model to determine the overall vulnerability of the county based on social vulnerability as well as physical vulnerability.

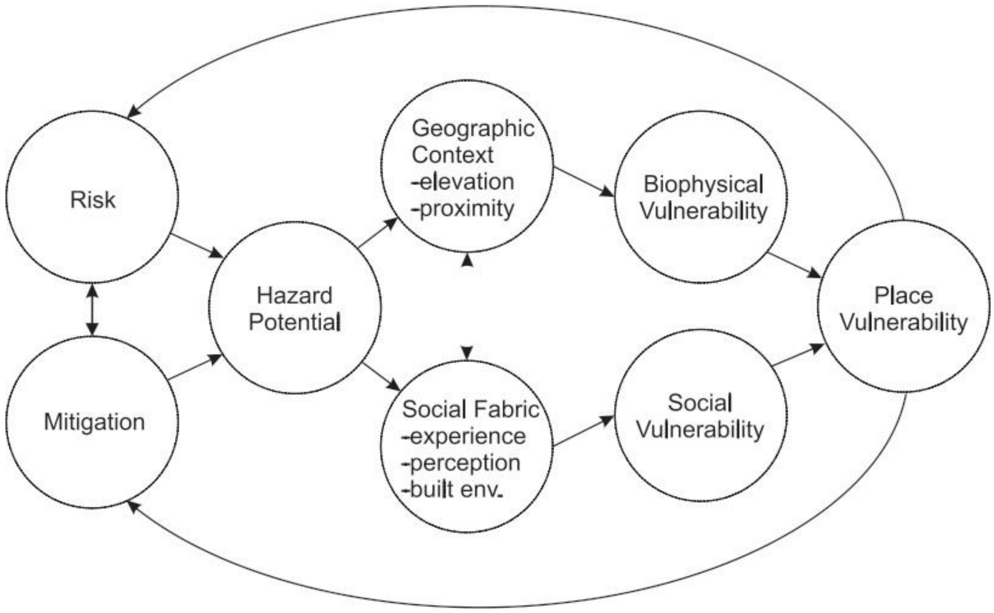


Figure 1. Hazards of Place Model (Cutter 1996).

Social Vulnerability

Social vulnerability is an essential part in any vulnerability assessment. According to Cutter et al. (2008a) social vulnerability is defined as "a measure of both sensitivity of a population to natural hazards and its ability to respond to and recover from the impacts of hazards (pg. 2301)." Social vulnerability highlights a community's vulnerability as well as its resilience. A social vulnerability index (SoVI) is an index used to classify areas of high vulnerability as well as areas of low vulnerability based on a chosen set of variables. Cutter et al. (2003) constructed a social vulnerability index map for the United States at a county level. They utilized county-level demographic and socio-economic data to complete the SoVI for each county in the United States. Originally, there were over 250 variables collected for this project, but eventually it was reduced to 11 factors through a principal component analysis. The 11 factors that were included in the final SoVI production were personal wealth; age; density of the built environment; single-sector economic dependence; housing stock and tenancy; race; ethnicity; occupation; and infrastructure dependence (Cutter 2003).

Personal wealth, age, race, ethnicity, and occupation are all factors that are assessed on an individual level. Hypothetically, a poor person who is elderly and of a minority race and/or ethnicity will be highly vulnerable in a natural hazard when compared to a rich, American male who has a full-time salaried job. The later mentioned person is more likely to be of good health and have access to more resources, such as money, technology, and transportation, which would greatly reduce their vulnerability, whereas the former might be fragile and have health issues, have very little money and might not have the luxury of a television or smart phone to connect them with current events. Also, they might not have a vehicle and would have to rely on public transportation (if available) or family and friends for their transportation needs, making evacuating a difficult task. These factors would greatly increase their vulnerability. The authors concluded that the use of hazard event frequency data with economic loss data can aid in examining the individual factors that contribute most to dollar losses in a hazard event. This method could be utilized for assessing an individual hazard, such as a hurricane, or multiple hazards (Cutter et al 2003).

Morrow (1999) recommends mapping vulnerability at the community level by use of four factors that contribute to vulnerability within a community: economic and material resources; human and personal resources; family and social resources; and political resources. Economic and material resources focus heavily on poor or poverty stricken households. Poor households might not have the adequate funds to purchase the necessary materials to prepare for a natural hazard event prior to a natural hazard event as well as materials in the aftermath of the natural hazard event. The impacts could result in a higher death toll (Blaikie et al 1994) as well as more significant damage to the house (Cochrane 1975). The lack of funds and materials typically cause poor households to recover at a much slower rate that those with higher incomes (Bolin 1986, 1993; Bolin et al 1986). Moreover, they also tend to dwell in poorly built houses or mobile homes and the location of the dwellings are usually located in areas more prone to destruction in a hazard event, such as a floodplain. The poor usually have limited access to transportation, which can cause a delay in evacuation or cause individuals to not evacuate at all, which increases the potential for loss of life (Morrow 1997).

Human and personal resources include health and physical ability, relevant experience, education, time, and skills (Morrow 1999). For example, children, elderly, and people living with a physical or mental limitation are extremely vulnerable due to the fact they are usually dependent upon someone else, usually a healthy stable adult or a care-giving facility. Single-parent families and large families are also often extremely vulnerable usually due to financial limitations (Morrow 1999).

Family and social resources focuses on family and social networking. Family and social networks can play a significant role in how well an individuals or group of individual’s respond to a natural hazard by offering financial, housing, and emotional support in times of stress (Morrow 1997). Tourists and transients, for example, are highly vulnerable to natural hazards. Furthermore, many tourist destinations are located in highly vulnerable areas, such as coastal areas. Tourists may not have sufficient time to leave the area before a natural hazard event (Drabek 1996).

The fourth factor, political resources, focuses on how the control an individual has over their own situation can affect their vulnerability. For example, renters do not have much control over the building in which they live. If the landlord does not prepare that building for a hurricane, then the tenants are highly vulnerable (Morrow 1999).

Morrow (1999) also includes a list of categories that should be included when assessing at-risk groups in a community. The categories include: residents of group living facilities; elderly, particularly frail elderly; physically or mentally disabled; renters; poor households; women-headed households; ethnic minorities (by language); recent residents, immigrants, migrants; large households; large concentrations of children/youth; the homeless; and tourists and transients (Morrow 1999).

Resilience

Vulnerability and resilience are related concepts with an understanding that when a community enhances its resilience, it reduces its vulnerability. Furthermore, Cutter (2008b) notes that hazards managers prefer to use the terms "enhancing resilience" over "reducing vulnerability" because it communicates a more positive message. In follow-up research to her work on Hazards of Place (HoP) and social vulnerability, Cutter et al. (2008b) developed a Disaster Resilience of Place (DROP) model to obtain a better understanding of community resilience to natural hazards at the community level (Fig. 2). The model starts with the antecedent conditions, which are the interaction between social systems, natural systems, and the built environment systems. The antecedent conditions interact with the event characteristics (frequency, duration, intensity, magnitude, and rate of onset) resulting in the immediate effects. The immediate effects are followed by coping responses, which are how a community reacts to the immediate effects (evacuation plans, shelters, emergency warning dissemination, and emergency response plans). The hazard or disaster impact is a result of the antecedent conditions, event characteristics, and coping responses. This model assesses how much of an impact the community can absorb in the face of a natural disaster. If the community absorbs the impacts of the hazard and the capacity is not exceeded, then that community will be able to sufficiently recover. If the capacity is exceeded however, a community may have a difficult time recovering and, depending on the magnitude of the event, a community might not be able to recover at all (Cutter et al. 2008b).

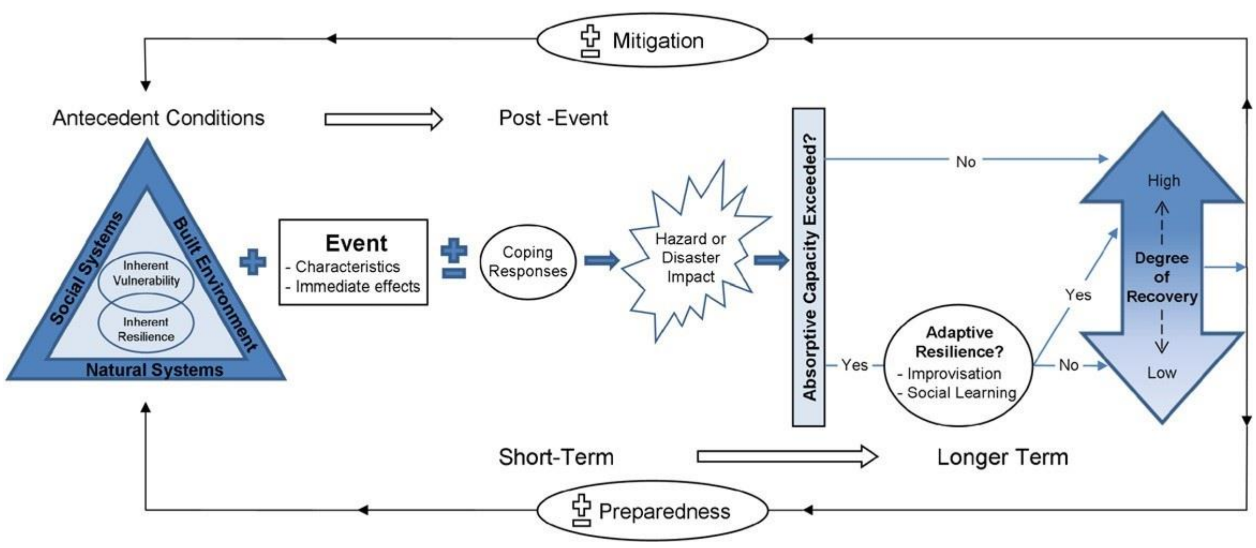


Figure 2. Disaster Resilience of Place Model (Cutter 2008).

There has been debate on whether coastal megacities are more resilient when faced with a natural hazard than smaller coastal towns and communities. According to Klein et al. (2004), there is no substantial evidence indicating that coastal megacities are more resilient than smaller coastal towns and communities. Handmer (1995) and Parker (1995) both argue that coastal megacities possess certain features and resources that smaller settlements don't have which allow them to deal with hazards better. This argument suggests that coastal megacities are more resilient. Cross (2001) also agrees that coastal megacities are more resilient than small settlements. He discusses how the long-term impacts on small settlements are much greater than that of coastal megacities.

Risk Assessment

Natural hazards risk assessments are essential in community planning, particularly along the hurricane coast. Risk assessments highlight areas of vulnerability within a given study area relating to a particular natural hazard. If areas of vulnerability are known, local government and Emergency Management Agency (EMA) officials can take action to better prepare a community for a natural hazards event.

According to Paul (2011), the two pertinent components in a risk assessment related to natural hazards are "a probability statement of an extreme event and its potential for consequences or magnitude of the potential loss" (Paul 2011, 103). What this means is that to conduct a risk assessment there are three steps that need to be completed. The first step is to identify the type of hazard that needs to be assessed. The second step is to calculate the probability of occurrence of the hazard. This can be derived from the frequency of the event over the number of years in the record. The third step is to estimate the losses in a unit that can be analyzed. This could include dollars in damage, fatalities, injuries, illness, loss of assets, and loss of income (Paul 2011).

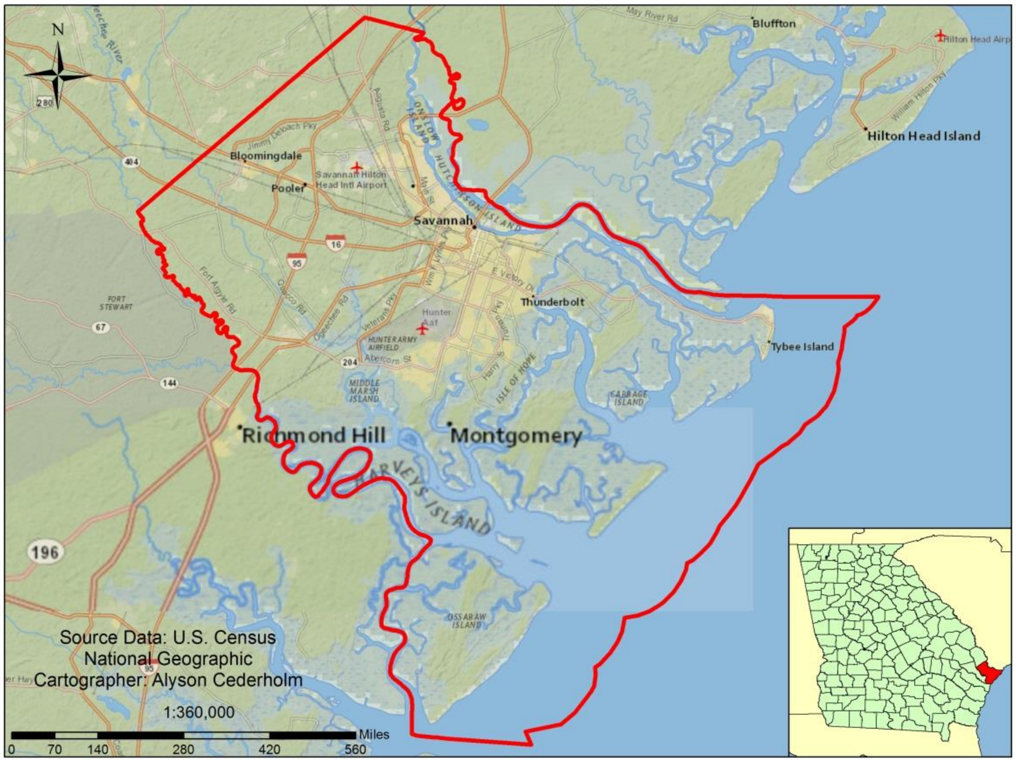
The variables used to assess vulnerability vary throughout hazards research. The scale of the study (local to global) plays a major role in which factors need to be assessed for a vulnerability study. This study will be assessing vulnerability at the county level; therefore the variables used will be specific to this location.

Chapter 3

Study Area

The study area for this project is Chatham County, Georgia, (Fig 3) which is located along the Atlantic Coast. The counties total area is approximately 632 square miles with total land area of about 426 square miles and water area of about 206 square miles. It is home to many popular tourist destinations such as Savannah and Tybee Island. Chatham County is the most populous county in the state of Georgia outside of the Atlanta metro area (US Census 2010). The last United States Census was conducted in 2010 and Chatham County had a population of 265,128. The estimated 2013 population for the county is 278,434 (US Census 2014). Furthermore, the county is experiencing tremendous growth with an increase of 14.3 percent since the 2000 census.

The Weather Channel (TWC) has produced lists in recent years naming the top hurricane vulnerable and overdue cities in the United States. Such lists were produced in 2010, 2011, and 2013 with Savannah, GA making the list each year (Table 1). The 2010 list included 5 cities and ranked Savannah, GA as the fourth most overdue city for a hurricane (Knabb 2010). The 2011 list also included 5 cities and once again ranked Savannah, GA as the fourth most overdue city for a hurricane (Knabb 2011). The 2013 list included 10 cities and Savannah, GA was ranked as the sixth most overdue city for a hurricane.



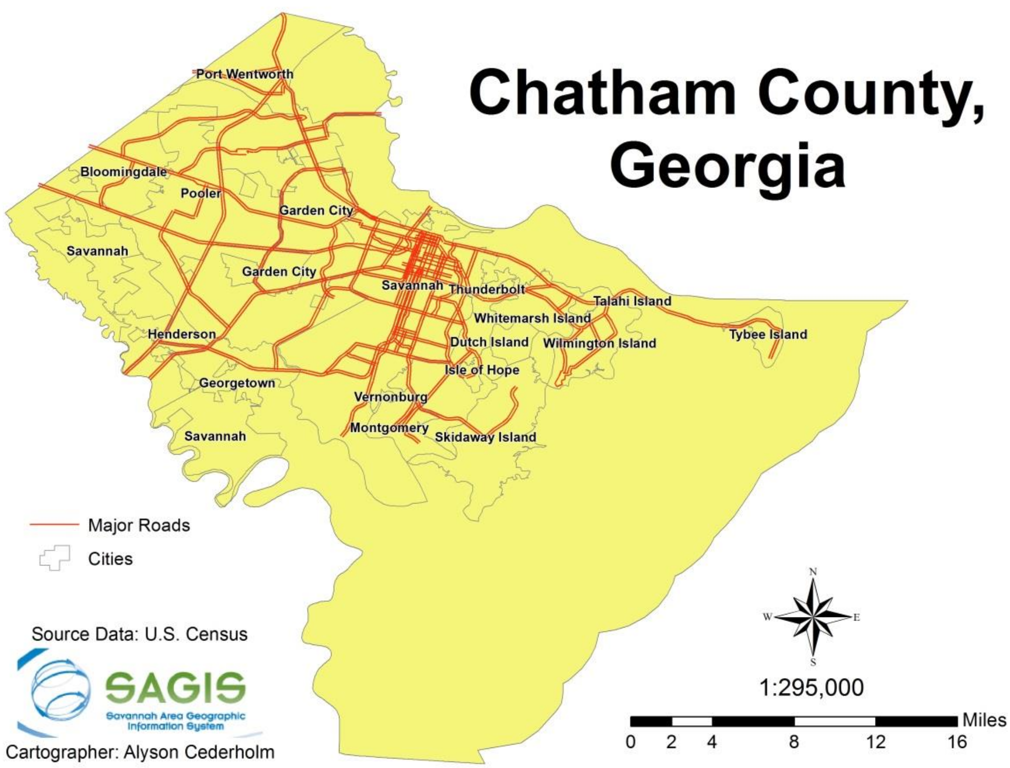


Figure 3. Study area maps showing Chatham County, Georgia.

Table 1. TWC Top Hurricane Vulnerable and Overdue Cities

Rank	2010	2011	2013
1	Miami/Ft. Lauderdale, FL	Honolulu, HI	Tampa, FL
2	New York City, NY	San Diego, CA	Naples, FL
3	Tampa Bay, FL	New York City, NY	Jacksonville, FL
4	Savannah, GA	Savannah, GA	Honolulu, HI
5	Atlantic City, NJ	Tampa Bay, FL	Houston, TX
6	N/A	N/A	Savannah, GA
7	N/A	N/A	Mobile, AL
8	N/A	N/A	Charleston, SC
9	N/A	N/A	Key West, FL
10	N/A	N/A	Providence, RI

Given its relative location, Chatham County is clearly vulnerable to hurricane and storm surge events. To help the county prepare for such events, it is essential to perform a hurricane risk assessment. The last available risk assessment for Chatham County was produced in 2005. The need for an updated risk assessment for Chatham County is essential, especially given the fact that the area has not been affected by a hurricane in over 30 years.

From 1850 to the present there have been 6 major hurricanes that have made landfall along the Atlantic Coast of Chatham County: September 1854, August 1881, August1893, August 1898, October 1947, and Hurricane David 1979. Hurricane David made landfall as a Category 1 hurricane but the impacts to the area were not very significant. The storm surge along the coast did not exceed 5 feet and maximum wind speeds were no stronger than tropical storm force winds (39-73 mph). Hurricane David passed directly over the city of Savannah. The tide gate at the Corps of Engineers' yard recorded a maximum tide level of 6.44 feet relative to the North American Vertical Datum (NAVDD88), which was about 2.6 feet above average tide level). For the hurricanes prior to Hurricane David, there is no official storm tide data available for these storms. However, estimates of the storm tide for these earlier hurricanes can be made from observations by local residents at the time (Chatham County Emergency Operation Plan Incident Annex A, Appendix 5 Historic Storm Tide Elevations 2009. Since then, The U.S. Army Corps of Engineers has utilized the Sea, Lake, and Overland Surges for Hurricanes (SLOSH) model to calculate the peak storm surge levels for category 1 through 5 hurricanes for various locations throughout Chatham County. This allowed for a more accurate assessment of the possible storm surge that occurred during past hurricanes (Chatham County Emergency Operation Plan Incident Annex A, Appendix 5 Historic Storm Tide Elevations 2009).

In addition to physical hazards of storm surge, Chatham County Emergency Management Agency (EMA) produced a report detailing technological and natural hazards in the county in 2005 (Chatham County Pre-Disaster Mitigation Plan 2005). The second chapter of the report highlights natural hazards in the county and a summary of the associated risk and vulnerability. The risk assessment for hurricanes simply states that the county is susceptible to Category 5 hurricanes and the impact could be felt countywide. Chatham County has only experienced five hurricanes since 1979, however, none of them made landfall in Chatham County. In 2005 the probability of experiencing a hurricane of any category between 1 June and 30 November was only 5 percent. For a category 5 hurricane in 2003, the projected number of people that could have been effected was 230,730 (99 percent of the population) and 447 structures/buildings (89 percent of buildings/structures) could have been affected and the estimated potential dollar loss (EPDL) would have been $56.235 billion (Chatham County Pre-Disaster Mitigation Plan 2005).

The same risk assessment was also conducted by the Chatham County EMA for storm surge. It is important to note that there was no storm surge record for Chatham County. While Chatham County is susceptible to category 5 hurricanes, the SLOSH model data in this risk assessment only covers hurricanes through a category 3 ranking. To assess storm surge damage the National Hurricane Center's SLOSH model was utilized by the U.S. Army Corps of Engineers. In 2005, the probability of experiencing a category 5 hurricane was 5 percent; therefore, the probability of experiencing category 5 hurricane storm surge was also 5 percent. The SLOSH model projected that 76 percent of the population would have been affected and 57 percent of its buildings/structures would have been affected and the estimated potential dollar loss (EPDL) would have been $26.9 billion ("Chatham County Pre-Disaster Mitigation Plan" 2005).

In December of 2012, the Chatham County Department of Engineering released a flood mitigation plan document. This document included a risk assessment section which was comprised of four subsections: Hazard Assessment, Problem Assessment, Floodplain Natural Functions and Management, and Impact of Population Trends and New Development. The hazard assessment identifies the major flood hazards for the area as rainwater flooding, coastal storms, storm surge, sea-level rise, and coastal erosion. The report states that 61 percent of the county's floodplain is marshland/tidal areas with residential, commercial, and limited industrial development. Coastal storms (nor'easters, tropical depressions, tropical storms, and hurricanes) have had the most significant impact on the county with a total of 91 coastal storms since 1853. Rainwater flooding has the second highest impact on the area. There were three significant rainwater events between 1994 and 1999 that produced 536 NFIP claims with $2,950,890.64 paid out. As of 2012 there were approximately 16,456 structures in special flood hazard areas, with 15,353 of those structures being houses and 1,025 institutional, industrial, and commercial structures. Since 1978 there have been 702 NFIP claims for repetitive loss properties with payouts totaling $3,433,955.92. There are 44 repetitive loss properties in the county, and as of 2012 six of the properties were mitigated through either relation or acquisition/demolition. The report assessed the impact storm surge would have on the county using SLOSH model data. The data indicated that 73 percent of the county's population and 66 percent of its critical structures/buildings would be affected by storm surge. The flood problem assessment states that the flood problems in the county are caused by low elevations and flat slopes as well as the interaction of these geographic features with the fluctuating tides. The impact of population trends and new development predicts that most of the population growth in the next 25 years will occur in the western portion of the county. They expect the average household size to be approximately 2.38 by the year 2030 ("Flood Mitigation Plan Unicorporated Chatham County" December 2012).

There are several reasons why a new risk assessment for Chatham County needs to be conducted. The previous risk assessments that have been conducted for Chatham County only take the hurricane SLOSH model and tide level data into account. There were no social vulnerability or resilience assessments incorporated into the previous risk assessments. As previously stated, there has been a 14.3% increase in the population since 2000. This increase in population brings about the potential for a higher level of vulnerability in the area. The last risk assessment was conducted in 2012 by the Chatham County Department of Engineering. Vulnerability and resilience are factors that change constantly, so risk assessments should be conducted on a regular basis.

Chapter 4

Methods

A risk assessment was conducted to identify the areas of highest vulnerability in a hurricane and storm surge event in Chatham County, GA. The risk assessment includes a historical hurricane assessment, a storm surge assessment, a social vulnerability assessment, and an infrastructure and building vulnerability assessment. The four separate assessments were combined using a Geographic Information System (GIS) to produce an overall hurricane vulnerability map for the county (Fig 4). GIS is an integral tool in this assessment. The GIS allows for social data and geographic data to be combined to better understand natural hazards as both physical and social processes (Morrow 1999).

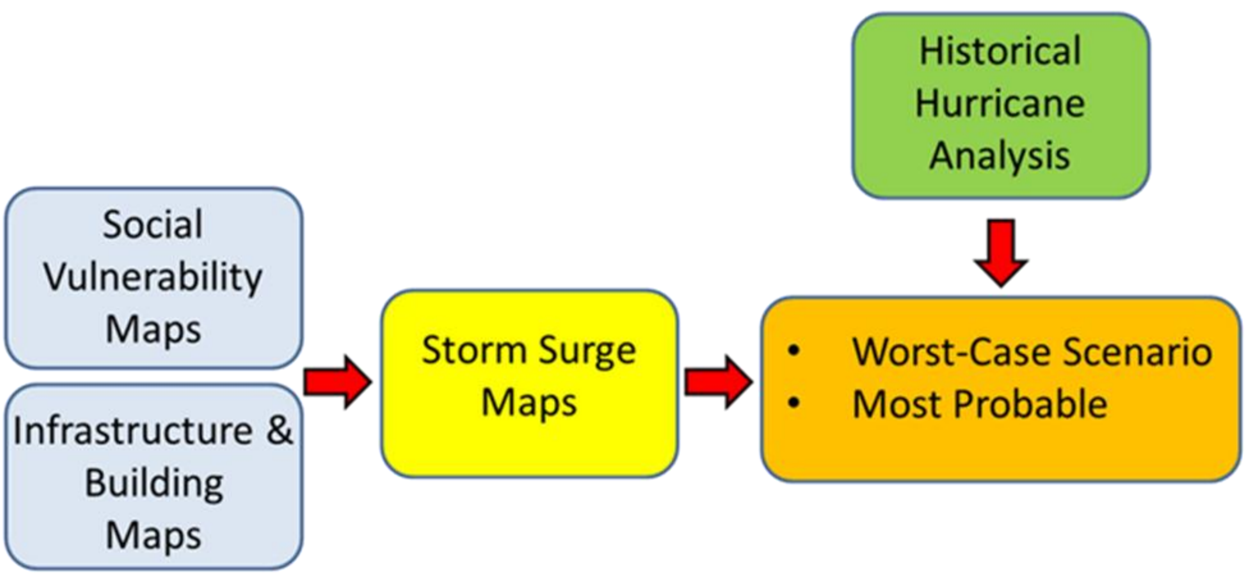


Figure 4. Flow Chart of Methods

Historical Hurricane Assessment

A historical hurricane assessment was performed using data from 1855 to 2012 obtained from the National Hurricane Center (NHC). A GIS layer of hurricane tracks was used to identify hurricanes that made landfall along the U.S. Atlantic Coast in the vicinity of the study area. Storm surge impacts can extend from low-lying coastal areas to several miles inland effecting the large populations that reside in coastal areas (Keim et al. 2004). The dimensions of the tropical storm and hurricane model developed by Keim et al. (2004 and 2007) was used for this task, which accounted for the counter-clockwise rotation of the tropical cyclone producing higher waves and storm surge on the right-hand side of the storm track as it makes landfall (Fig. 5, 6). For example, if a storm is moving north with a storm speed of 30 knots and sustained winds of 100 knots, the winds will be stronger on the right hand side of the storm relative to the storm motion and weaker on the left hand side of the storm relative to the storm motion. The counter-clockwise rotation of the storm and the storm motion work together on the right hand side of the storm which results in a wind speed of 130 knots (wind speed + storm speed). The opposite occurs on the left hand side of the storm. The counter-clockwise rotation and storm direction are working against each other; therefore the winds would be 70 knots (wind speed – storm speed). Based on the Keim et al. (2004 and 2007) model, this part of the analysis includes all hurricanes that made landfall approximately 150 miles south of the county to 100 miles north of the county.

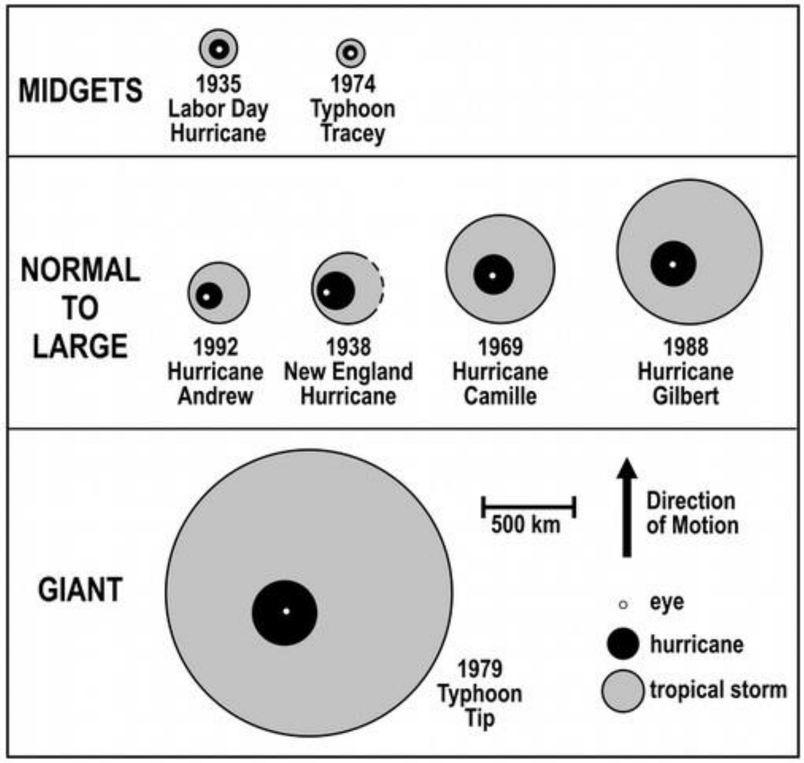


Figure 5. Range of hurricane sizes (Keim et al 2007)

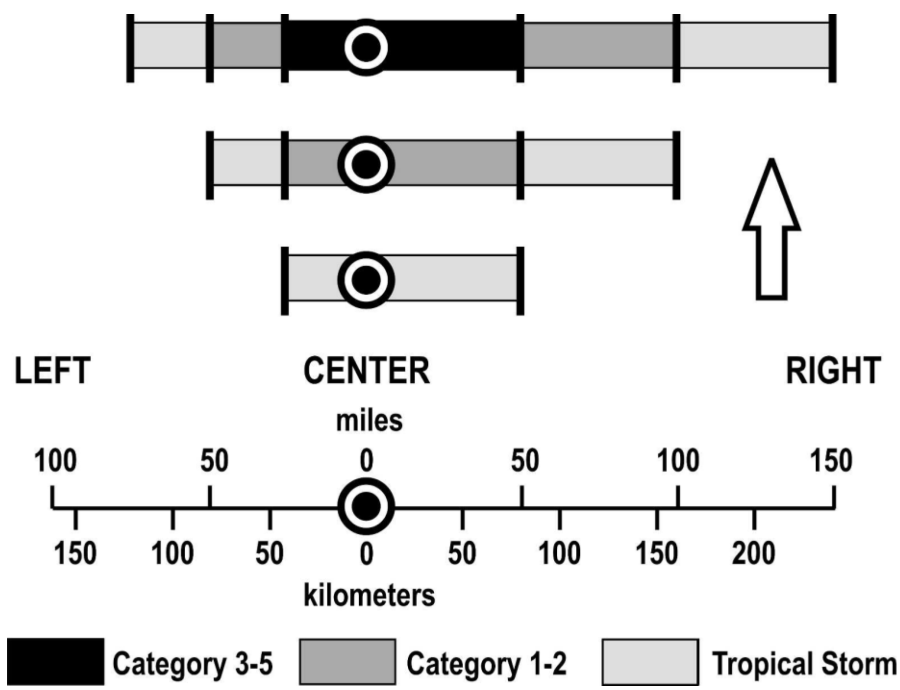


Figure 6. Model of tropical cyclone storm surge distribution (Keim et al 2007)

The hurricane track layer contained data for all hurricane basins, so the select by attribute tool was utilized to select all hurricanes in the Atlantic Basin. The selected hurricane tracks were then exported and displayed using GIS. A line shapefile extending from 100 miles north of the county to 150 miles south of the county was created to aid in the identification of hurricane tracks within the given landfall parameters. The select by location tool was utilized to highlight all hurricanes that made landfall within the given parameters. Each hurricane track that intersected the line was selected and then exported. The hurricane track data was displayed in line segments, so only the segment of the hurricane track that intersected the line was exported. The attribute table was used to determine the names of each storm that made landfall within the given parameters and the remaining segments for each hurricane track were selected from the attribute table of the Atlantic Basin layer and exported to allow for the full hurricane tracks to be displayed. For the purpose of this study, storms that were tropical depressions at the time of landfall were not included in the historical hurricane assessment; therefore all landfalling tropical depressions and their tracks were removed from the study area hurricane layer. All hurricane tracks that were exported were verified using the historical hurricane data provided by Unisys Weather (www.weather.unisys.com). The attribute table did not categorize each segment by category, but wind speeds were given. The table was exported and displayed in a worksheet. Based on the given windspeed (m/s) each segment was assigned a tropical cyclone category ranging from tropical storm to category 5 hurricane. The table was then added to the GIS software and joined with the study area hurricane layer. This allowed the hurricane tracks to be displayed showing their intensity throughout the duration of the storm. The study area hurricane layer produced pertinent data for the historical hurricane assessment as well as the hurricane risk assessment. Tables were created that showed number of landfalls for each category, number of landfalls north and south of the county, and the number of landfalls for each month.

Analyzing past hurricanes that have impacted Chatham County allowed for the calculation of the annual frequency of hurricanes. The annual frequency is the average number of events over a given time period, therefore it allowed for a deeper understanding of how often Chatham County is impacted by hurricanes. The annual frequency was calculated using the following equation: Annual Frequency = number of tropical cyclones / number of years in record. The annual frequency was calculated for the overall total of storms as well as for each category of hurricane on the Saffir-Simpson scale (Table 2). The return period for tropical cyclones was also calculated for the study area. The return period is an average of how many years are between tropical cyclone landfalls. The return period was calculated using the following equation: Return Period = number of years in record / number of tropical cyclones. Tables were created to display the overall and individual annual hurricane frequencies and return periods for the county. The annual frequency and return period contributed data used to determine the most probable case scenario and the worst case scenario. The most probable case scenario is the category of tropical cyclone that is most likely to occur in Chatham County based on past events. The worst case scenario is the worst possible category of tropical cyclone that could occur in Chatham County.

Table 2. Saffir-Simpson Hurricane Damage Potential Scale (NHC 2012).

Category	Wind Speed (mph)
1	74-95
2	96-110
3	111-129
4	130-156
5	157 or higher

Storm Surge Assessment

The hurricane assessment includes Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model data to assess the potential for storm surge impacts. The SLOSH model data was downloaded from the Savannah Area Geographic Information Systems database in GIS format. The details for the storm surge data are as follows:

> This storm surge zones layer was created as part of the Comprehensive Hurricane Preparedness Study (CHPS) project by the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center (CSC) and the Chatham County (GA) Emergency Management Agency (CEMA). This layer represents the potential storm surge inundation from worst-case scenario categories 1 through 5 hurricanes. The data used to develop this layer were the SLOSH (Sea, Lake, and Overland Surges from Hurricanes, NOAA National Weather Service) Model Categories 1 through 5 Maximum of Maximums (MOM) layers and a 15 ft resolution digital elevation model provided by SAGIS (Savannah Area GIS). A Storm Surge ReMapping Model (ArcGIS 9.1 Model Builder) developed by CSC was used to create this layer and is a methodology taken from the University of Georgia (UGA), Information Technology Outreach Services. This methodology was used by UGA to map Chatham County's previous surge zones using 30m elevation data.

The worst case scenario mentioned in the description above is what the National Oceanic and Atmospheric Administration has determined as worst case possible called the Maximum Envelope of Water (MEOW). The worst case scenario for each category is a compilation of several factors. The highest possible winds for each category are put in the model. It also takes into account the tides are highest tide as well as the lunar cycle. The semi-diurnal mean tidal range at the Fort Pulaski, GA observation station is 6.92 feet (2.11 meters) (NOAA 2013). The Fort Pulaski observation station is located at the mouth of the Savannah River in Chatham County.

The SLOSH model data displays the potential storm surge impact for each category of hurricane. This data was displayed using GIS to identify the areas of highest vulnerability for each hurricane category. Several maps were created to show the potential storm surge impact for each hurricane category. Once the maps were created, a detailed summary pertaining to the impacts of storm surge was provided. This summary includes details about the worst-case scenario and the most probable scenario for the county.

The storm surge layers were also utilized in the social vulnerability assessment and the building and infrastructure assessment. The storm surge layers were displayed over the socially vulnerable populations as well as the vulnerable buildings and infrastructure to further assess the vulnerability of those variables. Several maps were created to show the storm surge impacts for each storm surge category for each of the variables.

Social Vulnerability Assessment

The social vulnerability assessment highlights areas where there is a high concentration of vulnerable populations within the county. Census block data from the 2010 decennial census and data from the American Community Survey (ACS) produced by the United States Census bureau as well as data from Savanah Area GIS were utilized to identify vulnerable populations and their locations.

The vulnerable populations that were assessed include women-headed households; large concentrations of children/youth; elderly; and renters (Morrow 1999). The census data for each variable was displayed in a worksheet and a normalized vulnerability index was calculated for each variable (Cutter et al 2000). To obtain the normalized vulnerability index for each variable mentioned above, the following equation was used:

$$\text{(Block Value)} \div \text{(County Value)} = a;\ a \div \text{Max } a = \text{Index Value}$$

The block value is the value for each individual block. The county value is determined by adding all of the block values together. Dividing the block value by the county value produces an average value. To get the index value, the average value is divided by the maximum value from the averaged values. The vulnerability index value for each variable range from zero to one, with zero being areas of low vulnerability and one being areas of high vulnerability. No weight was assigned to the individual characteristics; it is assumed that each characteristic has an equal contribution to the overall social vulnerability of the county (Cutter et al 2003). The individual variables were combined to determine the overall vulnerability of the county. This allowed for the identification of the areas of highest overall vulnerability as well as areas of lowest overall vulnerability. A storm surge assessment was conducted to determine how many vulnerable blocks for each variable were in each storm surge zone. The storm surge layer was displayed over each variable index layer and the select by location tool was utilized to determine that number of blocks in each storm surge. The data was extracted and displayed in a table. Maps were created for each individual variable to show the distribution of the vulnerable areas. Maps showing the storm surge impact on each variable were also created.

A storm surge assessment for each variable was also conducted. The storm surge layer for each storm surge category was displayed over each of the socially vulnerable variables. The select by location tool was utilized to highlight the total number of people for each variable that fell within each storm surge category. This allowed for the extraction of the total number of people impacted for each variable in each storm surge category. The same process was also completed for the total population of the county. The data was recorded and displayed in a table to show the total number of people impacted for each storm surge category. Maps were also created to display the storm surge impact for each storm surge category on each variable.

There are only four socially vulnerable variables assessed in this research. The social vulnerability assessment demonstrates the methods used and steps taken to conduct a social vulnerability assessment. To conduct a more in depth social vulnerability assessment more variables, such a race and income, should be assessed. The variables that are assessed will be different from place to place due to factors such as social structure, the infrastructure, and economic status of the area. Certain variables might be considered more vulnerable in one location that wouldn't be considered vulnerable in another location.

Building and Infrastructure Assessment

The building and infrastructure vulnerability assessment highlights the areas where the most vulnerable infrastructure and buildings are concentrated throughout the county. The data for this assessment was obtained from the United States Census Bureau and the Savannah Area Geographic Information Systems. The data arrived in GIS format. The infrastructures that are represented include buildings, roads, and telecommunication towers.

The buildings were displayed to show their location and density within the county. The layer for each storm surge category was displayed over the buildings layer. The select by location tool was utilized to highlight the buildings within each storm surge category and the selected buildings were then exported as a layer. This allowed for the total number of buildings within each storm surge category to be determined. Once the data was exported, maps were created to display the vulnerable buildings for each storm surge category. This data was displayed in a table to show the total number of buildings impacted in each storm surge category.

Roads were displayed to show their location and connectivity within the county. The layer for each storm surge category was displayed over the roads layer. The select by location tool was used to highlight the roads within each storm surge category and the selected roads were then exported as a layer. This allowed for the identification of all vulnerable roads within each storm surge category. Maps were created to display the vulnerable roads within each storm surge category. The total mileage of roads impacted by the storm surge for each category was calculated and displayed in a table.

The telecommunication tower layer was displayed to show the location of each tower throughout the county. The layer for each storm surge category was displayed over the telecommunications tower layer. The select by location tool was used to highlight the telecommunication towers within each storm surge category and the selected telecommunication towers were then exported as a layer. This allowed for the identification of all vulnerable telecommunication towers within each storm surge category. Once the data was exported, maps were created to display the vulnerable telecommunication towers for each storm surge category. The data was then displayed in a table to show the total number of telecommunication towers in each storm surge category.

A zoning layer was displayed to show the distribution of the land use throughout the county. The zones were broken up into several sub-categories, so the attribute table was exported and the zones were reclassified into five different categories: Business/Commercial, Government/Institutional, Industrial, Other, and Residential. The table was added back to the GIS and joined to the original zoning layer. The zoning map allowed for the identification of building types throughout the county. The zoning layer was used to calculate the total number of buildings within each zoning category. The storm surge layer for each category was displayed over the zoning map to identify the number of buildings impacted within each zoning category as well as the total area impacted for each zoning category. Maps were created to display the vulnerable buildings for each zoning category for each storm surge category as well as the storm surge area impact for each zoning category. A table was also created to display the total number of buildings impacted within each zoning category for each storm surge category as well as the total area impacted for each zoning category.

Hurricane Risk Assessment

To obtain the overall hurricane risk assessment, the data gathered from the historical hurricane assessment, the storm surge assessment, the social vulnerability assessment, and the building and infrastructure assessment were combined and analyzed. The combination of the social vulnerability and building and infrastructure assessments provided the overall vulnerability of the county. The overall vulnerability of the county combined with the storm surge assessment showed how the vulnerable variables would be impacted by each category of storm surge in a tropical cyclone event. The combination of all this data aided in determining the most probable scenario and worst-case scenario for the county (Fig 6). With the areas of high vulnerability identified as well as the most probable scenario and worst-case scenario determined, mitigation efforts can be implemented to reduce vulnerability in the identified areas, which could in turn enhance the resilience of the county.

Chapter 5

Results

Historical Hurricane Assessment

A historical hurricane assessment provides crucial information about how an area has been impacted by tropical cyclones in the past. The data collected from such assessment can provide information that can be used to gain insight into details such as worst case scenario, most probable scenario, storm frequency, peak month of activity, and landfall distribution The results for the historical hurricane assessment were derived from the National Hurricane Center dataset.

Between 1851 and 2012 there were 48 tropical cyclones that made landfall within the set parameters (Fig 7, 8) (Table 3). The storms ranged in strength from tropical depressions to category 4 hurricanes (Table 4). Due to their minimal impact on the study area, tropical depressions were not included in the historical hurricane assessment. Tropical storms had the highest frequency of landfall events with 22 landfalls. As the tropical cyclone strength increased, the frequency of landfall events decreased. The majority of the tropical cyclones that made landfall within the set parameters originated in the Atlantic Ocean. There were 37 tropical cyclones that originated in the Atlantic Ocean and 9 tropical cyclones that originated in the Gulf of Mexico.

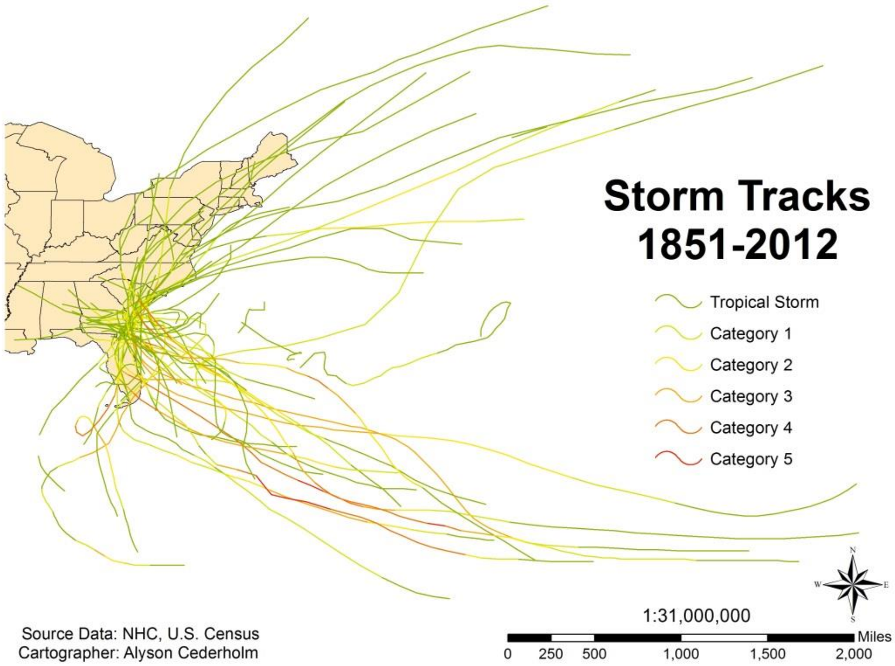


Figure 7. Tropical Cyclone Storm Tracks 1851-2012 for Chatham County

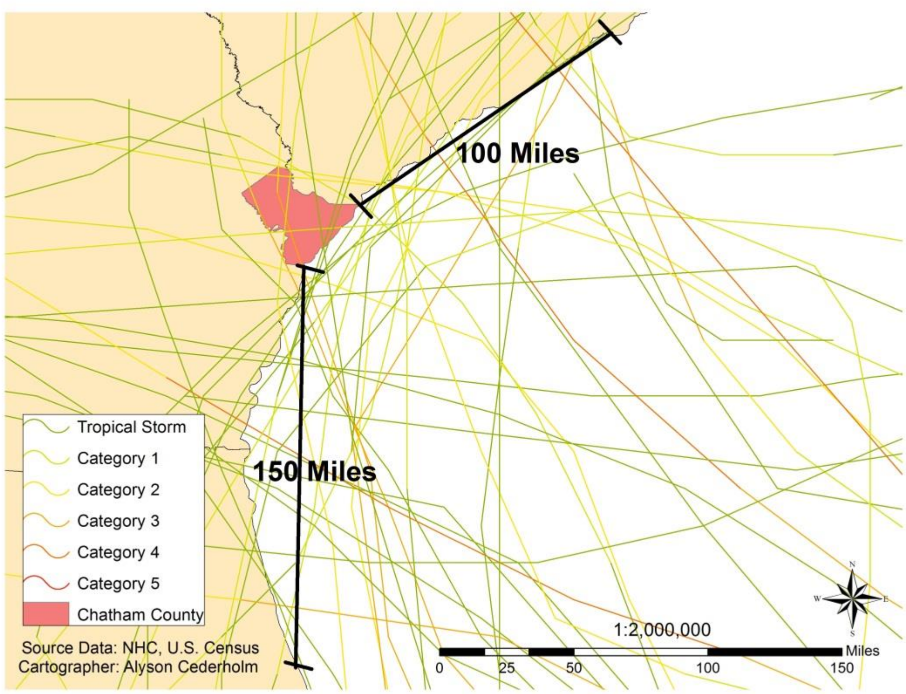


Figure 8. Tropical Cyclone Landfalls in Study Area

Table 3. Study Area Tropical Cyclone Landfalls (1851-2012)

Year	Landfall Intensity	Peak Intensity	Month (Landfall)	Location	Origin
1854	3	3	9	S	ATL
1867	1	1	6	N	ATL
1871	TS	3	8	S	ATL
1873	TS	TS	6	S	ATL
1874	1	1	9	N	GOM
1878	1	2	9	N	ATL
1881	2	2	8	S	ATL
1884	TS	1	9	S	ATL
1885	2	2	8	N	ATL
1893	3	2	8	N	ATL
1893	3	3	10	S	ATL
1894	1	3	9	N	ATL
1898	1	1	8	Direct	ATL
1898	4	4	10	S	ATL
1906	TS	3	10	S	GOM
1910	TS	4	10	N	GOM
1911	2	2	8	N	ATL
1912	TS	TS	7	S	ATL
1914	TS	TS	9	S	ATL
1916	TS	TS	5	N	ATL
1916	TS	TS	10	S	ATL
1916	2	3	7	N	GOM
1919	TS	TS	10	S	ATL
1927	TS	TS	10	N	ATL
1928	1	5	9	N	ATL
1940	2	2	8	N	ATL
1945	TS	4	9	Direct	ATL
1947	1	1	10	Direct	ATL
1947	TS	TS	10	S	GOM
1952	2	2	8	N	ATL
1959	1	1	7	N	ATL
1959	4	4	9	N	ATL
1964	3	4	9	S	ATL
1968	TS	1	6	S	GOM
1972	TS	TS	5	S	ATL
1976	TS	TS	8	Direct	GOM
1976	TS	TS	9	N	GOM
1979	2	5	9	S	ATL
1985	TS	TS	10	S	ATL
1985	1	1	7	N	GOM
1988	TS	TS	8	Direct	ATL
1989	4	4	9	N	ATL
2002	TS	1	10	N	ATL
2004	1	1	8	N	ATL
2005	TS	TS	10	S	ATL
2012	TS	TS	5	S	ATL

Table 4. Landfall Events by Category, Annual Frequency, and Return Period for 1851-2012

	Number of events (landfalls)	Annual Frequency	Return Period (Years)
Total	46	0.29	4
Tropical Storm	22	0.137	7
Category 1	10	0.062	16
Category 2	7	0.043	23
Category 3	4	0.025	40
Category 4	3	0.019	54
Category 5	0	0	161+

The data collected from the historical hurricane assessment was used to calculate the annual frequency for all tropical cyclones as well as for each category of tropical cyclone (Table 4). The annual frequency identifies how often an event occurs in a given area over a set time period. There were 161 years in the data set used for the historical hurricane assessment and a total of 46 tropical cyclones included within the study area. In the case of Chatham County, the annual frequency for all tropical cyclone events is relatively low with an annual frequency of 0.29. This means there are approximately 0.29 tropical cyclones that impact Chatham County each year. Tropical storms have the highest annual frequency when broken down by category. The annual frequency decreases as the storm category increases.

The return period was also calculated from the data provided through the historical hurricane assessment (Table 4). The return period identifies the number of years between landfalls for tropical cyclones. There were 161 years in the data set used for the historical hurricane assessment and a total of 46 tropical cyclones that made landfall in the set parameters. For all landfalling tropical cyclones, the return period for Chatham County was 3.5. This means that a tropical cyclone will make landfall within the set parameters on average every 3.5 years. The return period for tropical storms was 7 years, 16 years for category 1 hurricanes, 23 years for category 2 hurricanes, 40 years for category 3 hurricanes, 54 years for category 4 hurricanes, and 161+ years for category 5 hurricanes. Keim et al (2007) calculated the return period for Tybee Island, which is in Chatham County, GA. Their study found the return period for all tropical cyclones to be 4 years, 21 years for all hurricanes, and 105+ years for major hurricanes. This study calculated the return period for all tropical cyclones to be 4 years, 7 years for all hurricanes, and 23 years for major hurricanes. The difference in return period numbers could be attributed to several factors. This study included 161 years whereas Keim et al (2007) only included 105 years. This study also included all tropical cyclones that made landfall within 150 miles south of the county and 100 miles north of the county. Keim et al (2007) focused on the area specifically around Tybee Island.

The Atlantic hurricane season runs from 01 June through 30 November, with peak activity usually occurring between mid-August and late October ("Tropical Cyclone Climatology " March 19, 2014). Over the 161 years covered in this assessment, there were very few early season tropical cyclones. Chatham County experienced peak tropical cyclone activity between August and October, with the most activity during the month of September (Table 5).

Table 5. Landfall Events by Month

	Number of events (landfalls)
May	3
June	3
July	4
August	11
September	13
October	12

There were three distinct areas of interest for tropical cyclone landfalls surrounding the study area (Table 6). The location of landfall relative to the study area affects how the study area is impacted by the tropical cyclone, particularly by storm surge. There were only five storms that made a direct landfall in Chatham County. The results were relatively even between north and south of the county with the north having twenty-one landfalling storms and the south having twenty landfalling storms. The storms that made landfall south of the county would have had a more significant storm surge impact on Chatham County when compared to the storms that made landfall north of the county.

Table 6. Landfall Events by Location

	Number of events (landfalls)
Direct	5
North	21
South	20

Social Vulnerability Assessment

Four socially vulnerable populations were assessed for this study: women headed households, children, elderly, and renters (Table 7). The numbers that are stated in the results come from the 2010 United States Census data. The vulnerable populations were normalized and displayed using GIS to show their location and distribution throughout the county (Appendix 1). There were several highly vulnerable hotspots for each variable throughout the county.

Table 7. Total Number for Each Assessed Variable for Chatham County 2010

	Total Number
Total Population	265128
Renters	43572
Female Headed Household	18010
Children	60007
Elderly	62812
Buildings	131515
Roads (miles)	2360.778
Telecommunication Towers	146

Women headed households are usually single-parent homes with one or more children present. Women headed households are considered vulnerable because there is only a single income and one person is responsible not only for their life, but lives of all their dependents (Morrow 1999). There are a total of 18,010 women headed households in the county (Table 8). Women headed households only make up approximately 7 percent of the county's total population. This is the small population of all the vulnerable populations that were examined. The areas of highest vulnerability were located just outside of downtown Savannah, Talahi Island, Wilmington Island, Georgetown, Garden City, and north Pooler.

Children/youth, people under 18, are considered vulnerable because they are dependent upon their parent or parents (Morrow 1999). The total children/youth population for the county is 60,007 (Table 8). Children/youth account for approximately 23 percent of the county's total population. The areas of highest vulnerability were located in Talahi Island, Wilmington Island, Whitemarsh Island, Georgetown, Garden City, the Pooler area, near Port Wentworth, and just outside of downtown Savannah.

The elderly population is vulnerable for various reasons. Elderly people might be dependent upon others, such as family members or a group-living facility, to provide care and/or transportation. Some elderly might be heavily dependent upon medication to maintain their health. If these resources are cut off by a storm it could be detrimental to their health (Tobin et al 1992). Also, some elderly might be reluctant to leave their homes due to their deep roots in the area or community (Gladwin et al 1997). The elderly population in Chatham County was 62,812 (Table 8). The elderly population makes up approximately 24 percent of the county's total population. The areas with the highest vulnerability for the elderly are located along the coast with a few areas of high vulnerability located further inland. Cities with the highest vulnerability include Talahi Island, Wilminton Island, Skidaway Island, Whitemarsh Island, Dutch Island, Georgetown, Garden City, and north Pooler.

Renters are considered vulnerable due to their dependence on a landlord to maintain their dwelling. If the dwelling is damaged in a storm, the landlord is responsible for the repairs or rebuilding. This could leave the tenant of the dwelling without a place to return to after the storm (Morrow 1999). There are 43,572 people who rent in Chatham County (Table 8). This accounts for approximately 17 percent of the county's total population. The cities with the highest renter vulnerability include Wilmington Island, Whitemarsh Island, Georgetown, Garden City, north Pooler, and just outside of downtown Savannah.

The combination of the vulnerability for each variable produced the overall vulnerability for the county. The coastal cities with highest overall social vulnerability include Talahi Island, Wilmington Island, Whitemarsh Island, and Skidaway Island. The inland cities with the highest overall vulnerability include Georgetown, Garden City, Pooler, and the areas just outside of downtown Savannah.

Building and Infrastructure Assessment

The infrastructure and buildings assessment included buildings, roads, and telecommunication towers (Appendix 2). It is essential to know how these features would be affected in the event of a tropical cyclone for many reasons. When roads are covered by storm surge waters, recovery efforts and hindered and people could be left trapped in their homes or buildings for days, maybe even weeks. If a large number of buildings are impacted by storm surge, it would take a community some time to rebuild and fully recover. When telecommunication towers are wiped out communication is often times limited or completely disrupted. If there is limited or disrupted communication, then people who are trapped or need assistance might have a difficult time making their needs known. If communications are down, the effected people might not be able to let family members and friends know they are alive or need help, which can cause stress on both parties.

According to the data from 2010 provided by the Savannah Area GIS, there were a total of 131,515 buildings, 2,360.778 miles of roads, and 146 telecommunication towers in Chatham County (Table 8). Roads, buildings, and telecommunication towers all had the highest density in and immediately around the Savannah area. There are also smaller pockets of high density areas of roads and buildings around coastal cities such as Tybee Island, Talahi Island, Willmington Island, and Skidaway Island.

The zoning map showed the distribution of the land use throughout the county for five different categories (Appendix 2). The business/commercial areas are mainly located along the major roads. There are some business/commercial areas located in downtown Savannah and on Tybee Island. These include local businesses and commercial buildings, such as shopping centers. The government/institutional areas were dominant along the coast as well in downtown

Savannah. Government/institutional zones include government buildings and building utilized by or designated to serve the public (library, fire station, etc.) The majority of the industrial areas are located on the eastern side of the county along the Savannah River. The residential zones are most dense in cities along the coast and immediately inland. There are pockets of residential zones in the cities surrounding Savannah as well. The north, west, and south borders of the county are dominated by the zones designated as other. These are mainly planned projects and conservation areas.

Storm Surge Assessment

Given the coastal location of Chatham County, storm surge would have a significant impact on the area in the event of a tropical cyclone. A storm surge map was generated to show how significant this impact would be on the county (Table 8, Fig 9). The storm surge data was only generated for category 1-5 hurricanes, so storm surge generated by a tropical storm is not included in this assessment. If there were any storm surge generated by a tropical storm, the impact on the coastline and areas immediately inland would be minimal.

Table 8. County and Storm Surge Area

	Area (sq. miles)	Percent
County Total	426.0	-
Category 1 Storm Surge	191.3	44.9
Category 2 Storm Surge	237.1	55.7
Category 3 Storm Surge	306.3	71.9
Category 4 Storm Surge	369.3	86.7
Category 5 Storm Surge	404.9	95.0

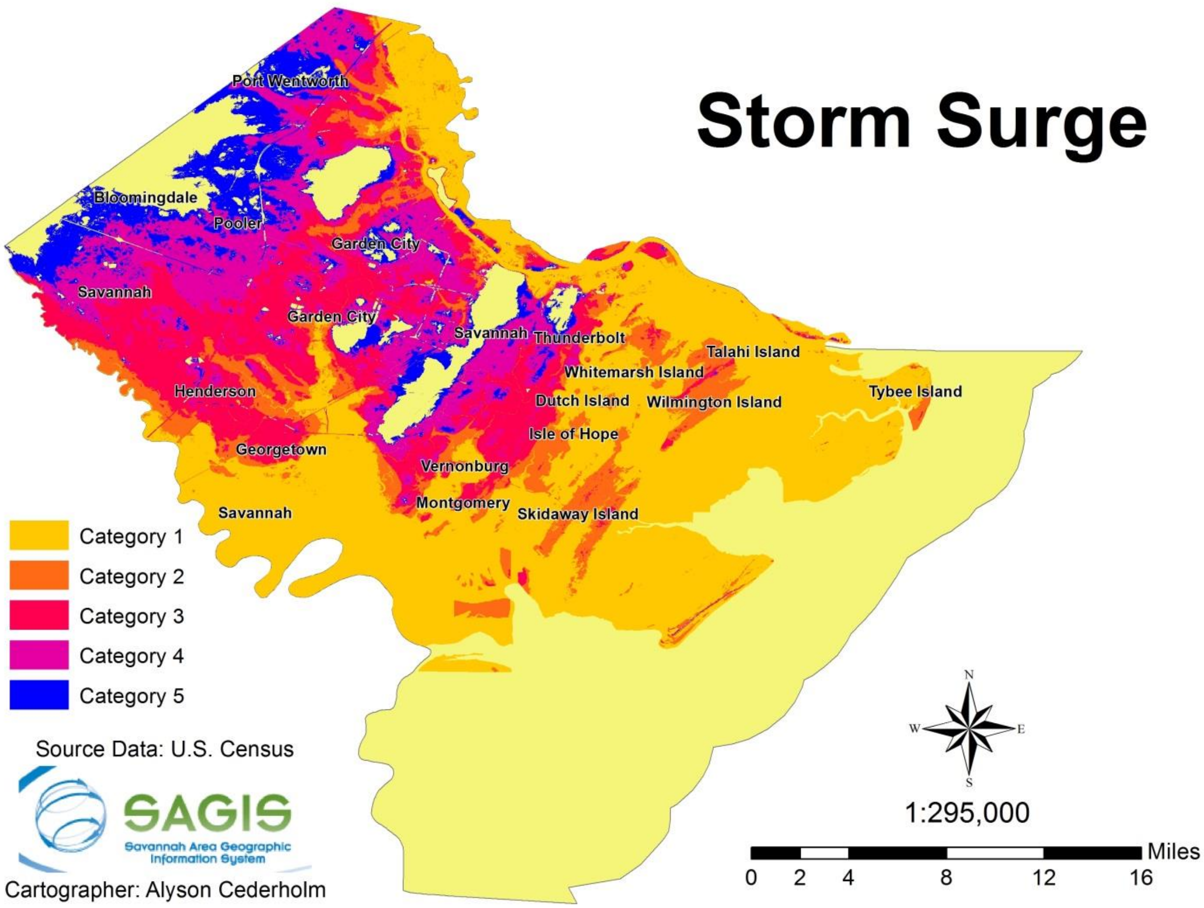


Figure 9. Chatham County Storm Surge Map

<u>Category 1</u>

The storm surge from a category 1 hurricane would have the most significant impact on the immediate coastline of the county. Areas along the Savannah River, which borders the county to the north, and the Ogeechee River, which borders the county to the south, would also be impacted by the storm surge. According to the data, the storm surge would impact approximately 191.3 square miles (44.9 percent) of the county. Tybee Island, Skidaway Island, Montgomery, Vernonberg, Whitemarsh Island, Dutch Island, and Isle of Hope are all coastal cities that would see the most significant storm surge impact from a category 1 hurricane (Appendix 3).

Category 2

The storm surge impact from a category 2 hurricane does not differ much from that of a category 1 hurricane. The same areas would be impacted with the storm surge extending slightly father inland. The data shows that approximately 237.1 square miles (55.7 percent) of the county would be impacted by storm surge. Additional cities that would be impacted include Wilmington Island and Talahi Island (Appendix 4).

Category 3

The storm surge impact from a category 3 hurricane starts to have a more significant impact on the county. The storm surge extends further inland affecting non-coastal cities. The data shows that approximately 306.3 square miles (71.9 percent) of the county would be impacted by storm surge. Additional cities that would be impacted include Thunderbolt, Georgetown, and Henderson (Appendix 5).

Category 4

The storm surge for a category 4 hurricane continues to extend farther inland affecting a larger area of the county. The data shows that approximately 369.3 square miles (86.7 percent) of the county would be impacted by storm surge. Additional cities that would be impacted include Garden City and Savannah (Appendix 6).

Category 5

The storm surge from a category 5 hurricane has the most significant impact on the county. Storm surge would affect the majority of the area. The data shows that approximately 404.9

square miles (95.0 percent) of the county would be impacted by storm surge. Additional cities that would be impacted include Pooler, Bloomingdale, and Port Wentworth (Appendix 7).

Social Vulnerability Storm Surge Assessment

The storm surge impact was assessed for each socially vulnerable variable within the county and displayed in a table (Table 9, 10). Since the majority of the areas of highest vulnerability for the elderly were located in and around the coastal cities, the storm surge impact for category 1 and 2 hurricanes most significant for the elderly population. At least half of the population for each variable was impacted by category 3 storm surge. The number of people impacted by storm surge increase significantly for category 4 and 5 hurricanes for each variable.

The storm surge impact on women headed households was minimal for category 1 and 2 hurricanes. There were a total of 12 highly vulnerable blocks for the women headed household population. Of those 12 blocks, two fell within the category 1 storm surge zone (Appendix 3) and three fell within the category 2 storms surge zone (Appendix 4). The storm surge impact was more significant for category 3 hurricanes with 6 of the highly vulnerable blocks falling within the category 3 storm surge zone (Appendix 5). The storm surge impact was most significant for category 4 and 5 hurricanes. There were 9 highly vulnerable blocks within the category 4 storm surge zone (Appendix 6) and 11 highly vulnerable blocks within the category 5 storm surge zone (Appendix 7).

There were a total of 16 highly vulnerable blocks for the children/youth population. The storm surge impact from category 1 and 2 hurricanes was not significant. There were only 3 highly vulnerable blocks within the category 1 storm surge zone (Appendix 3) and 5 highly vulnerable blocks within the category 2 storm surge zone (Appendix 4). Half of the highly vulnerable blocks were impacted by the storm surge from category 3 hurricanes with 8 of the highly vulnerable blocks falling within the category 3 storm surge zone (Appendix 5). The storm surge from category 4 and 5 hurricanes had the most significant impact on the population. There were 12 highly vulnerable blocks within the category 4 storm surge zone (Appendix 6) and 15 highly vulnerable blocks within the category 5 storm surge zone (Appendix 7).

There were a total of 21 highly vulnerable blocks for the elderly population. The storm surge from category 1 and 2 hurricanes had a significant impact on the elderly population. Of those 21 blocks, 9 were within the category 1 storms surge zone (Appendix 3), and 13 were within the category 2 storm surge zone (Appendix 4). A few more blocks are impacted by category 3 hurricane storm surge, with 19 blocks falling within the category 3 storm surge zone (Appendix 5). The storm surge from category 4 and 5 hurricanes affects the last two highly vulnerable blocks in the county. There were 20 blocks within the category 4 storm surge zone (Appendix 6), and all 21 were within the category 5 storm surge zone (Appendix 7).

There were a total of 12 highly vulnerable blocks for the renter population. The storm surge impact from category 1 and 2 hurricanes was low. There were only 2 highly vulnerable blocks within the category 1 storm surge zone (Appendix 3) and 3 blocks within the category 2 storm surge zone (Appendix 4). Half of the highly vulnerable blocks were impacted by the storm surge from category 3 hurricanes with 6 highly vulnerable blocks within the category 3 storm surge zone (Appendix 5). The storm surge from category 4 and 5 hurricanes had the most significant impact on the renter population. There were 8 highly vulnerable blocks within the category 4 storm surge zone (Appendix 6) and all 12 highly vulnerable blocks were within the category 5 storm surge zone (Appendix 7).

When the four variables were combined to obtain the overall social vulnerability, there were a total of 22 highly vulnerable blocks in the county. The storm surge impact from category 1 and 2 hurricanes was minimal. There were 6 highly vulnerable blocks within the category 1 storm surge zone (Appendix 3) and 7 highly vulnerable blocks within the category 2 storm surge zone (Appendix 4). More than half of the highly vulnerable blocks were impacted by the storm surge from category 3 hurricanes with 13 highly vulnerable blocks within the category 3 storm surge zone (Appendix 5). The storm surge from category 4 and 5 hurricanes had that most significant impact on the overall social vulnerability. There were 17 highly vulnerable blocks within the category 4 storm surge zone (Appendix 6) and 21 highly vulnerable blocks within the category 5 storm surge zone (Appendix 7).

Table 9. Storm Surge Impact on Vulnerable Blocks

	Total	**Category 1**	**Category 2**	**Category 3**	**Category 4**	**Category 5**
Women Headed Household	12	2	3	6	9	11
Children	16	3	5	8	12	15
Elderly	21	9	13	19	20	21
Renters	12	2	3	6	8	12
Overall Vulnerability	22	6	7	13	17	21

Table 10. Social Vulnerability Storm Surge Impact

	Total				
	Category 1	**Category 2**	**Category 3**	**Category 4**	**Category 5**
Total Population	36274	51097	70281	94840	102666
Women Headed Household	3797	5679	9158	13719	15202
Children	15778	23366	34847	48308	53022
Elerly	22362	30347	40261	52117	55982
Renters	11403	16081	22129	31993	34738
	Percent				
	Category 1	**Category 2**	**Category 3**	**Category 4**	**Category 5**
Total Population	13.7	19.3	26.5	35.8	38.7
Women Headed Household	21.1	31.5	50.8	76.2	84.4
Children	26.3	38.9	58.1	80.5	88.4
Elerly	35.6	48.3	64.1	83.0	89.1
Renters	26.2	36.9	50.8	73.4	79.7

Building and Infrastructure Storm Surge Assessment

The storm surge impact for each hurricane category was assessed for the buildings and infrastructure within the county and displayed in a table (Table 11, 12). The storm surge from category 1,2, and 3 hurricanes would have the most significant impact on the roads what compared to the buildings and telecommunication towers. The storm surge from category 4 and 5 hurricanes would have a significant impact on all three variables.

There were a total of 2,360.778 miles of roads in Chatham County. The storm surge impact on roads was low for category 1 hurricanes with only 806.4 miles of roads within the category 1 storm surge zone (Appendix 3). The storm surge impact for category 2 and 3 hurricane was moderate, with 1,124.6 miles of roads within the category 2 storm surge zone (Appendix 4) and 1,567.6 miles of roads within the category 3 storm surge zone (Appendix 5). The storm surge from category 4 and 5 hurricanes had the most significant impact on the roads throughout the county with 1,959.1 miles of roads within the category 4 storm surge zone (Appendix 6) and 2,121.2 miles of roads within the category 5 storm surge zone (Appendix 7).

There were a total of 146 telecommunication towers throughout Chatham County. The storm surge impact on telecommunication towers was minimal for category 1 hurricanes with only 11 of the telecommunication towers within the category 1 storm surge zone (Appendix 3). The storm surge impact on the telecommunication towers was moderate for category 2 and 3 hurricanes, with 32 of the telecommunication towers within the category 2 storm surge zone (Appendix 4) and 57 of the telecommunication towers within the category 3 storm surge zone (Appendix 5). The storm surge from category 4 and 5 hurricanes had the most significant impact on the telecommunication towers throughout the county with 109 of the telecommunication towers within the category 4 storm surge zone (Appendix 6) and 122 of the telecommunication towers within the category 5 storm surge zone (Appendix 7).

There were a total of 131,515 buildings in Chatham County. The storm surge impact was low on all buildings for category 1 and 2 hurricanes with 8,100 buildings within the category 1 storm surge zone (Appendix 3) and 26,919 buildings within the category 2 storm surge zone (Appendix 4). There was a moderate storm surge impact on the buildings for category 3 hurricanes with 58,712 buildings within the category 3 storm surge zone (Appendix 5). There was a significant impact on the buildings for category 4 and 5 hurricanes with 94,308 buildings within the category 4 storm surge zone (Appendix 6) and 108984 buildings within the category 5 storm surge zone (Appendix 7).

There were a total of 4,671 business/commercial buildings in Chatham County. The storm surge impact on business/commercial buildings was minimal for category 1, 2, and 3 hurricanes. There were only 228 business/commercial buildings within the category 1 storm surge zone (Appendix 3), 440 business/commercial buildings within the category 2 storm surge zone (Appendix 4), and 924 business/commercial buildings within the category 3 storm surge zone (Appendix 5). The storm surge impact was moderate for category 4 hurricanes with 2,422 business/commercial buildings within the category 4 storm surge zone (Appendix 6). The storm surge from category 5 hurricanes had the most significant impact, with 3,176 business/commercial buildings within the category 5 storm surge zones (Appendix 7).

There were a total of 408 government/institutional buildings in Chatham County. The storm surge impact on government/institutional buildings was low for category 1 and 2 hurricanes with 64 government/institutional buildings within the category 1 storm surge zone (Appendix 3) and 78 government/institutional buildings within the category 2 storm surge zone (Appendix 4). The storm surge from category 3 hurricanes had a moderate impact on government/institutional buildings with 251 government/institutional buildings within the category 3 storm surge zone (Appendix 5). The storm surge impact on government/institutional buildings was significant for category 4 and 5 hurricanes with 353 government/institutional buildings within the category 4 storm surge zone (Appendix 6) and 360 government/institutional buildings within the category 5 storm surge zone (Appendix 7).

There were a total of 4,604 industrial buildings within Chatham County. The storm surge impact was minimal for category 1, 2, and 3 hurricanes with 298 industrial buildings within the category 1 storm surge zone (Appendix 3), 654 industrial buildings within the category 2 storm surge zone (Appendix 4), and 1,797 industrial buildings within the category 3 storm surge zone (Appendix 5). There was a significant storm surge impact on industrial buildings for category 4 and 5 hurricanes with 3,344 industrial buildings within the category 4 storm surge zone

(Appendix 6) and 3,742 industrial buildings within the category 5 storm surge zone (Appendix 7).

There were a total of 41,434 buildings classified as other in Chatham County. The storm surge impact on other buildings was low for category 1 and 2 hurricanes with 3,690 other buildings within the category 1 storm surge zone (Appendix 3) and 11,157 other buildings within the category 2 storm surge zone (Appendix 4). There was a moderate impact on other buildings for category 3 hurricanes with 23,232 other buildings within the category 3 storm surge zone (Appendix 5). There was a significant storm surge impact on other buildings for category 4 and 5 hurricanes with 29,350 other buildings within the category 4 storm surge zone (Appendix 6) and 33,943 other buildings within the category 5 storm surge zone (Appendix 7).

There were a total of 81,848 residential buildings in Chatham County. The storm surge impact on residential buildings was low for category 1 and 2 hurricanes with 3,968 residential buildings within the category 1 storm surge zone (Appendix 3) and 14,896 residential buildings within the category 2 storm surge zone (Appendix 4). There was a moderate storm surge impact on residential buildings for category 3 hurricanes with 33,108 residential buildings within the category 3 storm surge zone (Appendix 5). There was a significant impact on residential buildings for category 4 and 5 hurricanes with 59,753 residential buildings within the category 4 storm surge zone (Appendix 6) and 68,809 residential buildings within the category 5 storm sure zone (Appendix 7).

Table 11. Infrastructure Storm Surge Impact

	Roads (miles)		Telecommunication Towers	
	Total	%	Total	%
Category 1	806.4	34.2	11	7.5
Category 2	1124.6	47.6	32	21.9
Category 3	1567.6	66.4	57	39.0
Category 4	1959.1	83.0	109	74.7
Category 5	2121.2	89.9	122	83.6

Table 12. Building Types by Land Use Zones Storm Surge Impact

Total						
	Total	**Category 1**	**Category 2**	**Category 3**	**Category4**	**Category5**
All Buildings	131515	8100	26919	58712	94308	108984
Business/Commercial	4671	228	440	924	2422	3176
Government/Institutional	408	64	78	251	353	360
Industrial	4604	298	654	1797	3344	3742
Other	41434	3690	11157	23232	29350	33943
Residential	81848	3968	14896	33108	59753	68809
Percent						
All Buildings		6.2	20.5	44.6	71.7	82.9
Business/Commercial	-	4.9	9.4	19.8	51.9	70.0
Government/Institutional	-	15.7	19.1	61.5	86.5	88.2
Industrial	-	6.5	14.2	39.0	72.6	81.3
Other	-	8.9	26.9	56.2	70.8	81.9
Residential	-	4.8	18.2	40.5	73.0	84.1

A zoning map was created to show how land was utilized throughout the county. The land use categories were business/commercial, government/institutional, industrial, other, and residential. The total area impacted by storm surge for each zoning category was calculated to better understand how Chatham County would be impacted by hurricane induced storm surge (Table 13).

There was a total of 8.7 square miles of business/commercial land in Chatham County. The storm surge impact on business/commercial land was low for category 1 and 2 hurricanes with 0.26 square miles of business/commercial land within the category 1 storm surge zone (Appendix 3) and 0.5 square miles of business/commercial land within the category 2 storm surge zone (Appendix 4). The storm surge impact on business/commercial land was moderate for category 3 and 4 hurricanes with 2.7 square miles of business/commercial land within the category 3 storm surge zone (Appendix 5) and 5.4 square miles of business/commercial land within the category 4 storm surge zone (Appendix 6). The most significant storm surge impact on business/commercial land was from category 5 hurricanes with 6.9 square miles of business/commercial land within the category 5 storm surge zone (Appendix 7).

There was a total of 3.5 square miles of government/institutional land in Chatham County. The storm surge impact was moderate on government/institutional land for category 1 hurricanes with 2.2 square miles of government/institutional land within the category 1 storm surge zone (Appendix 3). There was a significant storm surge impact on government/institutional land for category 2, 3, 4, and 5 hurricanes with 2.8 square miles of government/institutional land within the category 2 storm surge zone (Appendix 4), 3.2 square miles of government/institutional land within the category 3 storm surge zone (Appendix 5), and 3.4 square miles of government/institutional land within the category 4 and 5 storm surge zones (Appendix 6, 7).

There was a total of 43.5 square miles of industrial land in Chatham County. There was a moderate storm surge impact on industrial land for category 1, 2, and 3 hurricanes with 11.3 square miles of industrial land within the category 1 storm surge zone (Appendix 3), 16.6 square miles of industrial land within the category 2 storm surge zone (Appendix 4), and 25.1 square miles of industrial land within the category 3 storm surge zone (Appendix 5). There was a significant storm surge impact on industrial land for category 4 and 5 hurricanes with 34.8 square miles of industrial land within the category 4 storm surge zone (Appendix 6) and 39.1 square miles of industrial land within the category 5 storm surge zone (Appendix 7).

There was a total of 400.1 square miles of other land in Chatham County. There was a moderate storm surge impact on other land for category 1, 2, and 3 hurricanes with 166.6 square miles of other land within the category 1 storm surge zone (Appendix 3), 194 square miles of other land within the category 2 storm surge zone (Appendix 4), and 238.2 square miles of other land within the category 3 storm surge zone (Appendix 5). There was a significant storm surge impact on other land for category 4 and 5 hurricanes with 272.4 square miles of other land within the category 4 storm surge zone (Appendix 6) and 295.5 square miles of other land within the category 5 storm surge zone (Appendix 7).

There was a total of 66.2 square miles of residential land in Chatham County. There was a low storm surge impact on residential land for category 1 hurricanes with 8.5 square miles of residential land within the category 1 storm surge zone (Appendix 3). There was a moderate storm surge impact on residential land for category 2 and 3 hurricanes with 20.3 square miles of residential land within the category 2 storm surge zone (Appendix 4) and 33.8 square miles of residential land within the category 3 storm surge zone (Appendix 5). There was a significant storm surge impact on residential land for category 4 and 5 hurricanes with 50 square miles within the category 4 storm surge zone (Appendix 6) and 56.6 square miles within the category 5 storm surge zone (Appendix 7).

Table 13. Land Use Zones Storm Surge Impact

Total Area (sq. miles)						
	Total	**Category 1**	**Category 2**	**Category 3**	**Category4**	**Category5**
Business/Commercial	8.7	0.26	0.5	2.7	5.4	6.9
Government/Institutional	3.5	2.2	2.8	3.2	3.4	3.4
Industrial	43.5	11.3	16.6	25.1	34.8	39.1
Other	400.1	166.6	194	238.2	272.4	295.5
Residential	66.2	8.5	20.3	33.8	50	56.6
Percent						
Business/Commercial	-	3	5.7	31	62.1	79.3
Government/Institutional	-	62.9	80	91.4	97.1	97.1
Industrial	-	26	38.2	57.7	80	89.9
Other	-	41.3	48.5	59.6	68.1	73.9
Residential	-	12.8	30.7	51.1	75.5	85.5

Hurricane Risk Assessment

Worst Case Scenario

Theoretically, the worst case scenario is a Category 5 hurricane making landfall at high tide. However, the historical hurricane analysis for Chatham County showed that no category 5 hurricanes had made landfall along the study area coast within the study period of 1851-2012. Therefore, the worst case scenario would be a category 4 hurricane at high tide based on the historical record. Any landfalling Category 4 or 5 hurricane within 150 miles south of the county and 100 miles north of the county would be devastating to the area. When considering the counter-clockwise rotation of a tropical cyclone, a direct hit or landfall to the south of the county would have a more significant storm surge impact. Potential impacts of the worst case scenario for Chatham County can be viewed in tables 3 to 13.

Most Probable Scenario

The most probable scenario when considering all strengths of tropical cyclones would be a tropical storm at landfall. When considering only hurricanes, the most probable scenario would be a Category 1 hurricane. The historical hurricane data suggests that a tropical cyclone would most likely impact the county during the months of August, September, and October. The location of past landfalls suggests that the chances for a direct landfall are small. It is most likely that a tropical cyclone would make landfall within 150 miles south of the county and 100 miles north of the county. Potential impacts of the most probable scenario for Chatham County can be viewed in tables 3 to 13.

Chapter 6

Summary and Conclusions

Summary

Risk assessments should be conducted every couple of years to keep current with the changing data and demographics. Vulnerability is localized and dependent upon several factors that can change drastically over a few years (i.e. population and economy). Hazards and vulnerability vary from place to place, as well as through time. Natural hazards risk assessments are essential in community planning. Risk assessments highlight areas of vulnerability within a given study area relating to a particular natural hazard. If areas of vulnerability are known, local government and Emergency Management Agency (EMA) officials can take action to better prepare a community for a natural hazards event. This hurricane risk assessment will provide Chatham County with important information and tools that can aid in hurricane preparation for the future. Risk assessments can not only reduce risk, but build resilience (Cutter 2008).

There was a 7 year gap between the 2005 and the 2012 risk assessments for Chatham County. The 2012 risk assessment focused on flood hazards for the area, which included hurricane flood risks. Both of these risk assessments heavily focused on the financial costs of a hazard, as well as past hazards, in this area and paid little attention to the impact hazards would have on socially vulnerable populations.

This study produced a report of hurricane activity from 1851 through 2012. It included overall hurricane frequency as well as hurricane frequency by category. This study also produced a detailed social vulnerability maps showing the location of the highest and lowest vulnerable population. An overall hurricane vulnerability map was produced to show the areas of highest vulnerability in the event of a hurricane. The hurricane vulnerability map combined with the SLOSH model storm surge maps will allow for a detailed assessment of the potential impacts of a hurricane on Chatham County.

Research Question Conclusions

1. What is the history of hurricane activity in Chatham County, GA?

From 1851 to 2012 the hurricane activity in Chatham County was relatively low, with only 46 tropical cyclones ranging from tropical storm to category 4 hurricanes in strength. Tropical storms were the most common tropical cyclone strength to impact the area with a total of 22 storms. Chatham County saw its peak tropical cyclone activity between the months of August and October, which is common for this area. When the area was impacted by a tropical cyclone, the location of landfall was distributed evenly between north and south of the county. The annual frequency was relatively low, with only 0.29 storms impacting the area each year. The return period for all tropical cyclones was 4 years, 7 years for all hurricanes (category 1-4) and 23 years for major hurricanes (category 3 and 4).

2. How would hurricane-induced storm surge impact Chatham County, GA?

Storm surge would have a significant impact on Chatham County. Category 1 and 2 hurricane storm surge would impact 44.9 to 55.65 percent of the county respectively and would mainly affect the coastline and the areas immediately inland. Category 3 and 4 hurricane storm surge would impact 71.9 to 86.7 percent of the county respectively and would affect more than two-thirds of the county. A category 5 hurricane would be devastating to the county with 95 percent of the county experiencing some type of storm surge impact.

3. Where are the socially vulnerable populations located in Chatham County, GA?

Women headed households, children/youth, elderly, and renters were assessed as vulnerable populations for this thesis. For women headed households, children/youth, and renters, the majority of the highly vulnerable populations were located in inland cities. There was very few area of high vulnerability for these populations along the coast. The elderly population was the exact opposite. The majority of the highly vulnerable areas were located along the coast of the county with very few areas of high vulnerability inland. The overall social vulnerability for the county was distributed throughout the entire county. This is due to the areas of high vulnerability for women headed households, children/youth, and renters being most dominant in the inland cities and the areas of high vulnerability for elderly being most dominant in the coastal cities.

4. Where are the vulnerable buildings and infrastructure in Chatham County, GA?

Roads, buildings, and telecommunication towers were assessed as the vulnerable infrastructure for this thesis. The highest density of buildings was located in the city of Savannah. There were a few clusters of high density areas in the coastal cities as well. The same was found for the roads as well. The highest density of roads was within the city of Savannah with clusters of high density areas in the coastal cities.

5. What is the overall hurricane vulnerability for Chatham County, GA?

Theoretically, the worst case scenario for Chatham County would be a Category 5 hurricane at landfall at high tide. While a category 5 hurricane would have the most devastating impact, the historical hurricane assessment revealed the area has not been impacted by a category 5 hurricane since 1851. The strongest tropical cyclone to impact this area was a category 4 hurricane; therefore, the most likely worst case scenario for Chatham County would be a category 4 hurricane at landfall at high tide.

The most probable scenario for Chatham County could be viewed in two ways. When all tropical cyclone strengths that were assessed in the historical hurricane assessment are considered, the most probable scenario would be a tropical storm. Tropical storms had the highest frequency of impacts on the county over the 161 year study period. When only tropical cyclones that were hurricane strength are considered, the most probable scenario would be a category 1 hurricane. Out of all hurricane categories, this area experienced more category 1 hurricanes than any other hurricane category. This area would most likely be impacted between the month of August and October during the areas peak activity months.

Hurricanes impact the United States Atlantic and Gulf of Mexico coasts each year. Vulnerability varies from one location to another due to different social, infrastructure, and economic statuses. The methods in this research can be applied to other coastal counties to assess their unique vulnerability to hurricanes. A hurricane risk assessment could help community planners and government officials to assess their vulnerable areas to better prepare for a hurricane event in their county. With the vulnerable areas highlighted, this data could be utilized to develop public policies for coastal development and management for the future.

Chatham County has not been significantly impacted by a hurricane in over 30 years. It is a matter of time before the county will be impacted by a tropical cyclone again. Since tropical cyclones have had a low frequency in the area, many people will not be prepared for the impact or know how to react to the situation. The hurricane risk assessment that was completed and the methods that were outlined through this thesis will be extremely beneficial to Chatham County planning, managing, and government officials.

The research completed in this thesis can be applied to the Hazards of Place Model (Cutter 1996). The risk for Chatham County was identified as tropical cyclone induced storm surge. With the risk identified, social vulnerability can be assessed. The social vulnerability assessment and the building and infrastructure assessment highlighted the areas of highest vulnerability in Chatham County. The combination of these two assessments allows for the identification of the place vulnerability. After the place vulnerability is identified, mitigation efforts can be implemented to reduce the vulnerability. In turn, if the vulnerability is reduced, the resilience of the area should increase. This thesis research can also be applied to the Disaster Resilience of Place Model (Cutter 2008). The actions taken leading up to a disaster event are going to determine how well a community can bounce back after the event. The identification of the vulnerability allows for mitigation efforts to be put in place and builds preparedness for when a disaster occurs. This in turn is what builds the resilience of a community. If the community is well prepared ahead of time, then they will be able to better absorb the impact of the disaster and recover quickly.

The county is aware of the flood risk in the area and has taken certain precautions to reduce its vulnerability and build its resilience. Chatham County participates in the National Flood Insurance Program (NFIP). The purpose of the program is to provide flood insurance to homeowners, renters, and business owners who reside in areas that are flood prone (FEMA 2014). The county has also taken advantage of the Federal Emergency Management Agency Property Acquisition Program to buyout properties in flood zones. The buyout program is completely voluntary and homeowners will never be forced into a buyout. Homeowners who choose to participate in the buyout program are offered fair market value compensation for their property. Local communities work with the state to identify the areas of highest risk where buyouts would make the most sense. Local officials work with the community and homeowners to submit an application for assistance for property that has sustained severe damage or complete destruction. Once the land is purchased by the community and cleared, it must remain cleared and cannot be developed. The land may be utilized for things such as parks, wildlife refuges, green space, etc. (FEMA 2012). By eliminating properties that repeatedly flood; they are reducing the number of insurance claims as a result of flooding as well as providing residents a safer place to live. Another way to reduce vulnerability and build resilience is for the county government and planning officials to stay current on things such as evacuation plans and emergency response plans and make them know and easily accessible to the public. Public outreach can also play a role in reducing vulnerability and building resilience. If the public, especially the vulnerable populations, is made aware of the potential risks associated with hurricanes, they are more likely to make more informed decisions when faced with a disaster.

References

Berkes, Fikret. "Understanding uncertainty and reducing vulnerability: lessons from resilience thinking." *Natural Hazards*. no. 2 (2007): 283-295.

Blake, Eric S., Todd B. Kimberlain, Robert J. Berg, John P. Cangialosi, and John L. Beven II. Nation Hurricane Center, "Tropical Cyclone Report Hurricane Sandy 22-29 October 2012." Last modified February 12, 2013. Accessed October 21, 2013.

Blake, Eric. National Oceanic and Atmospheric Administration, "2013 Atlantic Hurricane Season." Last modified May 19, 2014. http://www.nhc.noaa.gov/data/tcr/summary_atlc_2013.pdf.

Blaikie, Piers, Terry Cannon, Ian Davis, and Ben Wisner. *At Risk: Natural Hazards, People's Vulnerability and Disaster*. Routledge, London: 1994.

Bolin, Robert. "Disaster Impact and Recovery: A Comparison of Black and White Victims." *International journal of mass emergencies and disasters* . no. 1 (1986): 35-50.

Bolin, Robert. *Household and Community Recovery after Earthquakes*. Institute of Behavioral Science, University of Colorado, Boulder: 1993.

Bolin, Robert, and Patricia Bolton. *Race, Religion, and Ethnicity in Disaster Recovery*. University of Colorado, Boulder: 1986.

Burton, Ian, and Robert Kates. "The Perception of Natural Hazards in Resource Management." *Natural Resources Journal*. no. 3 (1964): 412-441.

Burton, Ian, Robert W. Kates, and Gilbert F. White. *The Environment as Hazard*. New York, NY: The Guilford Press, 1993.

Chatham County Department of Engineering, "Flood Mitigation Plan Unicorporated Chatham County." Last modified December 2012. Accessed May 29, 2014. http://engineering.chathamcounty.org/Portals/Engineering/forms/floodZones/Flood Mitigation Plan.pdf.

Chatham Emergency Management Agency, "Chatham County Pre-Disaster Mitigation Plan." Last modified 2005. Accessed February 21, 2013. http://www.chathamemergency.org/Documents/HAZARD MITIGATION PLAN.pdf.

Cochrane, Harold. *Natural Hazards and their Distributive Effects*. Insitute of Behavioral Sciences, University of Colorado, Boulder: 1975.

Cross, J.A. "Megacities and small towns: different perspectives on hazard vulnerability." *Environmental Hazards*. no. 2 (2001): 63-80.

Cutter, Susan, and William Solecki. "The National Pattern of Airborne Toxic Releases." *Professional Geographer*. 41. no. 2 (1989): 149-161.

Cutter, Susan, Jerry Mitchell, and Michael Scott. "Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina." *Annals of the Association of American Geographers*. no. 4 (2000): 713-737.

Cutter, Susan, Bryan Boruff, and W. Lynn Shirley. "Social Vulnerability to Environmental Hazards." *Social Science Quarterly* . 84. no. 2 (2003): 242-261.

Cutter, Susan, Laurie Johnson, Christina Finch, and Melissa Berry. "The U.S. Hurricane Coasts: Increasingly Vulnerable." *Environment*. 49. no. 7 (2007): 8-20.

Cutter, Susan, and Christina Finch. "Temporal and Spatial Changes in Social Vulnerability to Natural Hazards."*Proceedings of the National Academy of Sciences*. 105. no. 7 (2008a): 2301-2306.

Cutter, Susan, Lindsey Barnes, Melissa Berry, Christopher Burton, Elijah Evans, Eric Tate, and Jennifer Webb . "A place-based model for understanding community resilience to natural disasters." *Global Environment Change*. 18. (2008b): 589-606.

Dima, Dr. Ioana, and Dr. Melicie Desflots. "Wind Profiles in Parametric Hurricane Models." *Air Worldwide*, July 19, 2010. http://www.air-worldwide.com/Publications/AIR-Currents/2010/Wind-Profiles-in-Parametric-Hurricane-Models/ (accessed October 21, 2013).

Drabek, Thomas. *Disaster Evacuation Behavior: Tourists and Other Transients*. Insitute of Behavioral Sciences, University of Colorado, Boulder: 1996.

FEMA, . National Flood Insurance Program, "About the National Flood Insurance Program." Last modified April 27, 2014. https://www.floodsmart.gov/floodsmart/pages/about/nfip_overview.jsp.

FEMA, . "Hazard Mitigation Assistance - Property Acquisition (Buyouts)." Last modified December 27, 2012. http://www.fema.gov/application-development-process/hazard-mitigation-assistance-property-acquisition-buyouts.

Georgia Emergency Management Agency/Homeland Security, "Hurricanes in Georgia." Last modified 2013. Accessed February 28, 2013. http://www.gema.ga.gov/gemaohsv10.nsf/c6049b8deb5d38a185257726003aa1dd/68ec9214ddb5b64a8525773500716735?OpenDocument.

Gladwin, Hugh, Walter Peacock. Warning and Evacuation: A Night for Hard Houses. In Peacock, Walter, Betty Morrow, and Hugh Gladwin. *Hurricane Andrew: Ethnicity, Gender, and the Sociology of Disasters*. Routledge, London: 1997.

Handmer, John W. "Managing vulnerability in Sydney: planning of providence?." *GeoJournal*. no. 3 (1995): 355-368.

Intergovernmental Panel on Climate Change, . *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. New York, NY : Cambridge University Press, 2012. http://www.ipcc-wg2.gov/SREX/images/uploads/SREX-All_FINAL.pdf .

Keim, Barry D., Robert D. Muller, and Gregory W. Stone. "Spatial and temporal variability of coastal storms in the North Atlantic Basin." *Marine Geology*. no. 1-4 (2004): 7-15.

Keim, Barry , Robert Muller, and Gregory Stone. "Spatiotemporal Patterns and Return Periods of Tropical Storm and Hurricane Strikes from Texas to Maine." *Journal of Climate*. no. 14 (2007): 3498-3509.

Kellogg, Becky. The Weather Channel, "10 Most Vulnerable and Overdue Hurricane Cities." Last modified June 04, 2013. http://www.weather.com/news/weather-hurricanes/10-most-overdue-hurricane-cities-20130531.

Klein, Richard J.T., Robert J. Nicholls, and Frank Thomalla. "Resilience to Natural Hazards: How Useful is This Concept?." *Global Environmental Change Part B: Environmental Hazards*. no. 1-2 (2003): 35-45.

Knabb, Rick. The Weather Channel, "Top 5 Hurricane Vulnerable & Overdue Cities." Last modified September 24, 2010. http://www.weather.com/outlook/weather-news/news/articles/top5-most-vulnerable-overdue-hurricane-cities_2010-07-14?page=2.

Knabb, Rick . The Weather Channel, "2011's Top 5 Hurricane Overdue Cities." Last modified 2011. Accessed April 2, 2013. http://www.weather.com/outlook/weather-news/news/articles/2011-hurricane-overdue-cities_2011-05-27?page=6.

Knabb, Richard D., Jamie R. Rhone, and Daniel P. Brown. Nation Hurricane Center, "Tropical Cyclone Report Hurricane Katrina 23-30 August 2005." Last modified December 20, 2005. Accessed October 21, 2013.

Knuston, Thomas, and Robert Tuleya. "Impact of CO2-Induced Warming on Simulated Hurricane Intensity and Precipitation: Sensitivity to the Choice of Climate Model and Convective Parameterization. ." *Journal of Climate*. no. 18 (2004): 3477-3495.

Montz, Burrell E., John A. Cross, and Susan L. Cutter. Hazards. In *Geography in the America at the Dawn of the 21st Century*, ed. Gary L. Gaile and Cort J. Willmott, 479-491 New York, NY: Oxford University Press, 2003.

Morrow, Betty. Stretching the Bonds: The Families of Andrew. In Peacock, Walter, Betty Morrow, and Hugh Gladwin. *Hurricane Andrew: Ethnicity, Gender, and the Sociology of Disasters*. Routledge, London: 1997.

Morrow, Betty. "Identifying and Mapping Community Vulnerability." *Disasters*. 23. no. 1 (1999): 1-18.

Muller, R.A., and G.W. Stone. "A climatology of tropical storm and hurricane strikes to enhance vulnerability prediction for the southeast US Coast." *Journal of Coastal Research*. no. 4 (2001): 949-956.

National Hurricane Center, "Saffir-Simpson Hurricane Wind Scale." Last modified 2012. Accessed March 20, 2013. http://www.nhc.noaa.gov/aboutsshws.php.

National Hurricane Center, "Tropical Cyclone Climatology ." Last modified March 19, 2014. Accessed April 2, 2014. http://www.nhc.noaa.gov/climo/.

National Oceanic and Atmospheric Administration, "NOAA predicts active 2013 Atlantic hurricane season." Last modified May 23, 2013. http://www.noaanews.noaa.gov/stories2013/20130523_hurricaneoutlook_atlantic.html.

National Oceanic and Atmospheric Administration, "NOAA predicts near-normal or below-normal 2014 Atlantic hurricane season." Last modified May 22, 20014. http://www.noaanews.noaa.gov/stories2014/20140522_hurricaneoutlook_atlantic.html.

NOAA, "Fort Pulaski, GA - Station ID: 8670870." Last modified October 15, 2013. http://tidesandcurrents.noaa.gov/stationhome.html?id=8670870.

Parker, Denis . "Hazard transformation and hazard management issues in the London megacity."*GeoJournal*. no. 7 (1995): 313-328.

Paul, Bimal. *Environmental Hazards and Disasters*. West Sussex, UK : John Wiley & Sons, Ltd., 2011.

Porter, David. "Hurricane Sandy Was Second-Costliest In U.S. History, Report Shows." *The Huffington Post*, U.S. editionFebruary 12, 2013.

Stewart, Stacy. Nation Hurricane Center, "Tropical Cyclone Report Hurricane Ivan 2-24 September 2004." Last modified May 27, 2005. Accessed October 21, 2013.

Tobin, Graham A. "Sustainability and community resilience: the holy grail of hazards planning?." *Environmental Hazards*. (1999): 13-25.

Tobin, Graham, and Jane Ollenburger. *Natural Hazards and the Elderly*. Natural Hazards Research and Applications Information Center, University of Colorado, Boulder: 1992.

Torrieri, Nancy K., and Michael R. Ratcliffe. Applied Geography. In *Geography in the America at the Dawn of the 21st Century*. ed. Gary L. Gaile and Cort J. Willmott, 541-549. New York, NY: Oxford University Press, 2003.

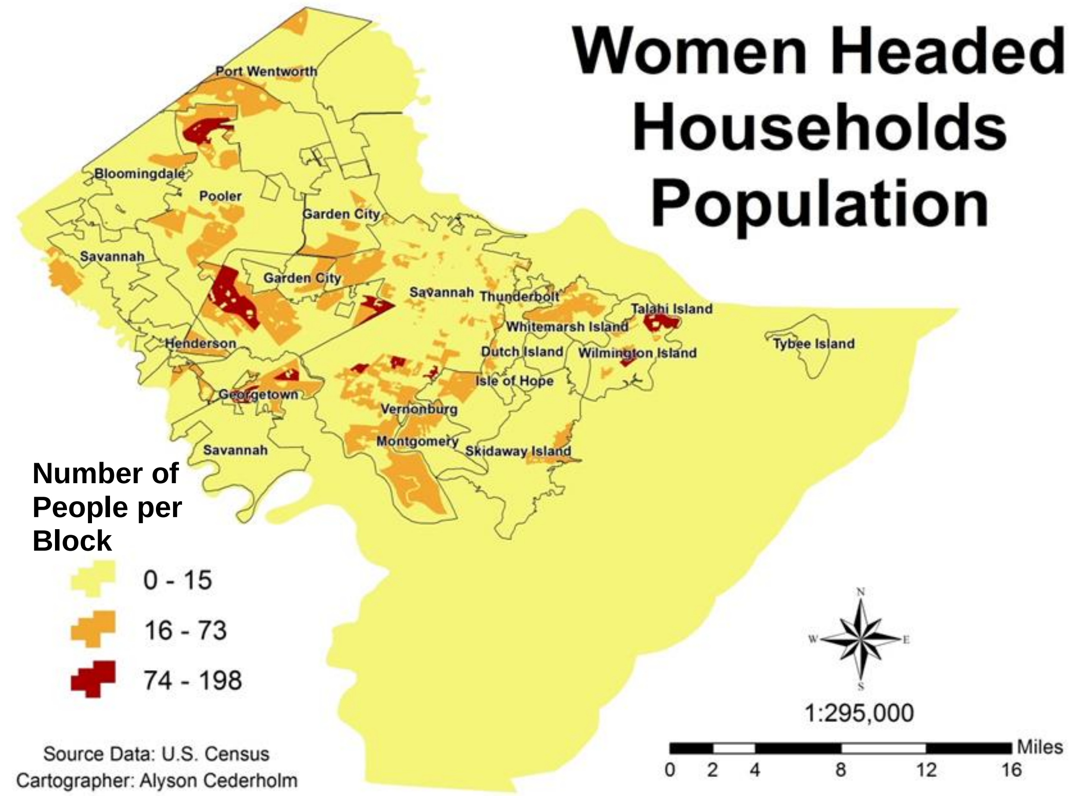
Turner, B.L., Roger E. Kasperson, and Pamela A. Matson et al. "A framework for vulnerability analysis in sustainability science." *Proceedings of the National Academy of Sciences*. no. 14 (2003): 8074-8079.

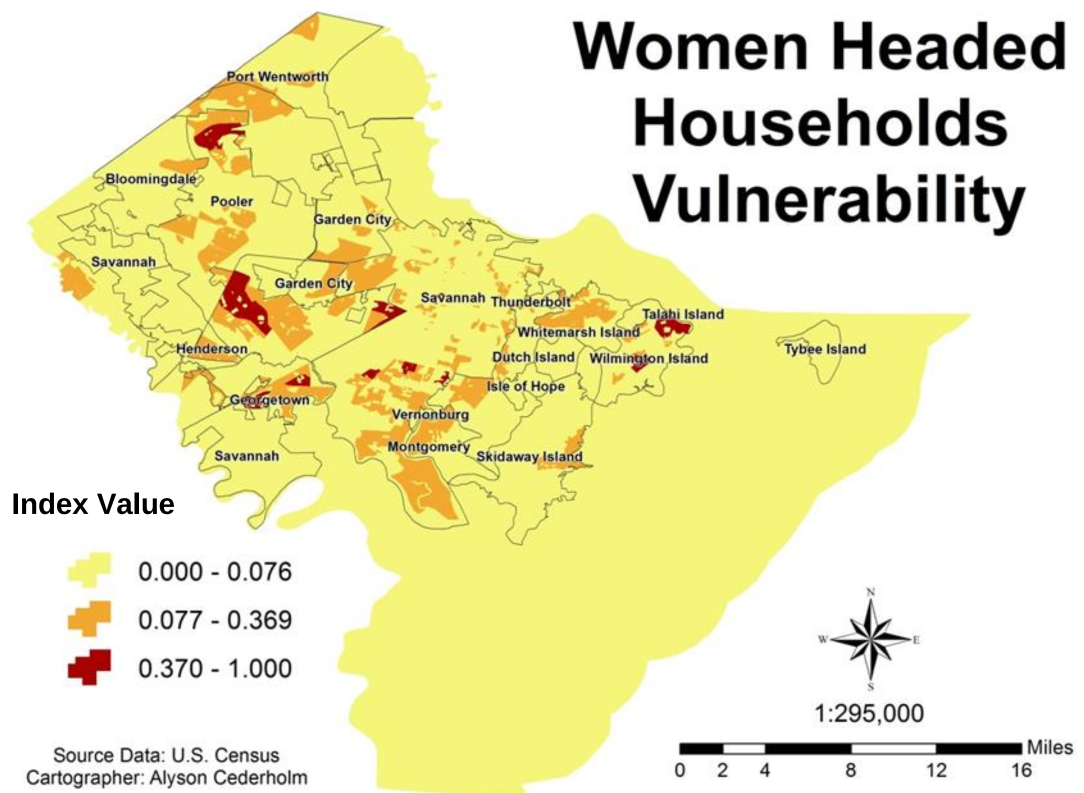
U.S. Army Corps of Engineers, "Chatham County Emergency Operation Plan Incident Annex A, Appendix 5 Historic Storm Tide Elevations." Last modified 2009. Accessed February 21, 2013. http://www.chathamemergency.org/documents/EOP INCIDENT ANNEX A APPENDIX 5 HISTORIC STORM TIDE ELEVATIONS REV0709.pdf.

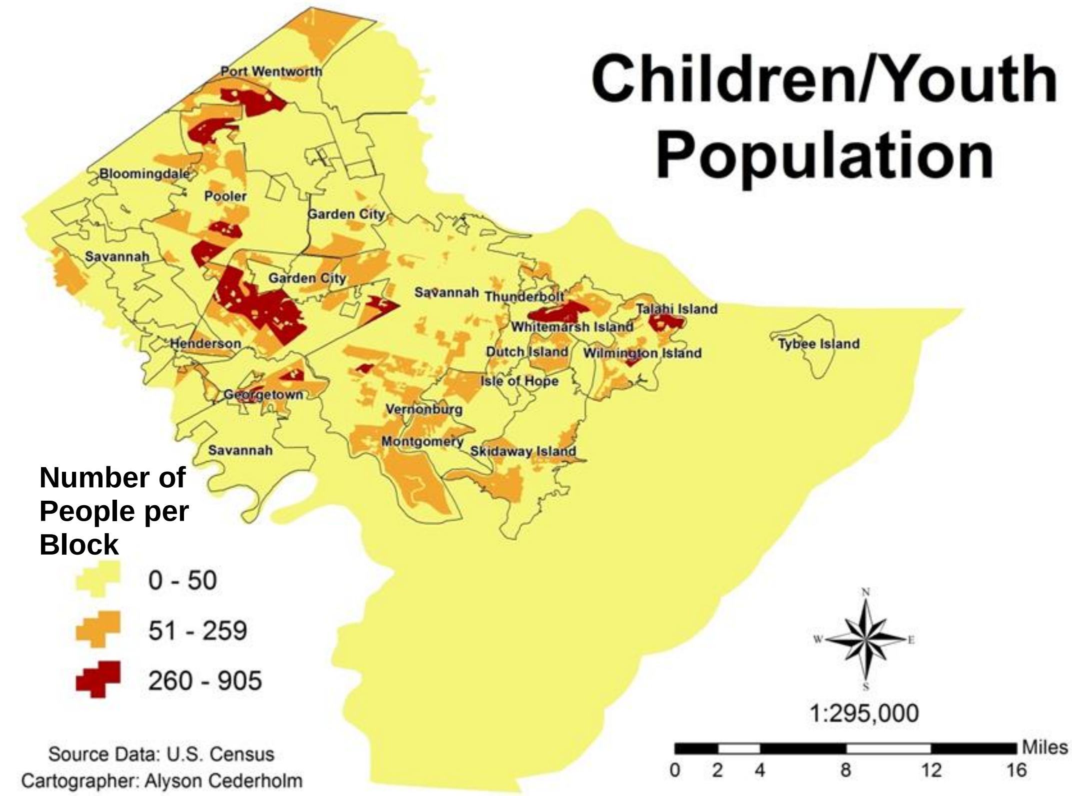
United States Census Bureau , "State and County Quick Facts ." Last modified 2014. Accessed March 29, 2014. http://quickfacts.census.gov/qfd/states/13/13051.html.

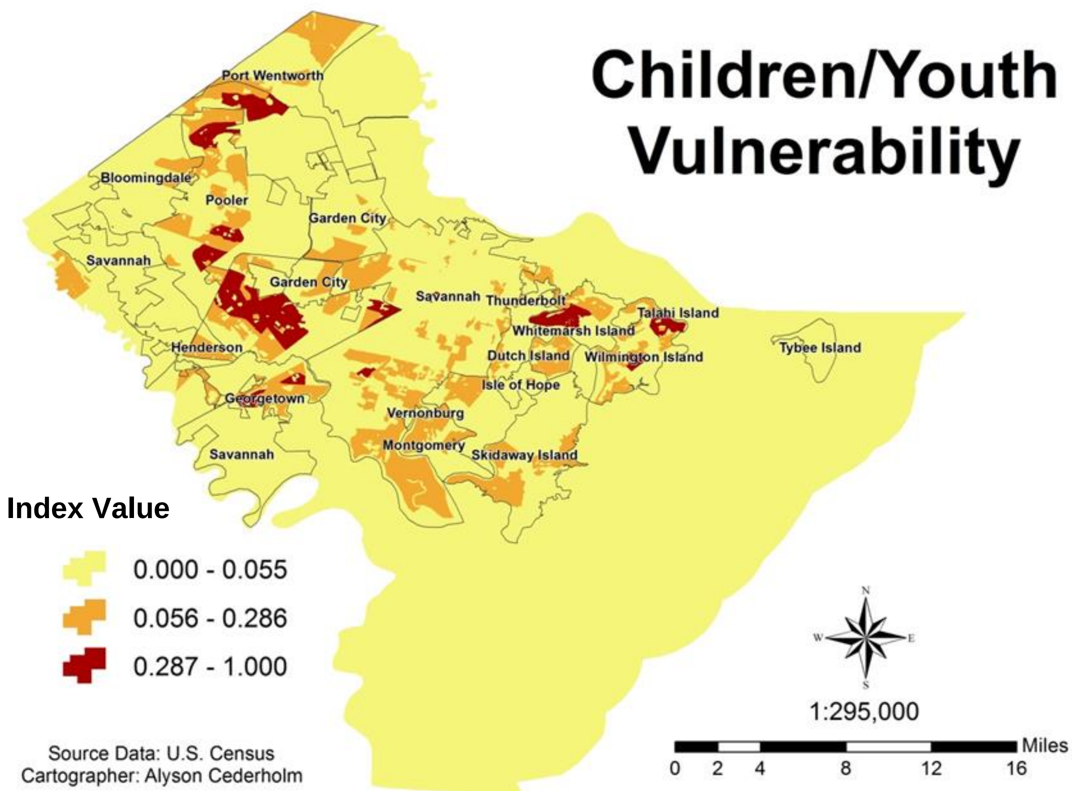
Appendix 1

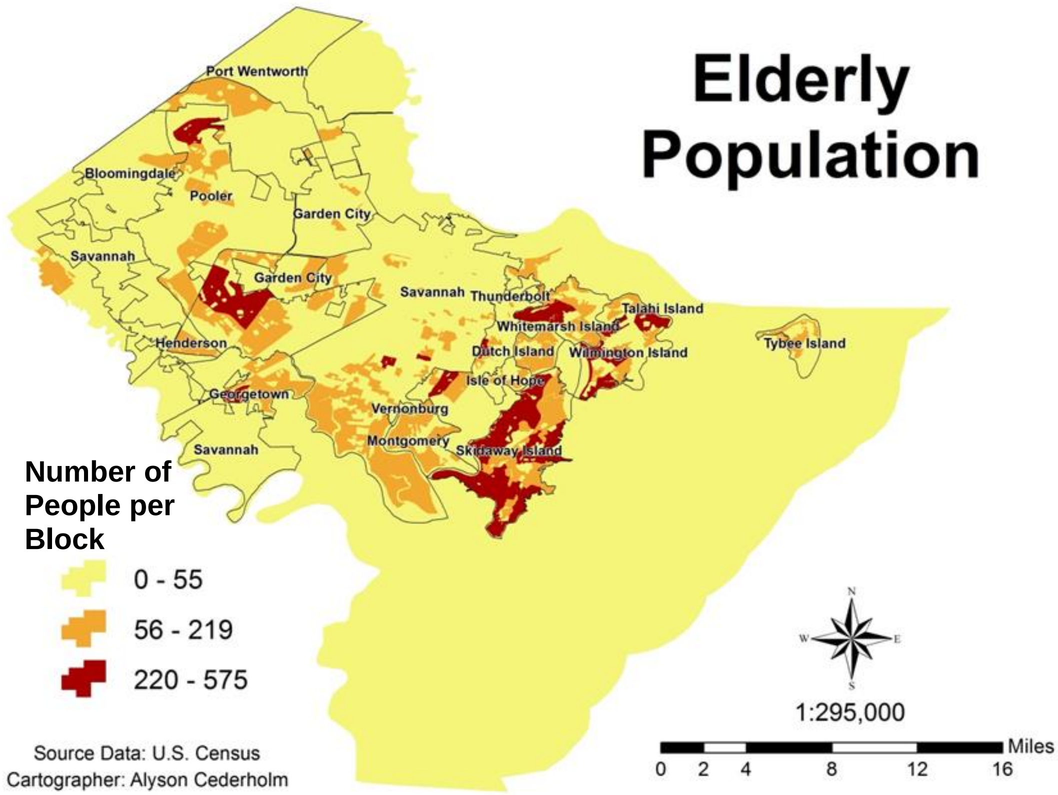
Social Vulnerability Maps

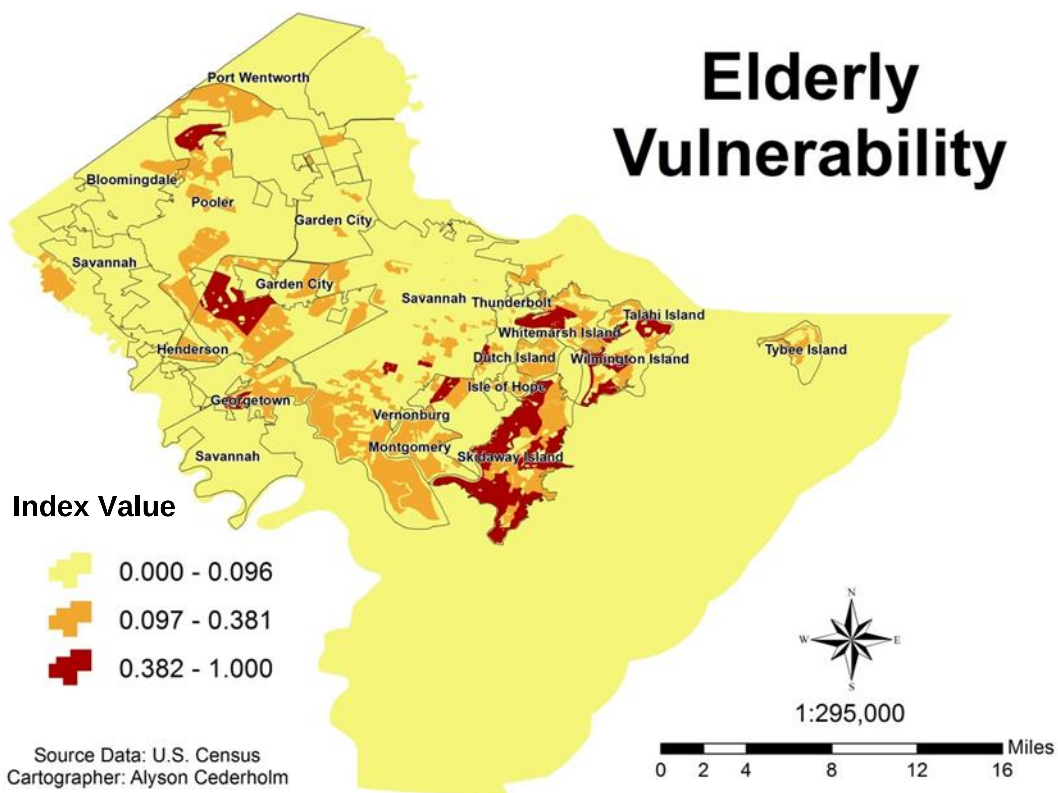

Women Headed Households Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 15
16 - 73
74 - 198
1:295,000
Miles
0 2 4 8 12 16
Source Data: U.S. Census
Cartographer: Alyson Cederholm

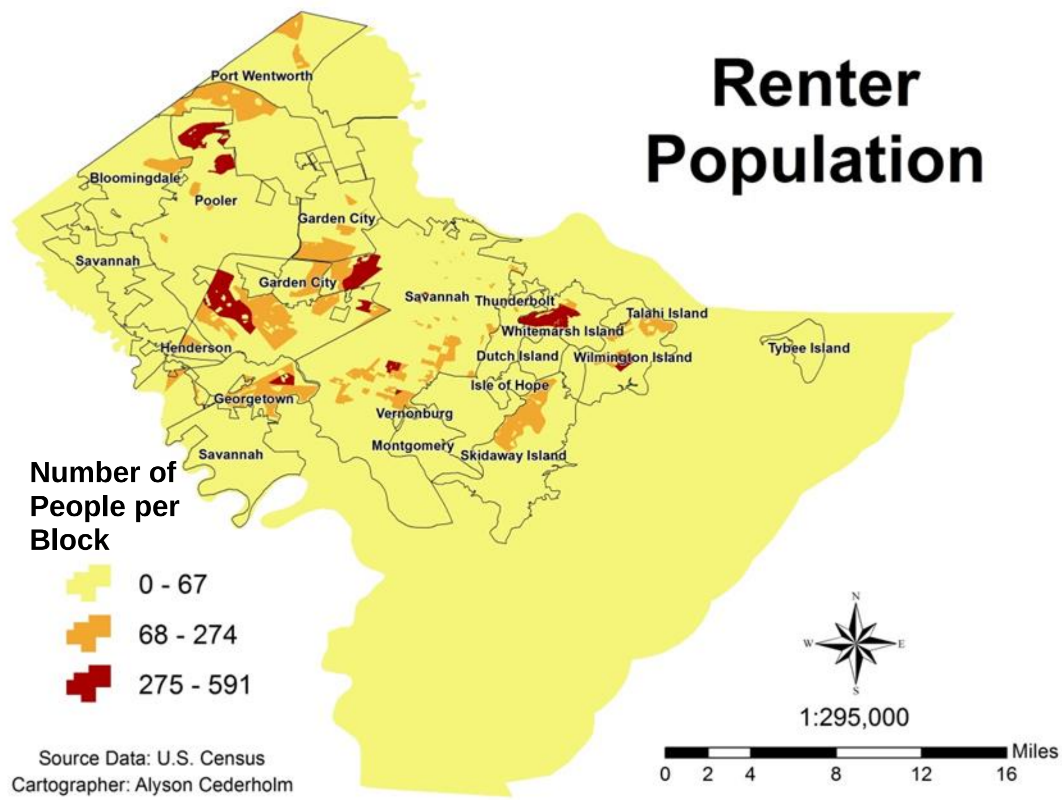

Women Headed Households Vulnerability
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Index Value
0.000 - 0.076
0.077 - 0.369
0.370 - 1.000
1:295,000
Miles
0 2 4 8 12 16
Source Data: U.S. Census
Cartographer: Alyson Cederholm

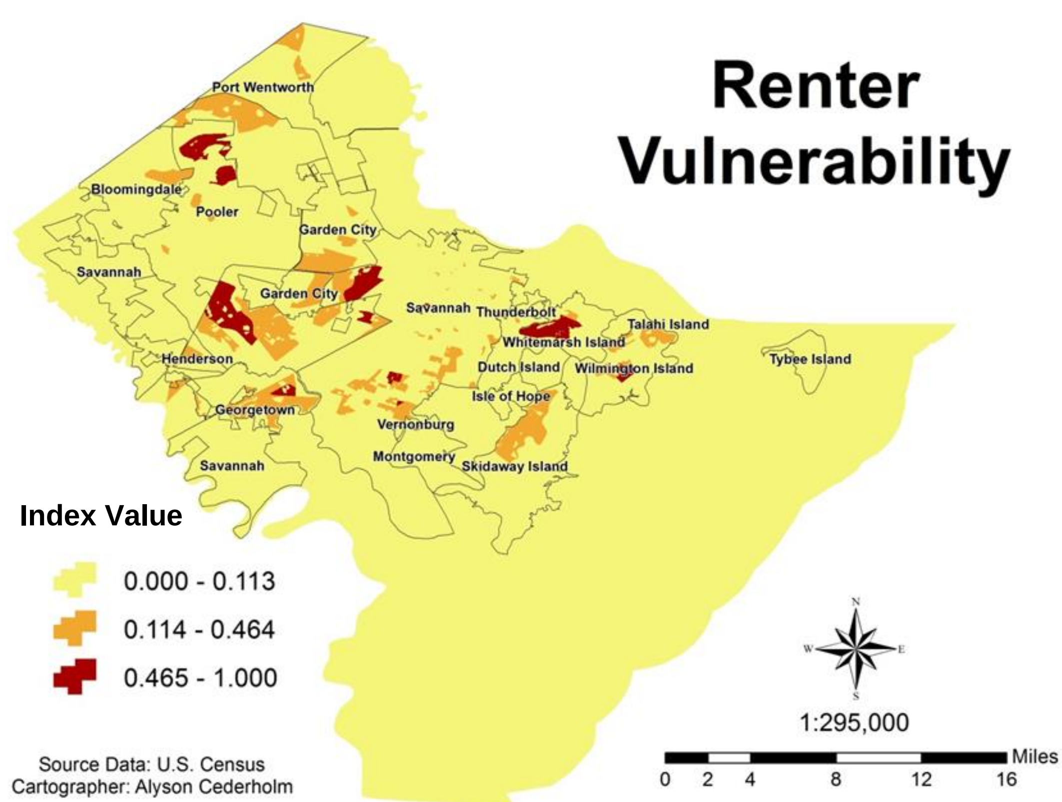

Children/Youth Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 50
51 - 259
260 - 905
1:295,000
Miles
0 2 4 8 12 16
Source Data: U.S. Census
Cartographer: Alyson Cederholm

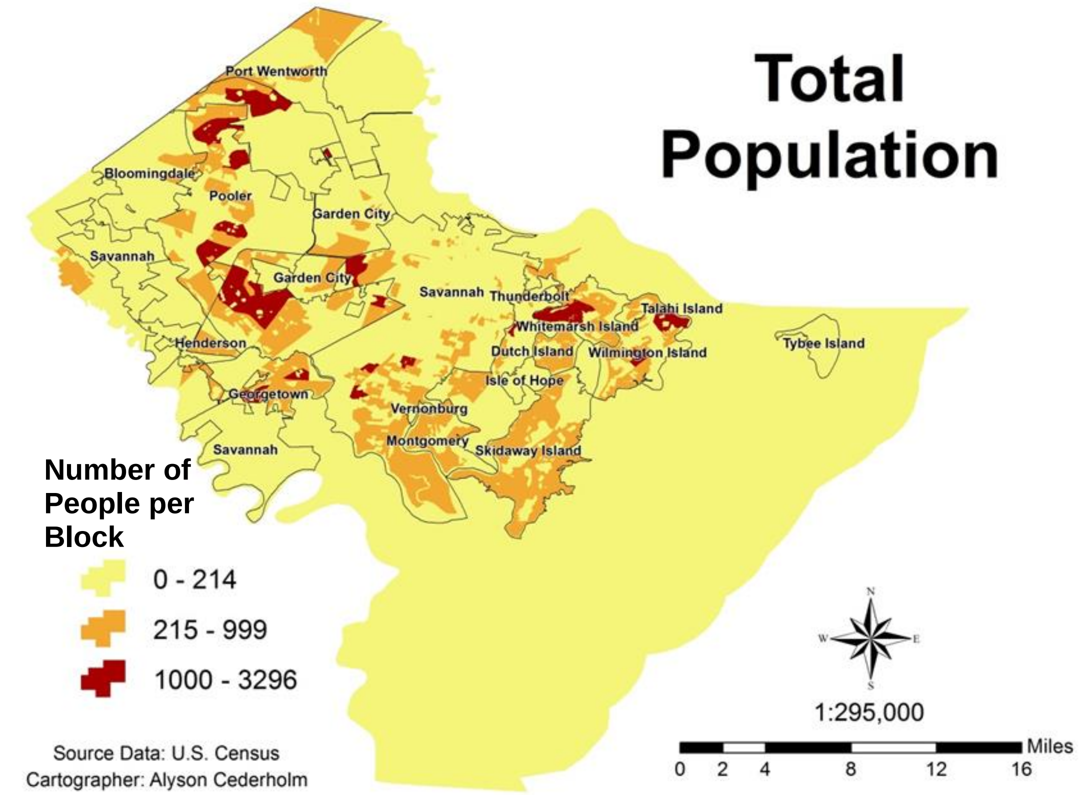

Children/Youth Vulnerability
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Index Value
0.000 - 0.055
0.056 - 0.286
0.287 - 1.000
1:295,000
Miles
0 2 4 8 12 16
Source Data: U.S. Census
Cartographer: Alyson Cederholm

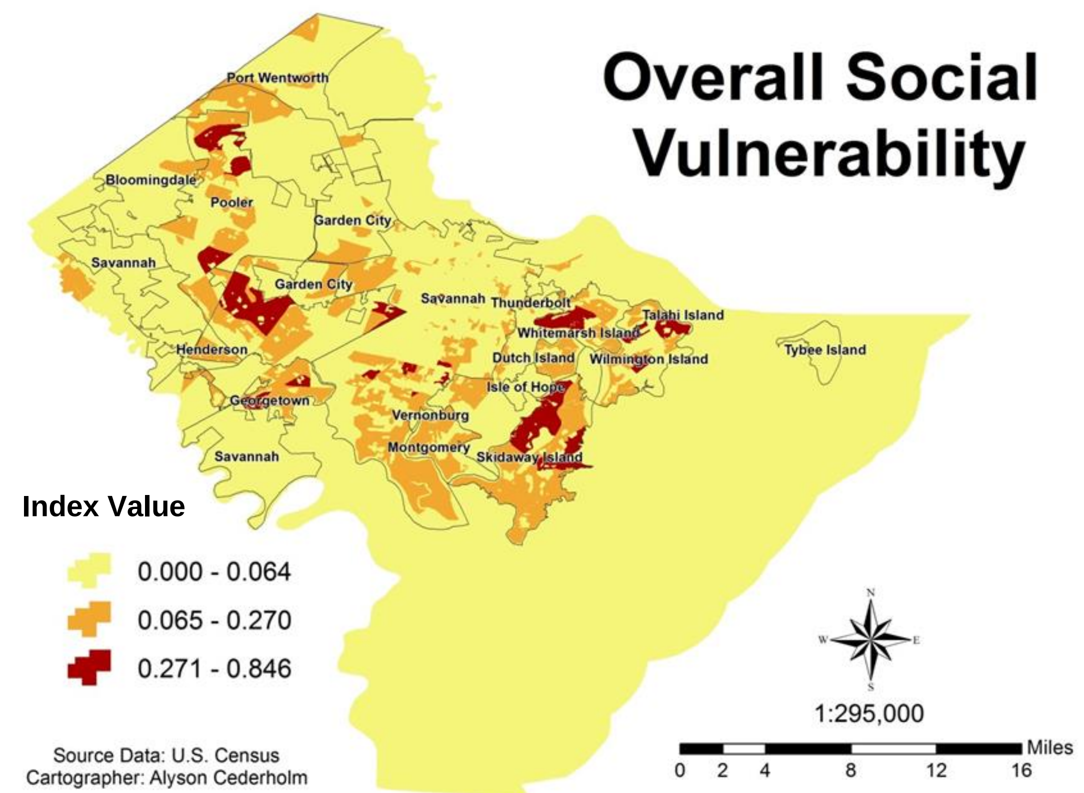

Elderly Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 55
56 - 219
220 - 575
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16
Source Data: U.S. Census
Cartographer: Alyson Cederholm


Elderly Vulnerability
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Index Value
0.000 - 0.096
0.097 - 0.381
0.382 - 1.000
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16
Source Data: U.S. Census
Cartographer: Alyson Cederholm


Renter Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 67
68 - 274
275 - 591
1:295,000
Miles
0 2 4 8 12 16
Source Data: U.S. Census
Cartographer: Alyson Cederholm

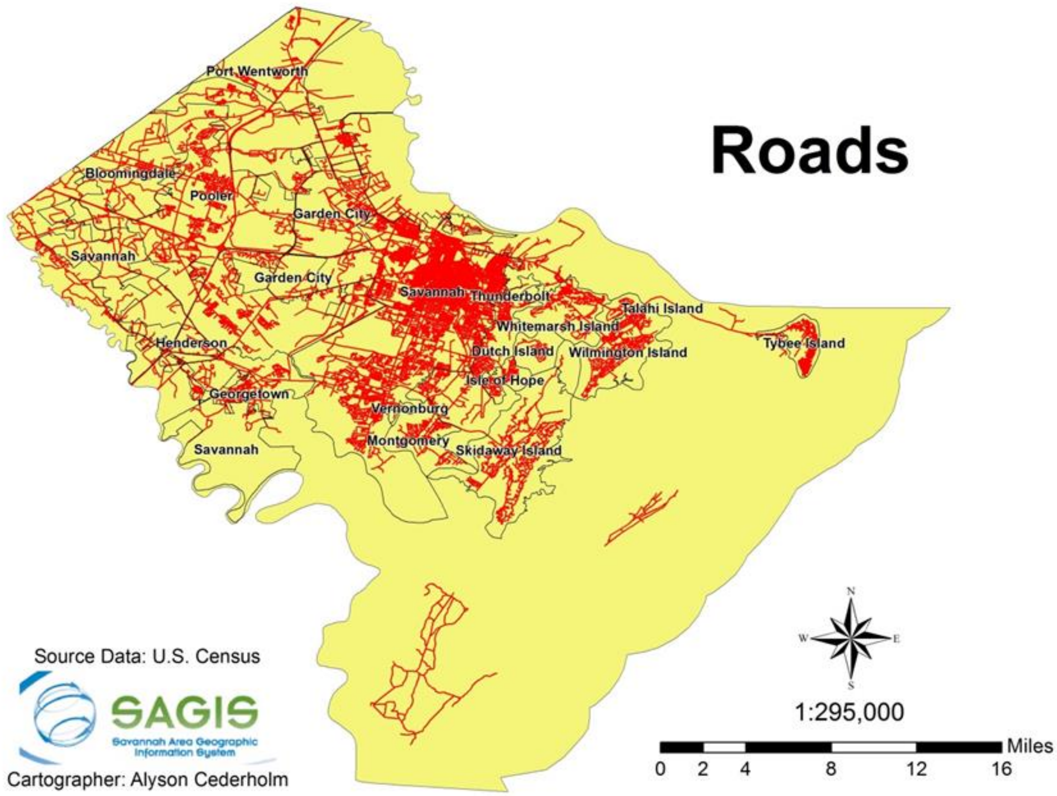

Renter Vulnerability
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Index Value
0.000 - 0.113
0.114 - 0.464
0.465 - 1.000
1:295,000
Miles
0 2 4 8 12 16
Source Data: U.S. Census
Cartographer: Alyson Cederholm

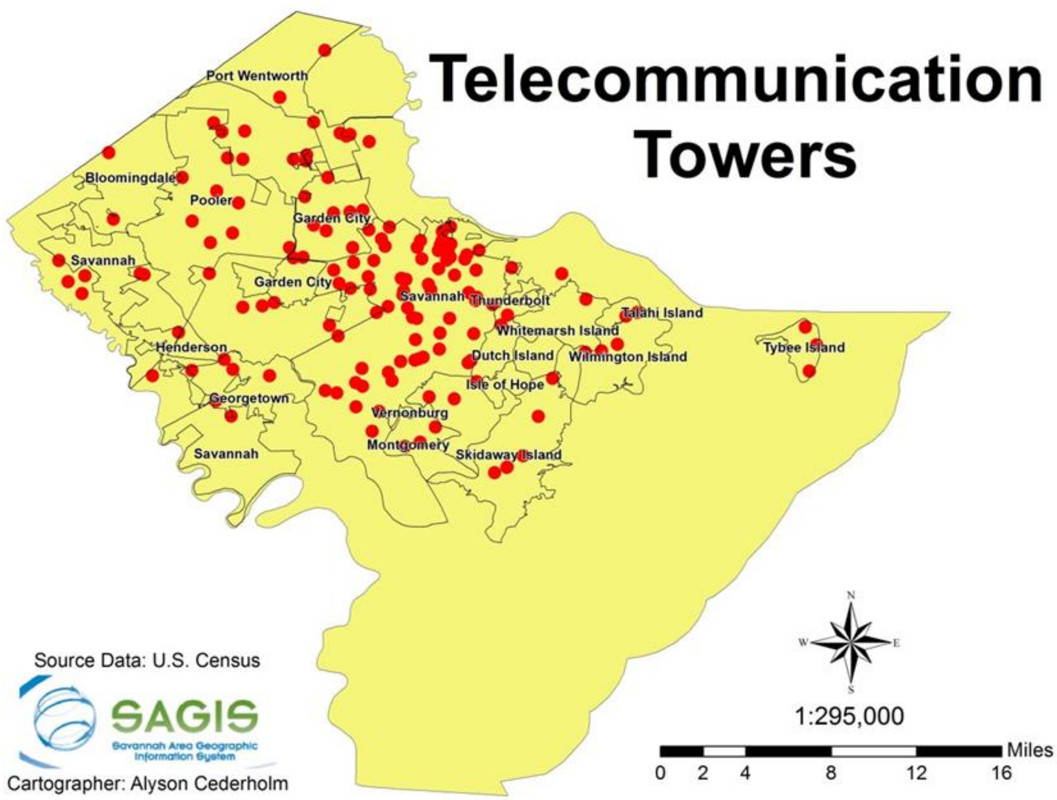

Total Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 214
215 - 999
1000 - 3296
1:295,000
Miles
0 2 4 8 12 16
Source Data: U.S. Census
Cartographer: Alyson Cederholm

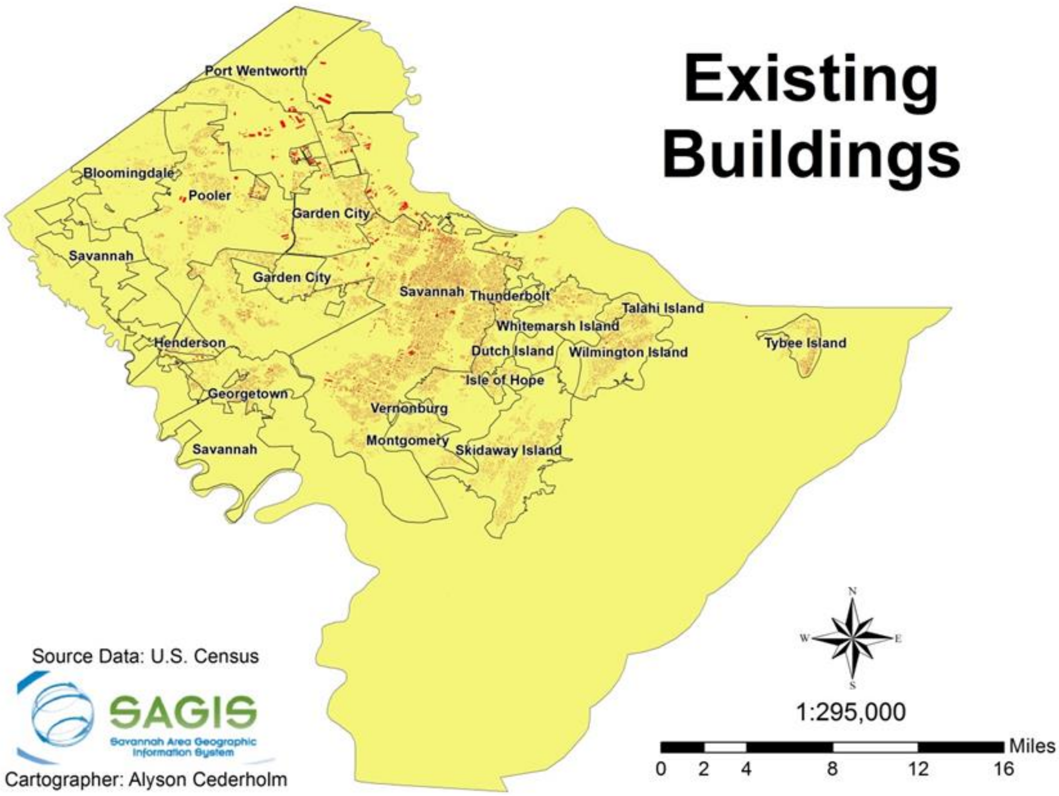

Overall Social Vulnerability
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Index Value
0.000 - 0.064
0.065 - 0.270
0.271 - 0.846
1:295,000
Miles
0 2 4 8 12 16
Source Data: U.S. Census
Cartographer: Alyson Cederholm

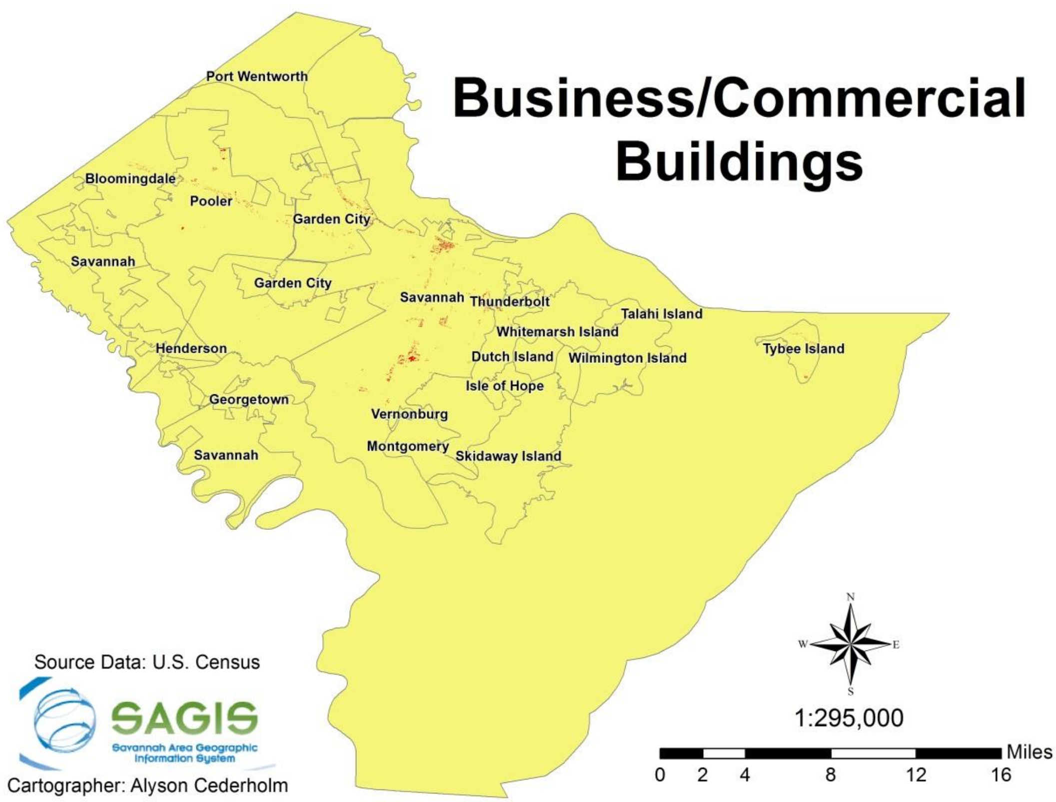
Appendix 2

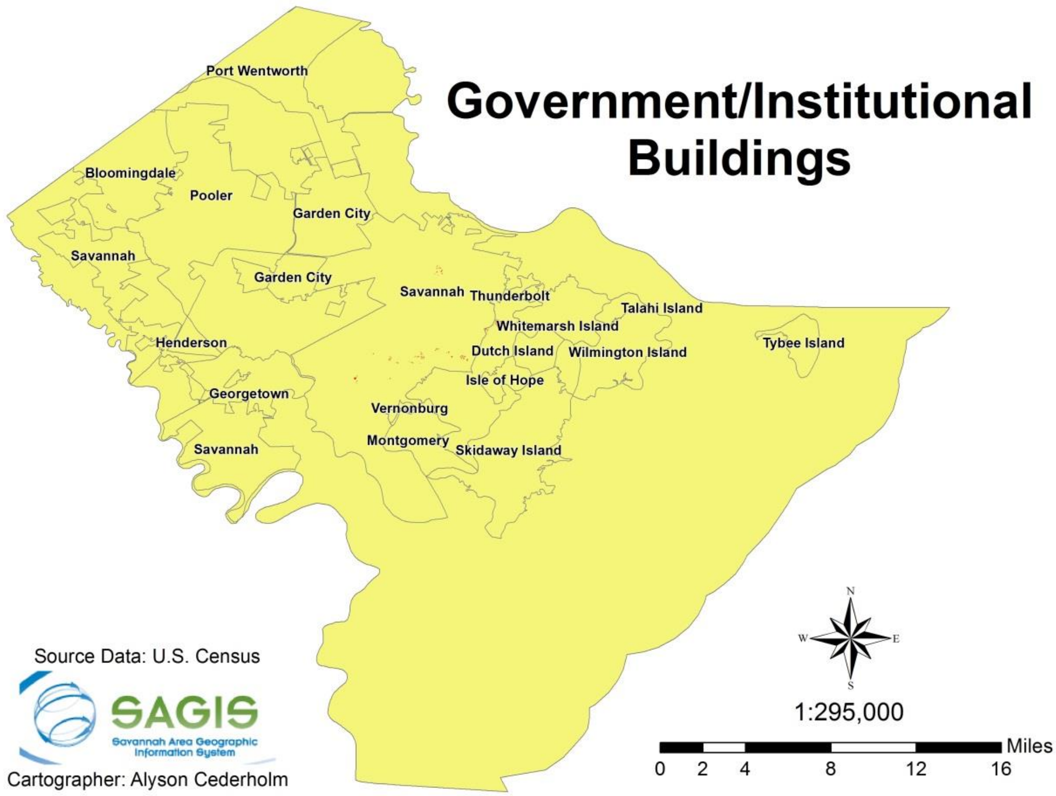
Building and Infrastructure Maps

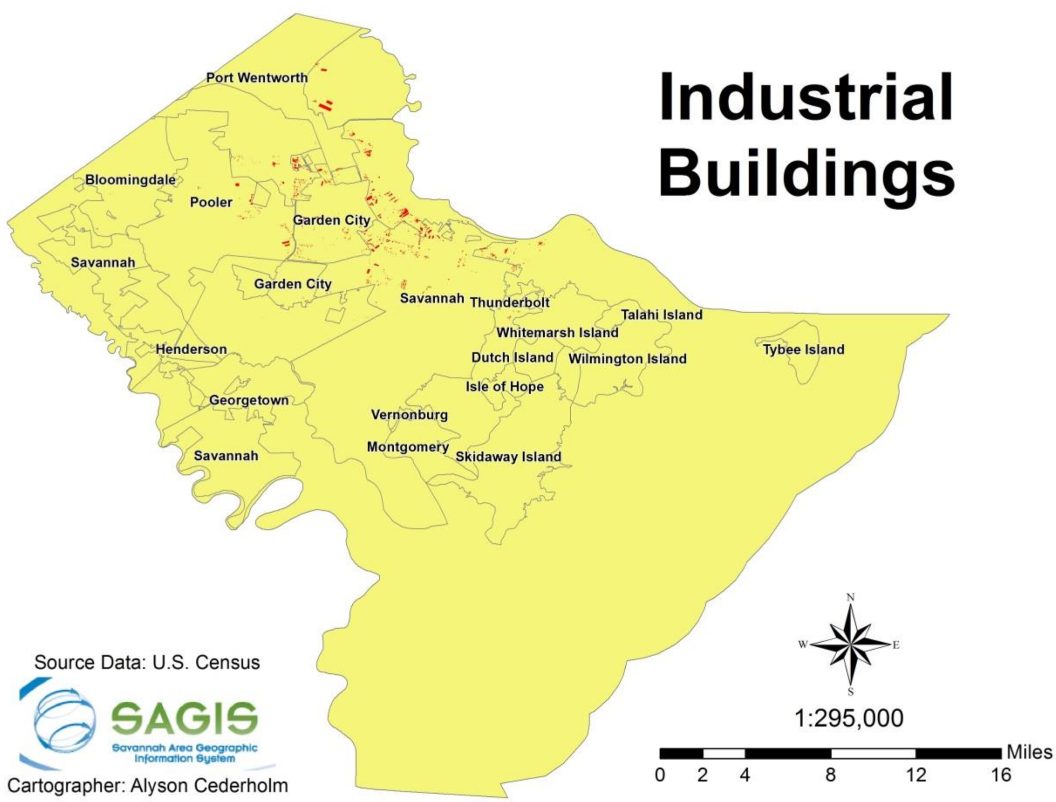

Roads
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Tybee Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

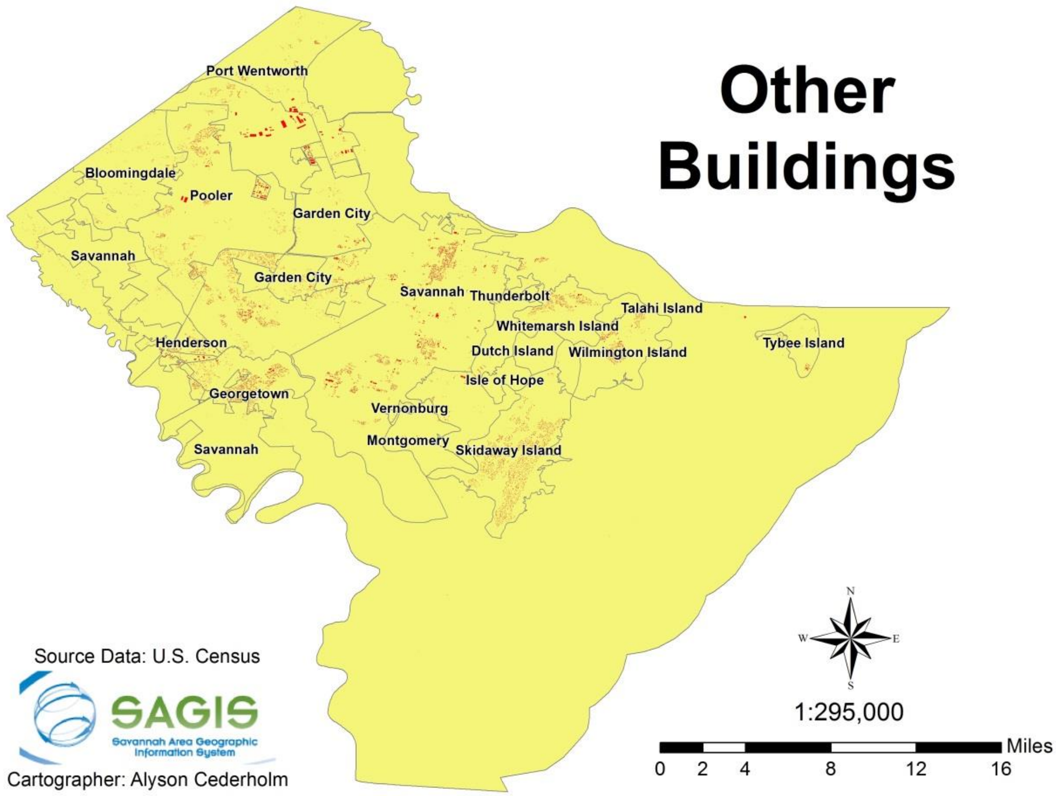

Telecommunication Towers
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Tybee Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

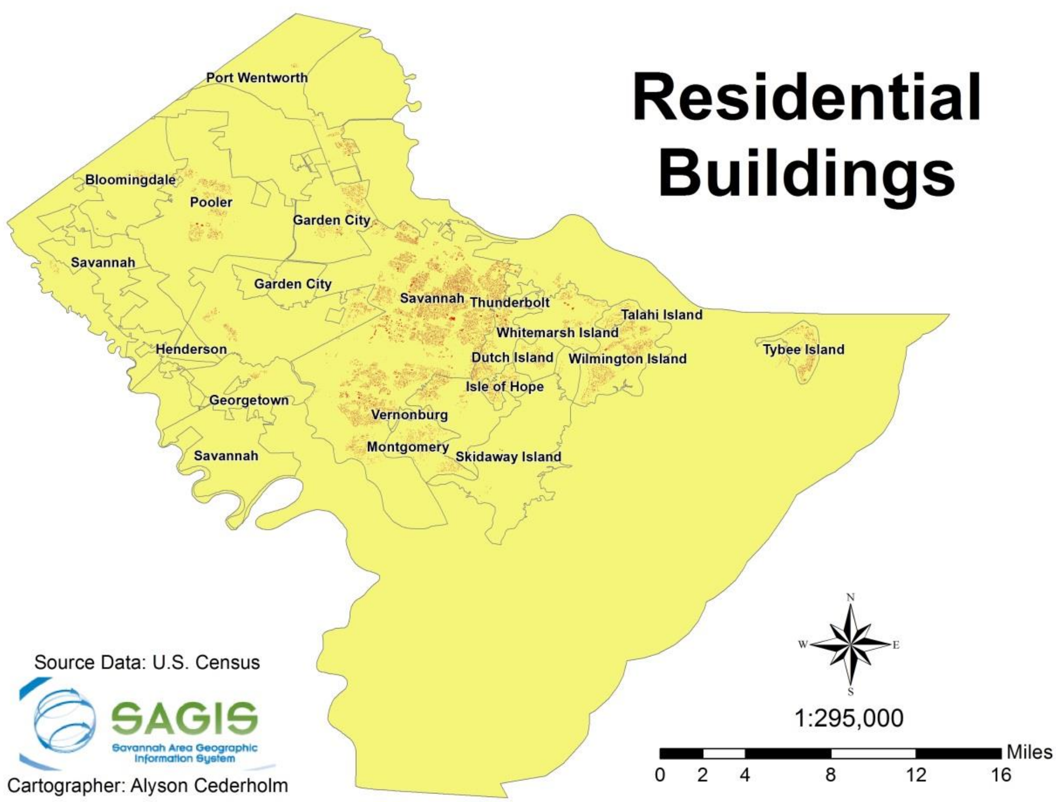

Existing Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

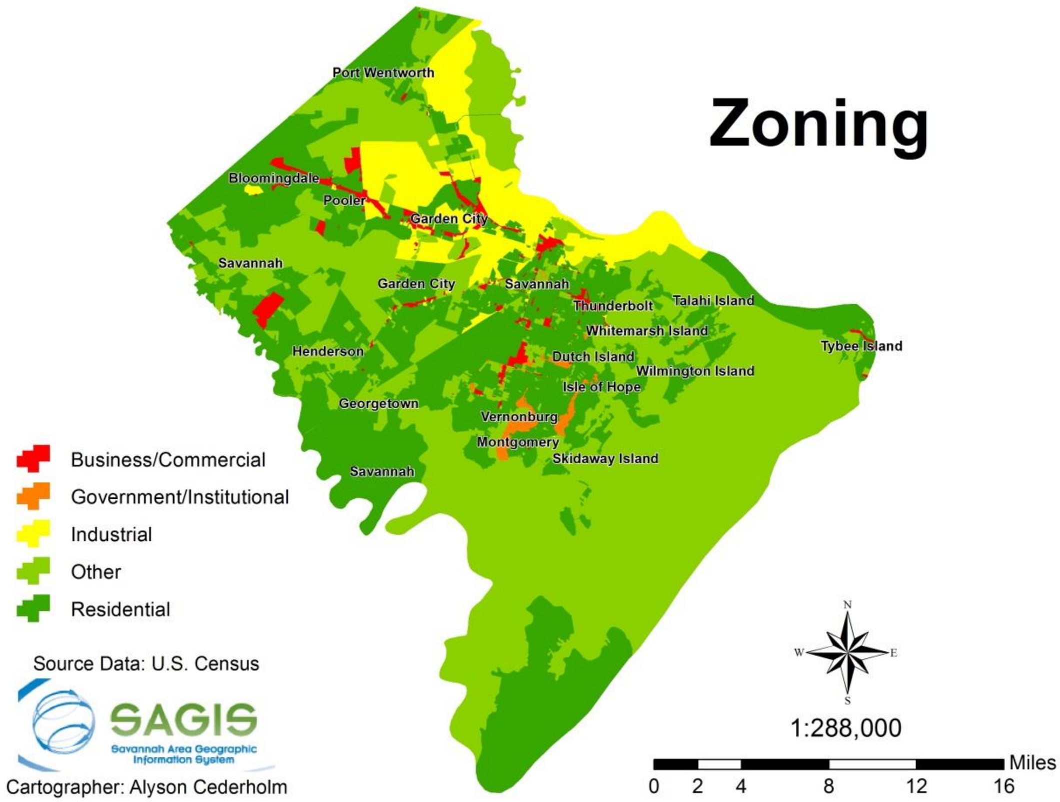

Business/Commercial Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16


Government/Institutional Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16


Industrial Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

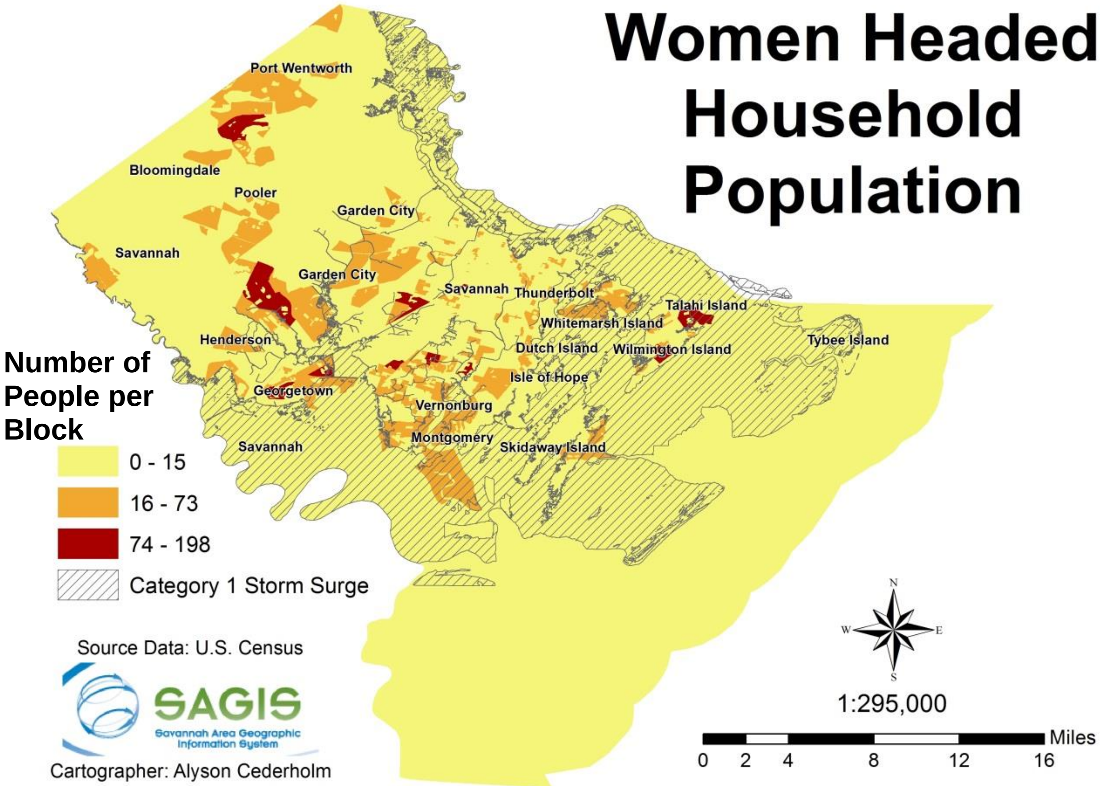

Other
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

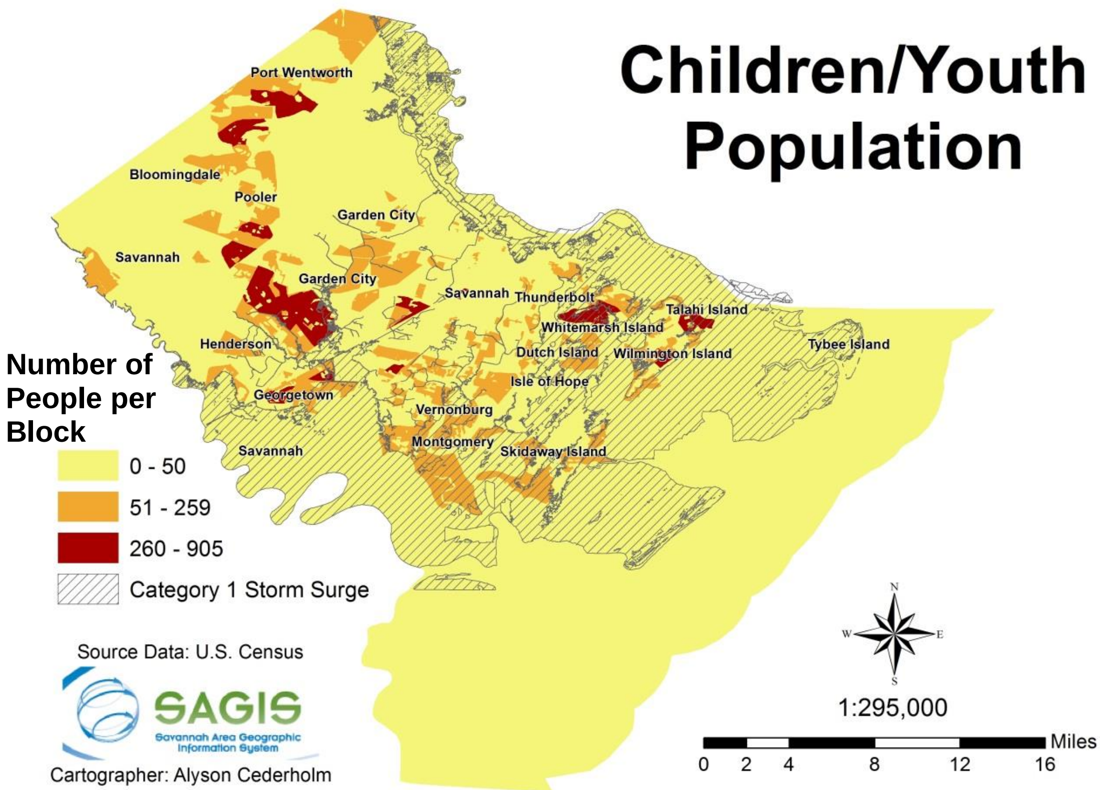

Residential
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

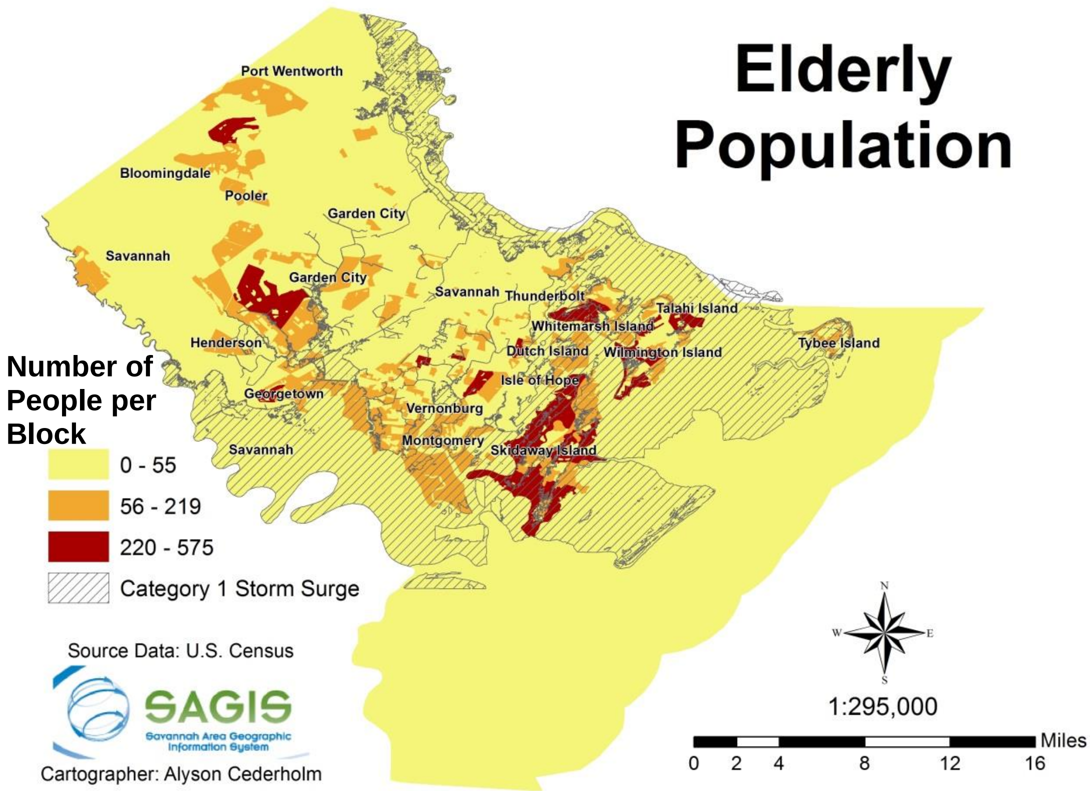

Zoning
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Business/Commercial
Government/Institutional
Industrial
Other
Residential
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:288,000
Miles
0 2 4 8 12 16

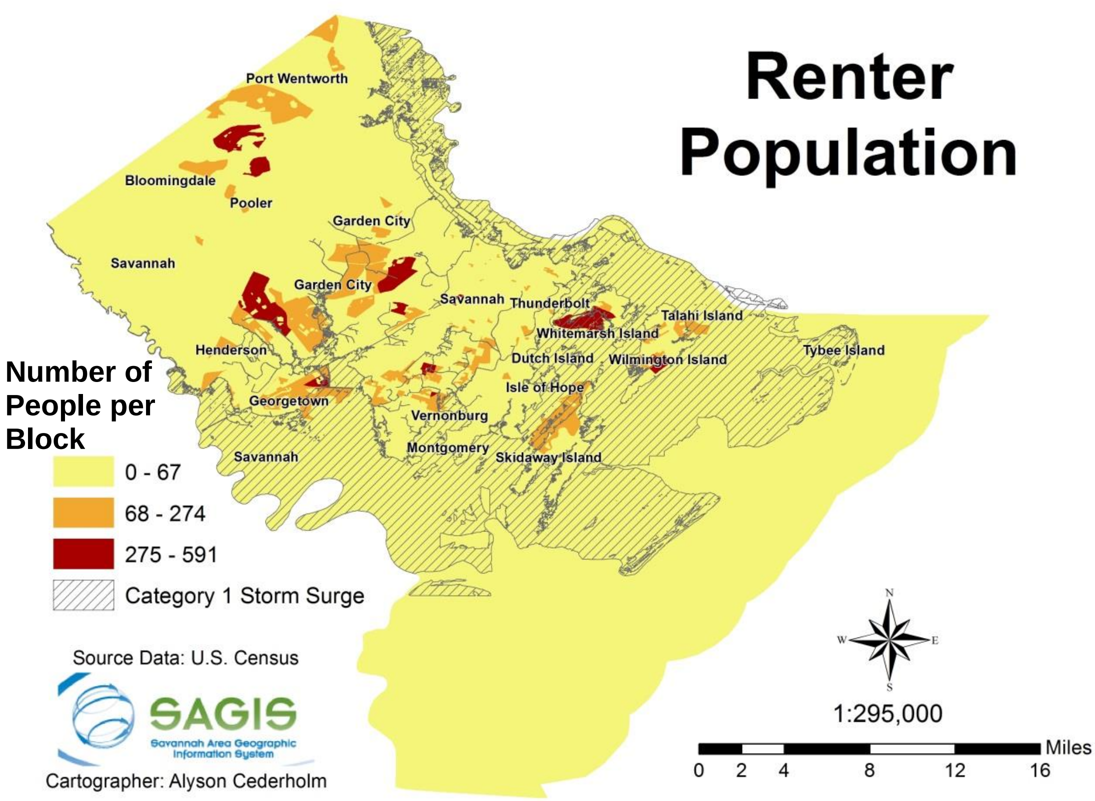
Appendix 3

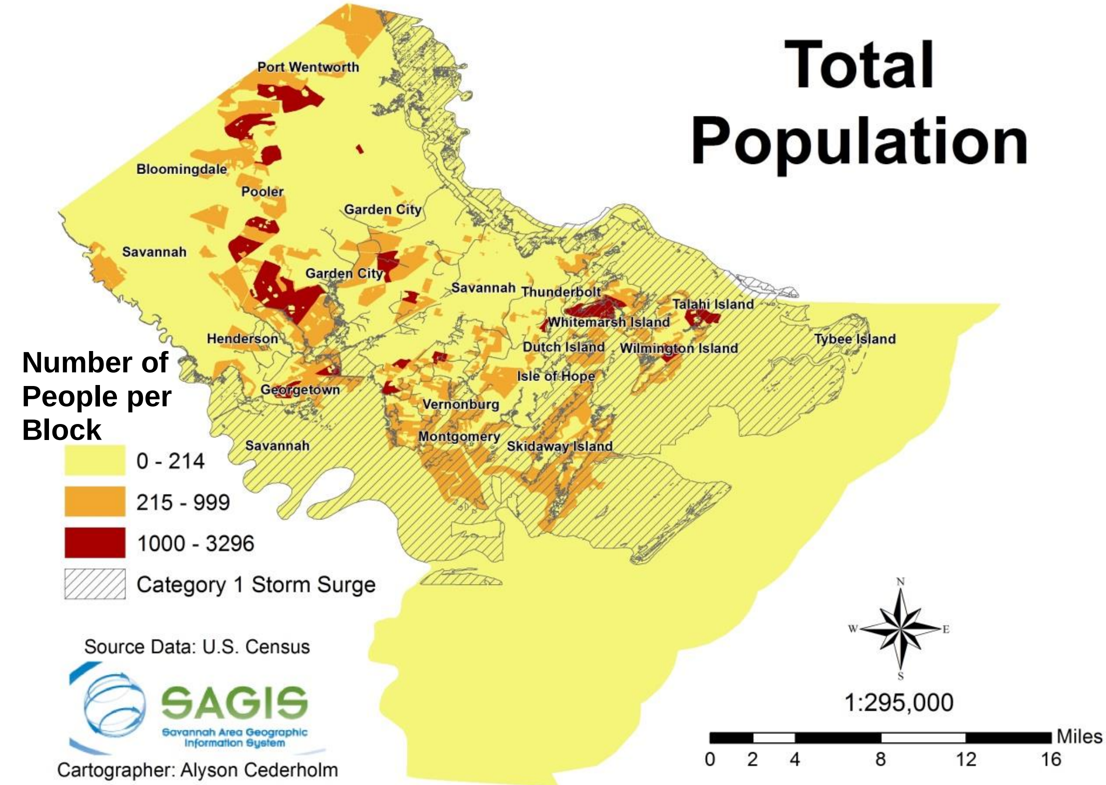
Category 1 Storm Surge Maps

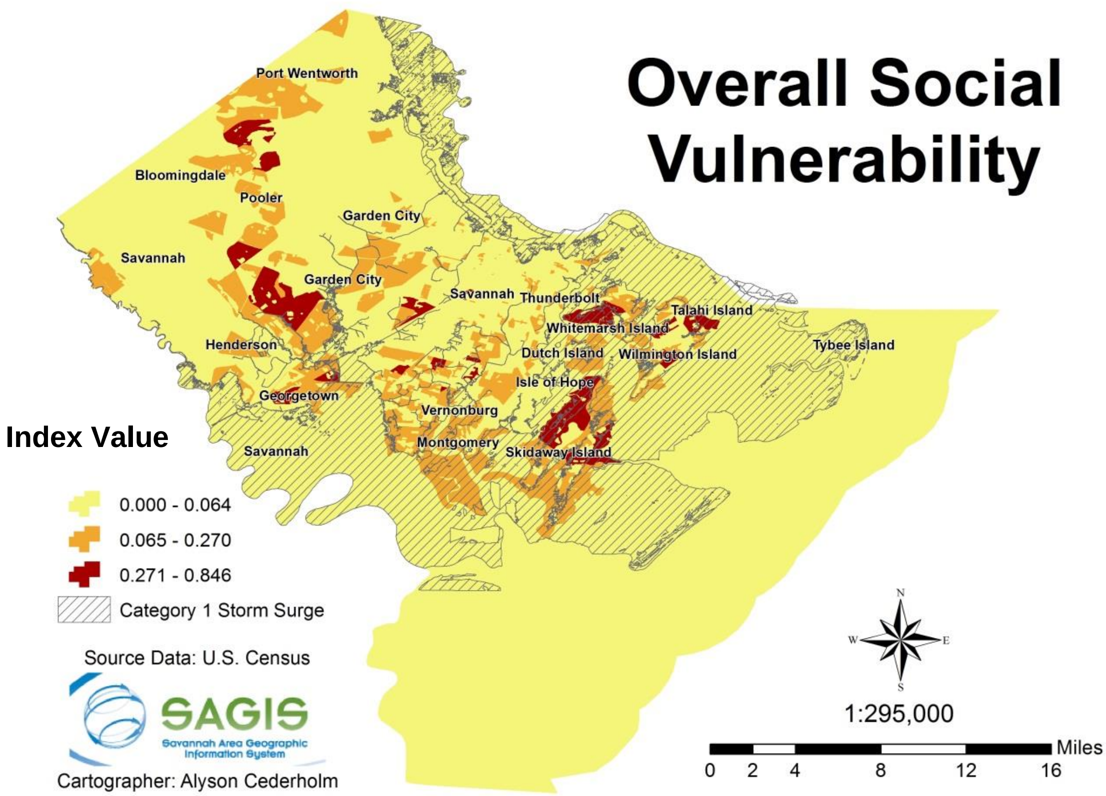

Women Headed Household Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Number of People per Block
0 - 15
16 - 73
74 - 198
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

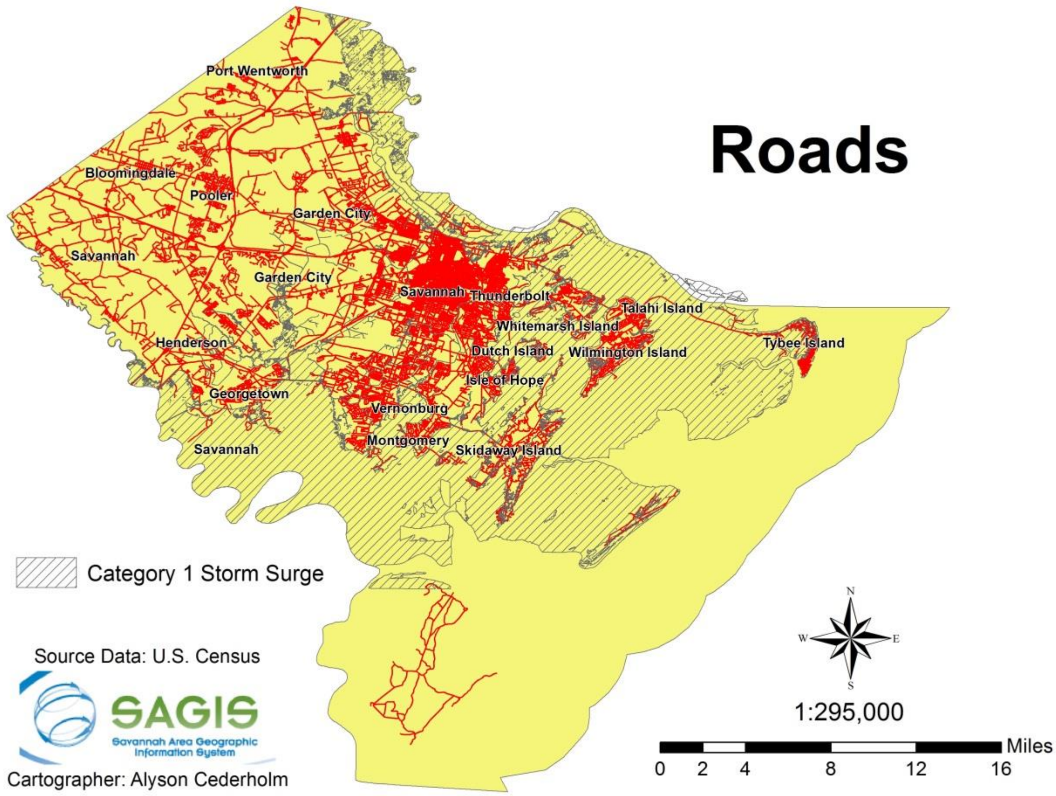

Children/Youth Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Number of People per Block
0 - 50
51 - 259
260 - 905
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

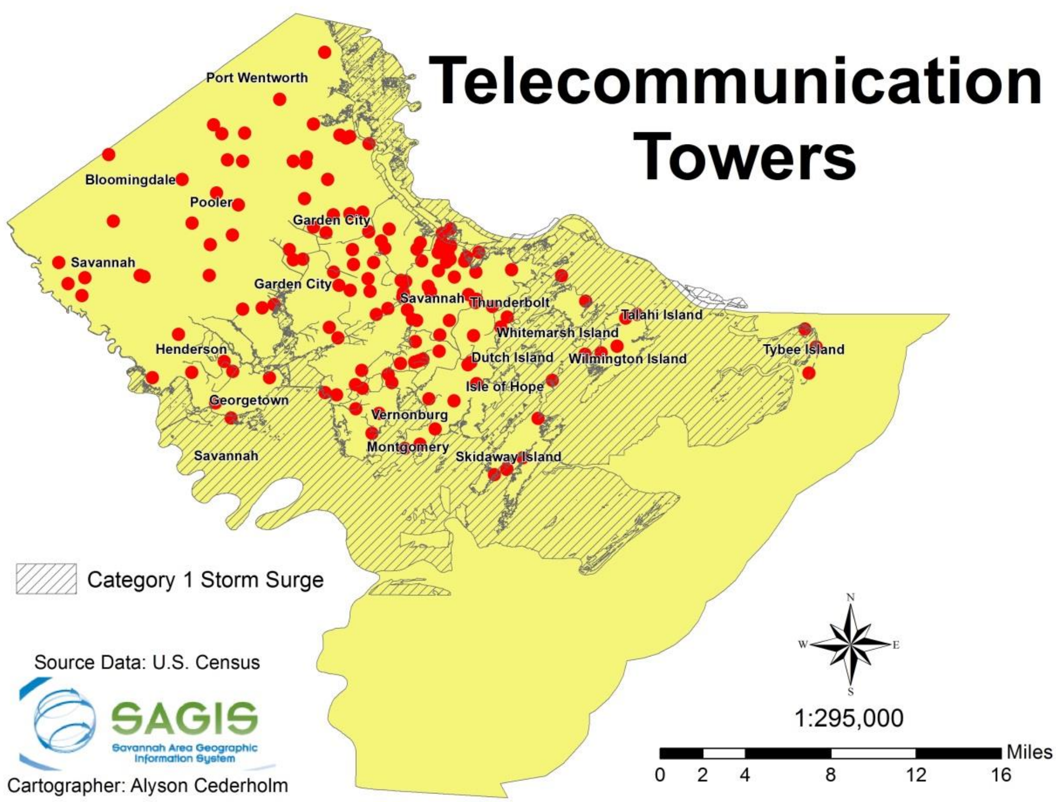

Elderly
Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 55
56 - 219
220 - 575
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

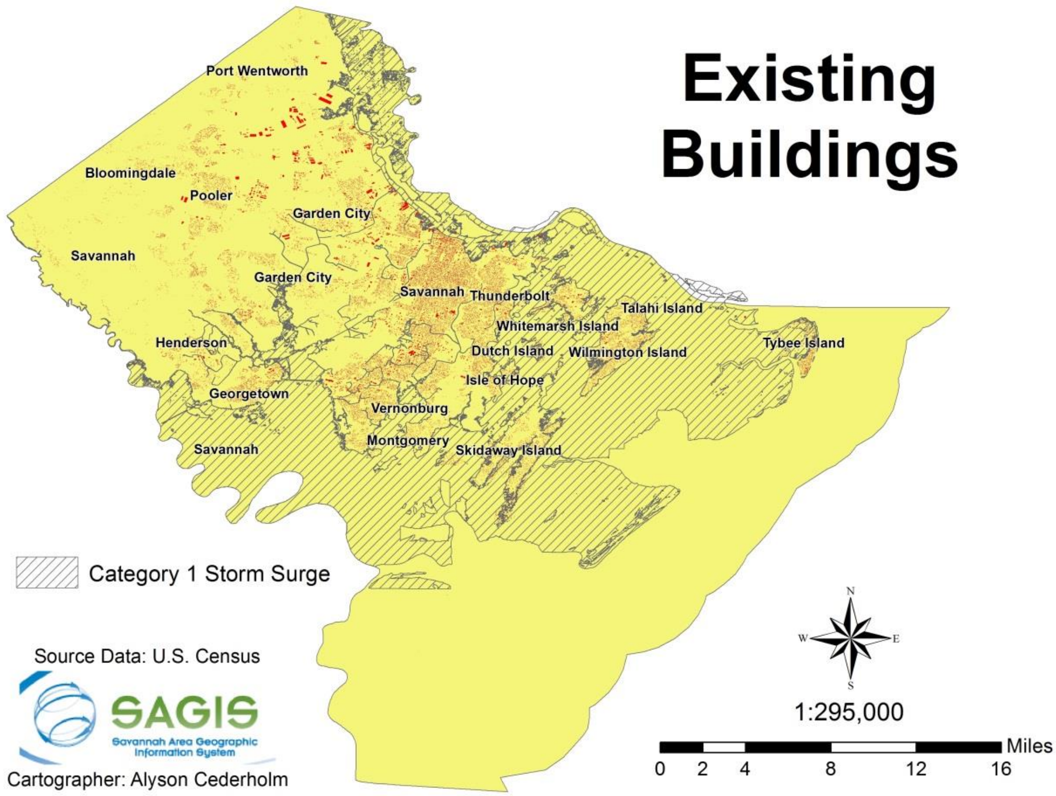

Renter
Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 67
68 - 274
275 - 591
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

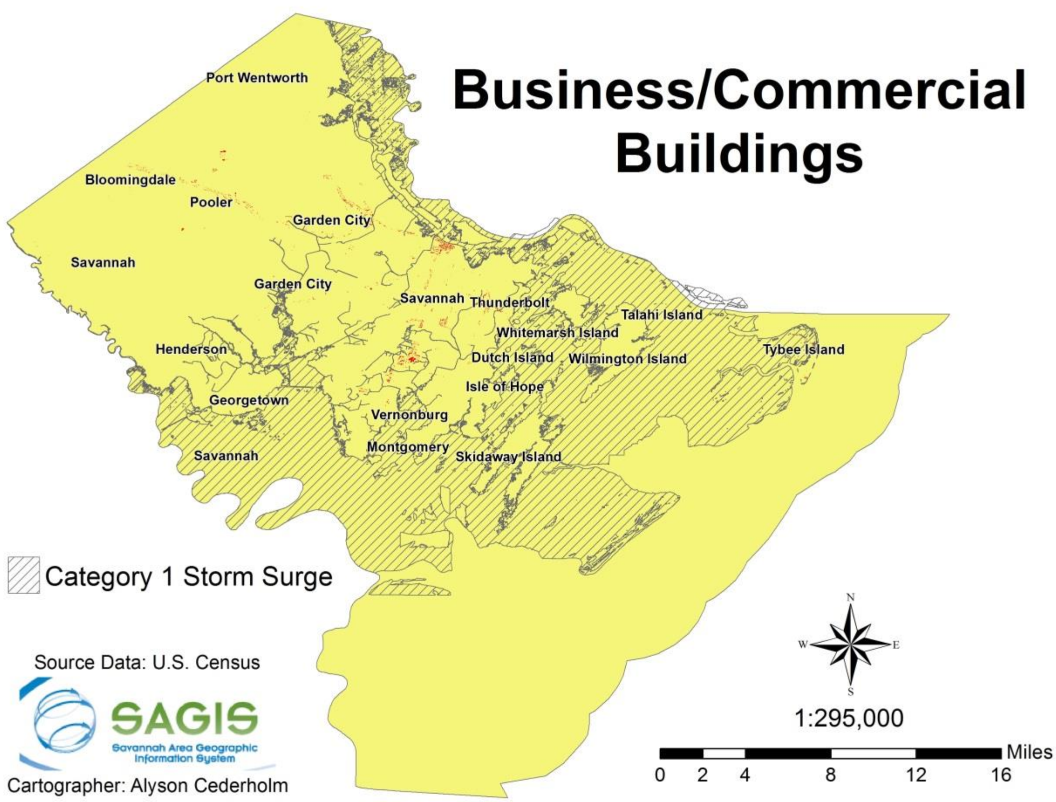

Total Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 214
215 - 999
1000 - 3296
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
0 2 4 8 12 16 Miles

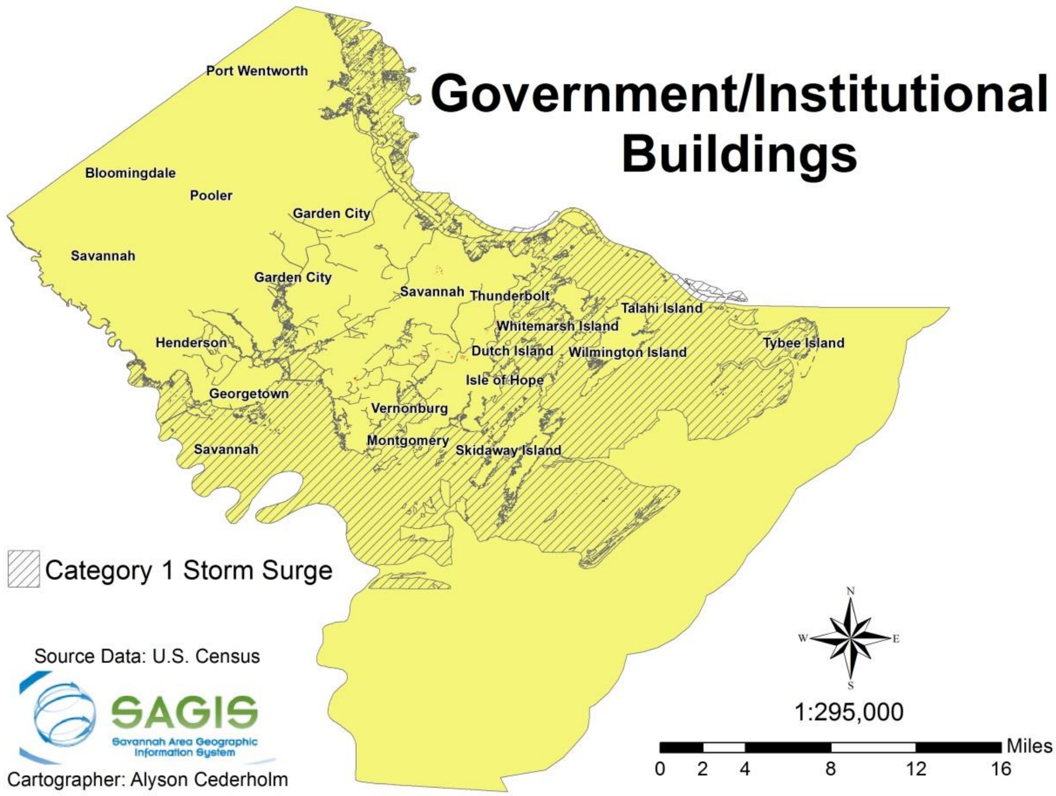

Overall Social Vulnerability
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Index Value
0.000 - 0.064
0.065 - 0.270
0.271 - 0.846
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
0 2 4 8 12 16 Miles

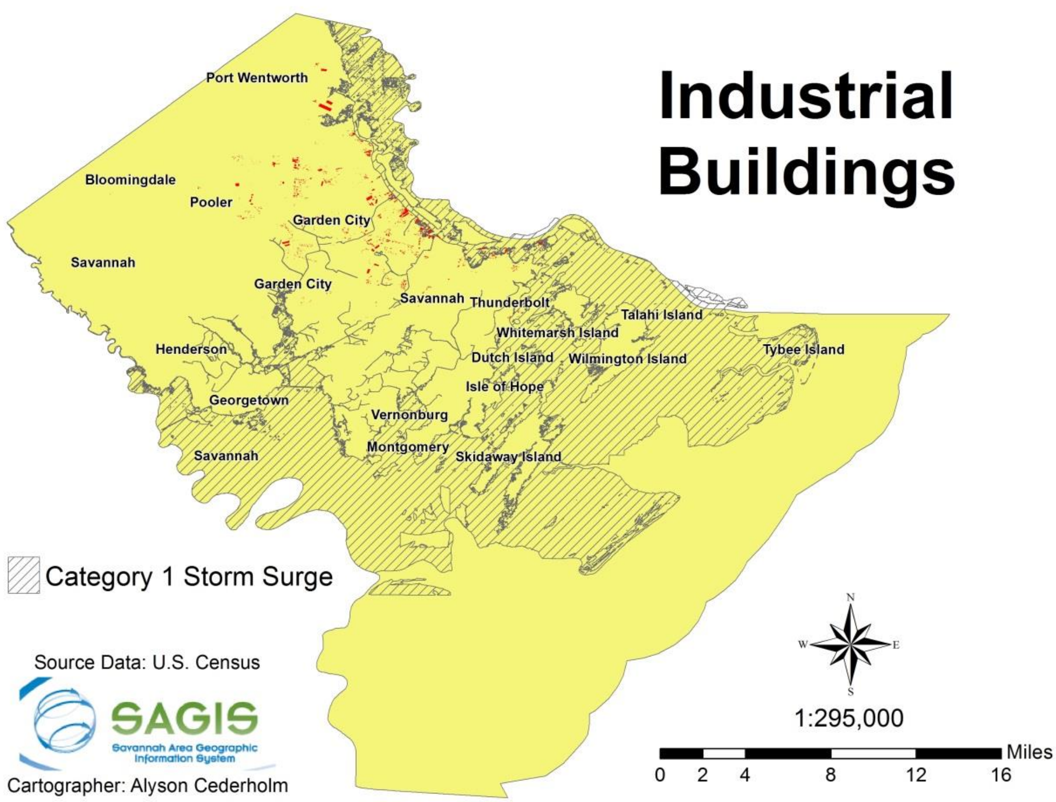

Roads
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Category 1 Storm Surge
Source Data: U.S. Census
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

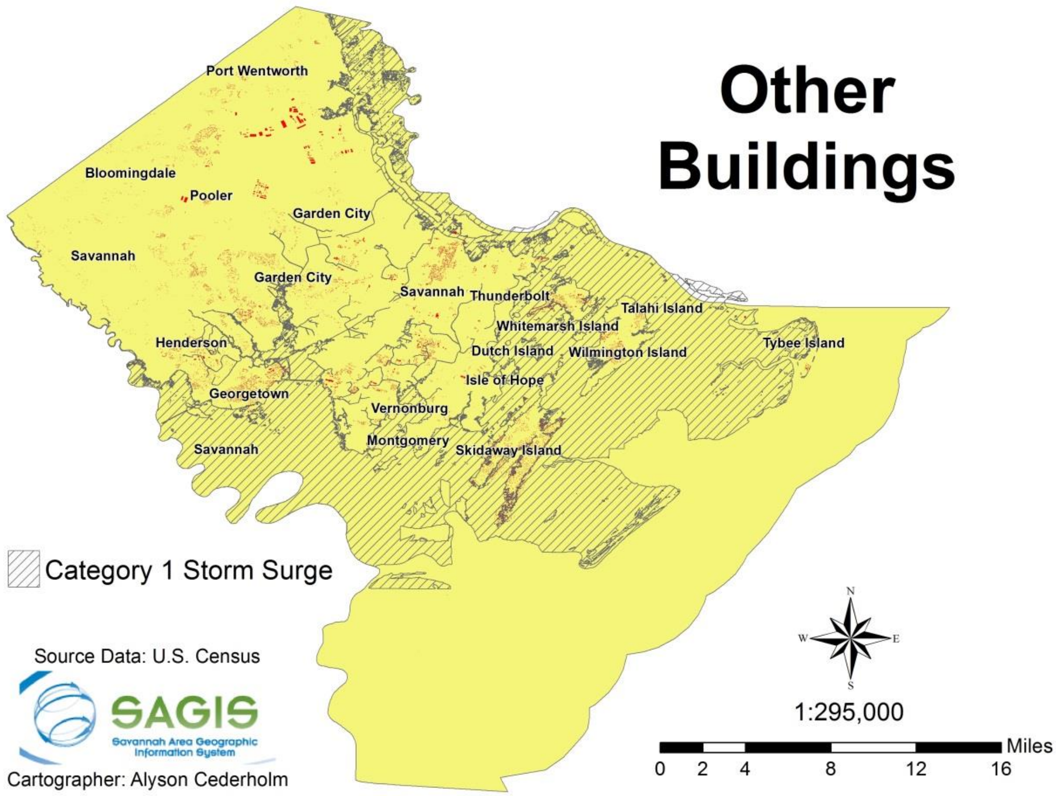

Telecommunication Towers
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Category 1 Storm Surge
Source Data: U.S. Census
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16


Existing
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

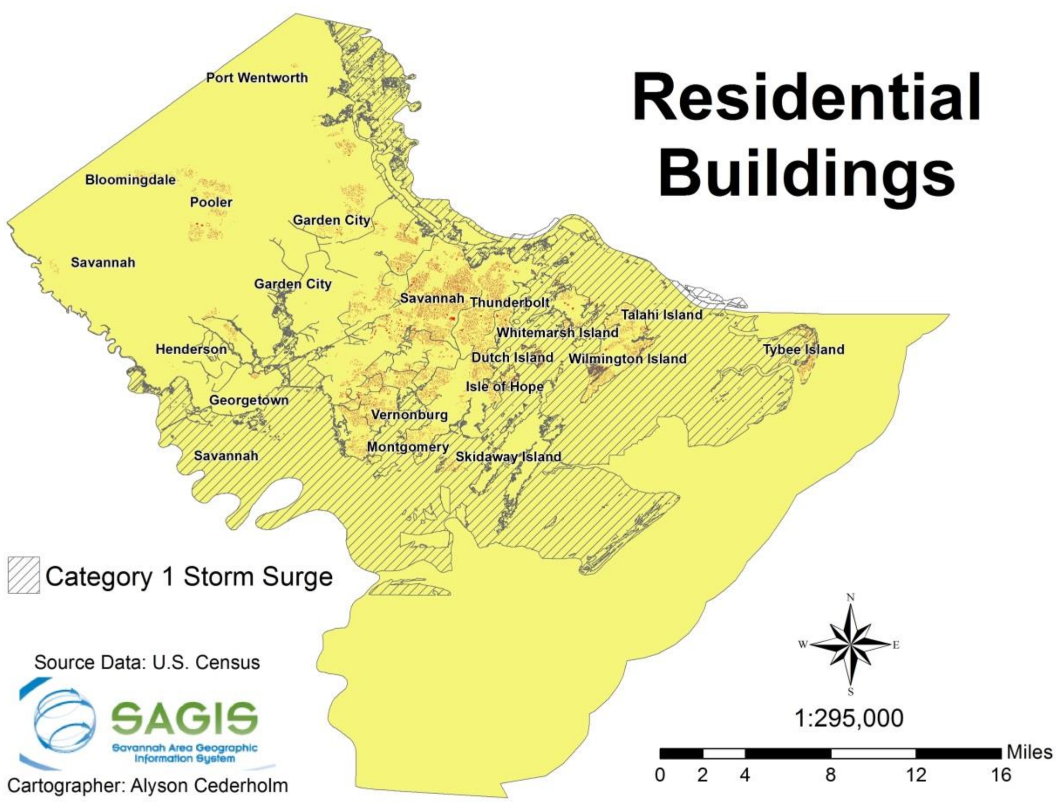

Business/Commercial
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16


Government/Institutional Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
0 2 4 8 12 16 Miles

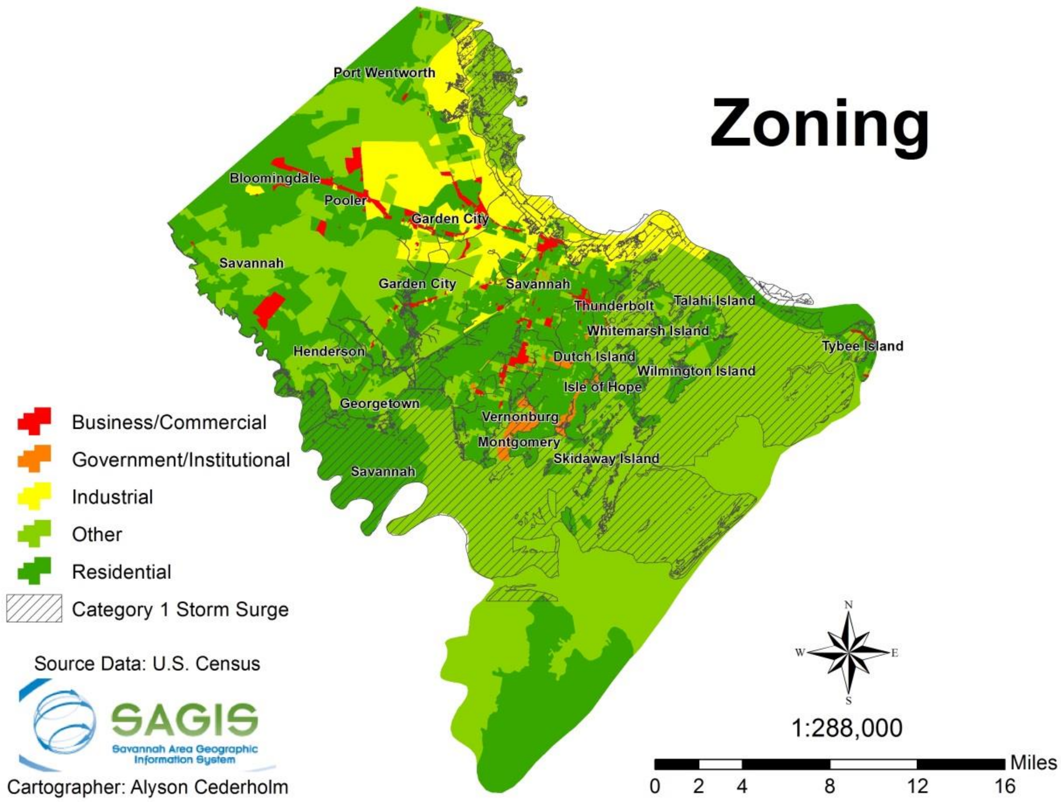

Industrial Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
0 2 4 8 12 16 Miles



Other
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

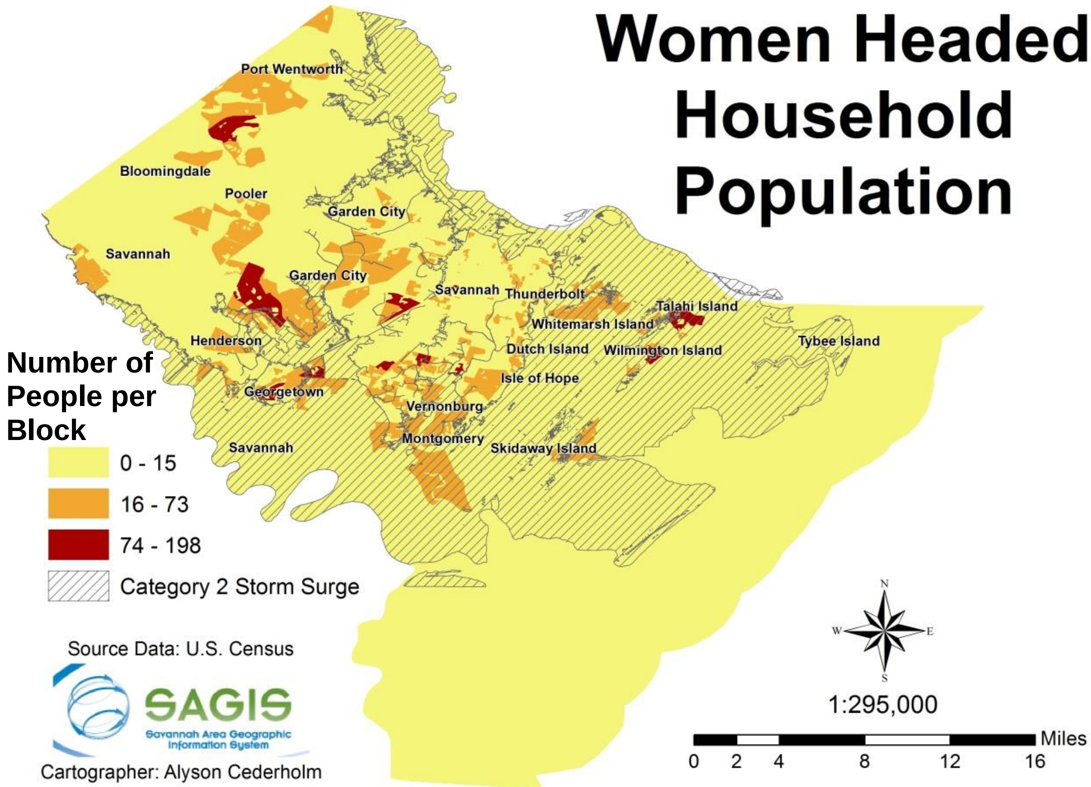


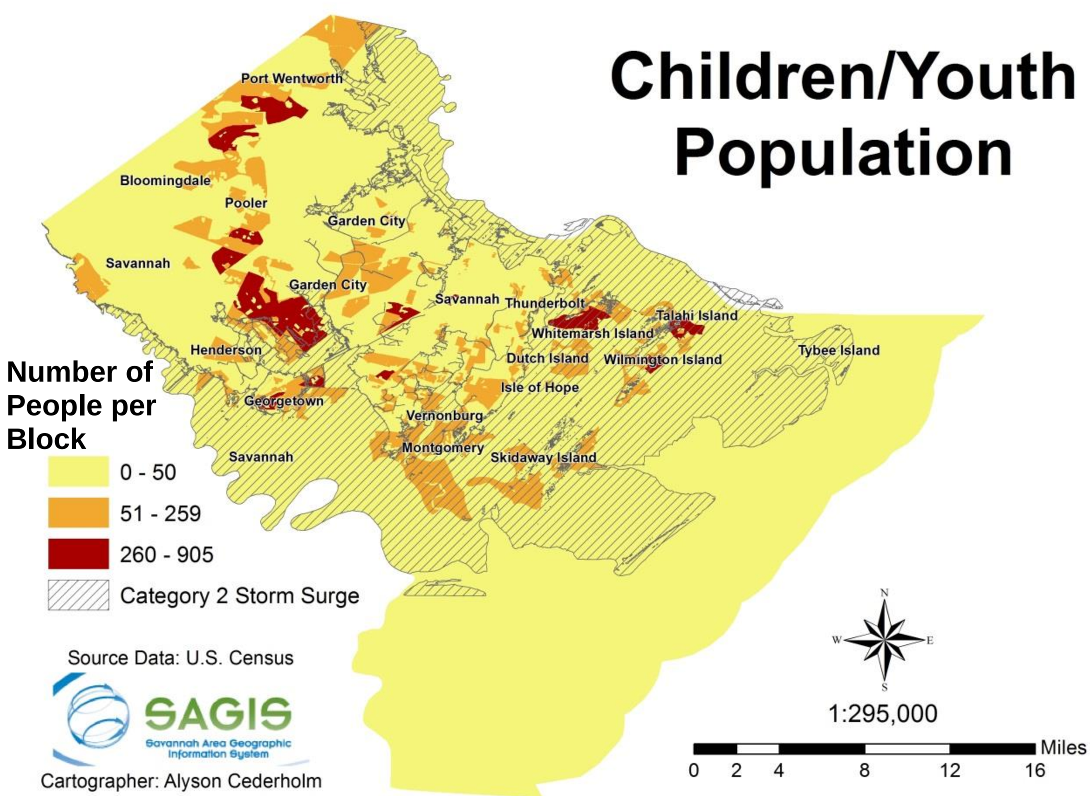
Residential
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

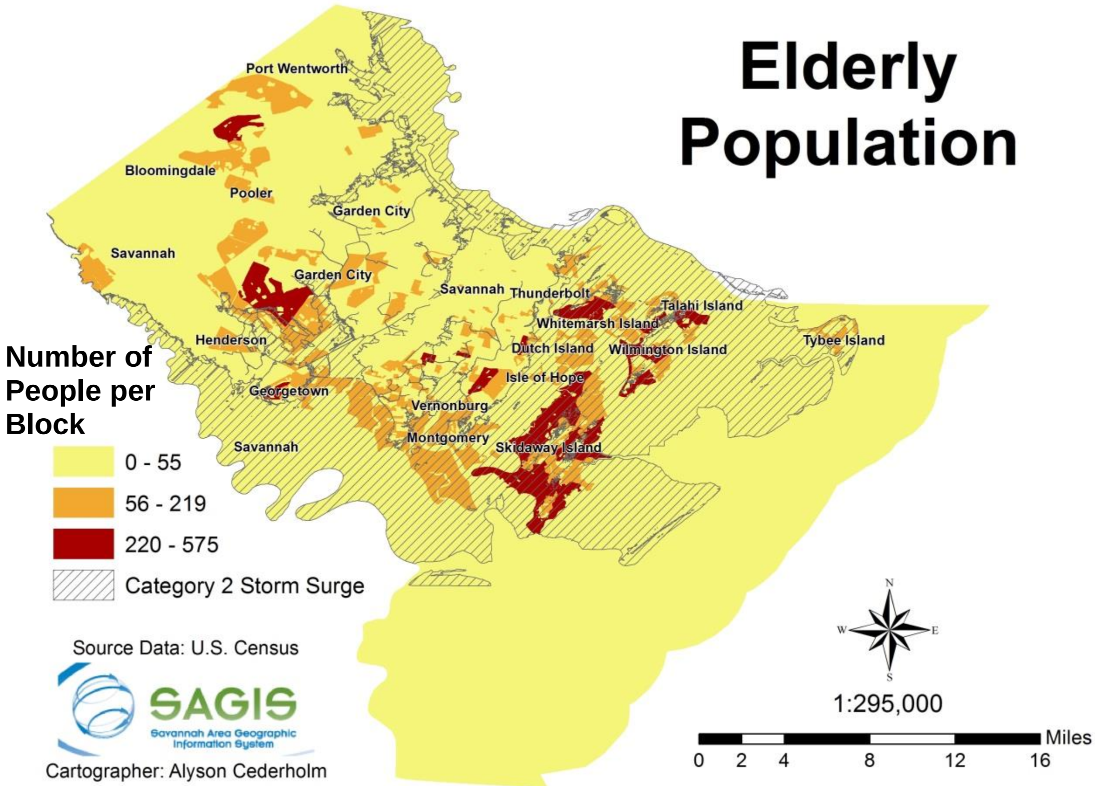

Zoning
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Business/Commercial
Government/Institutional
Industrial
Other
Residential
Category 1 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:288,000
0 2 4 8 12 16
Miles

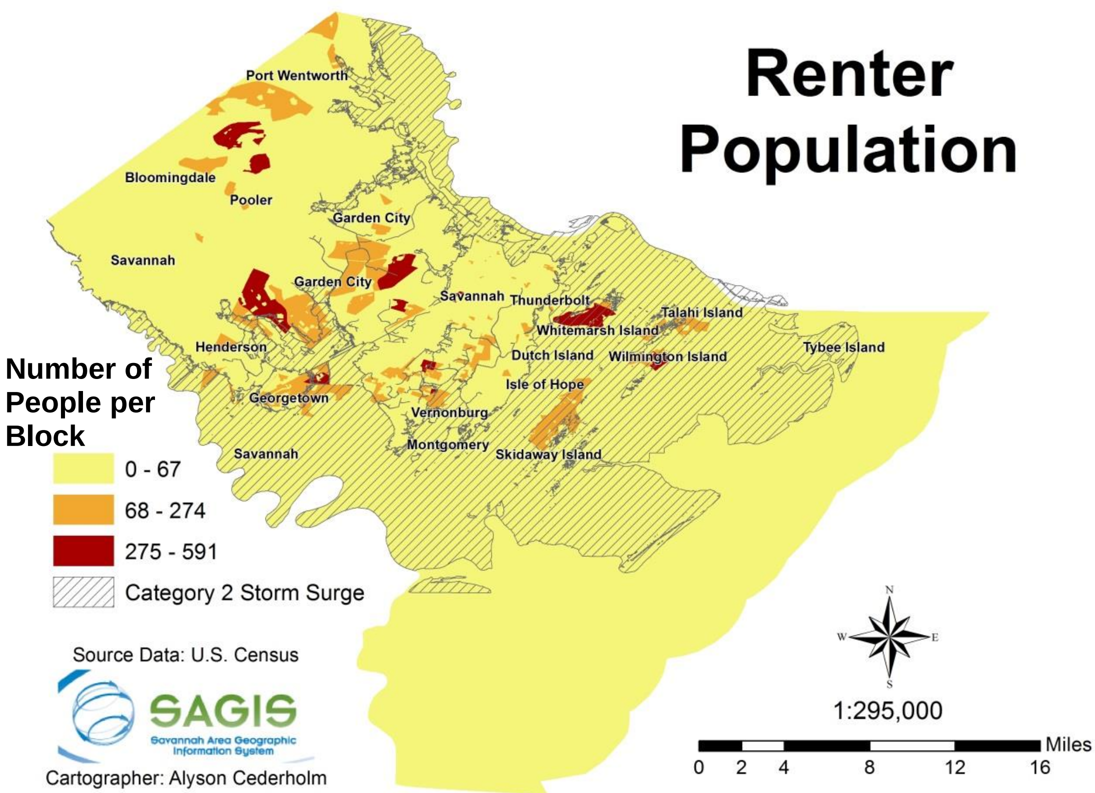
Appendix 4

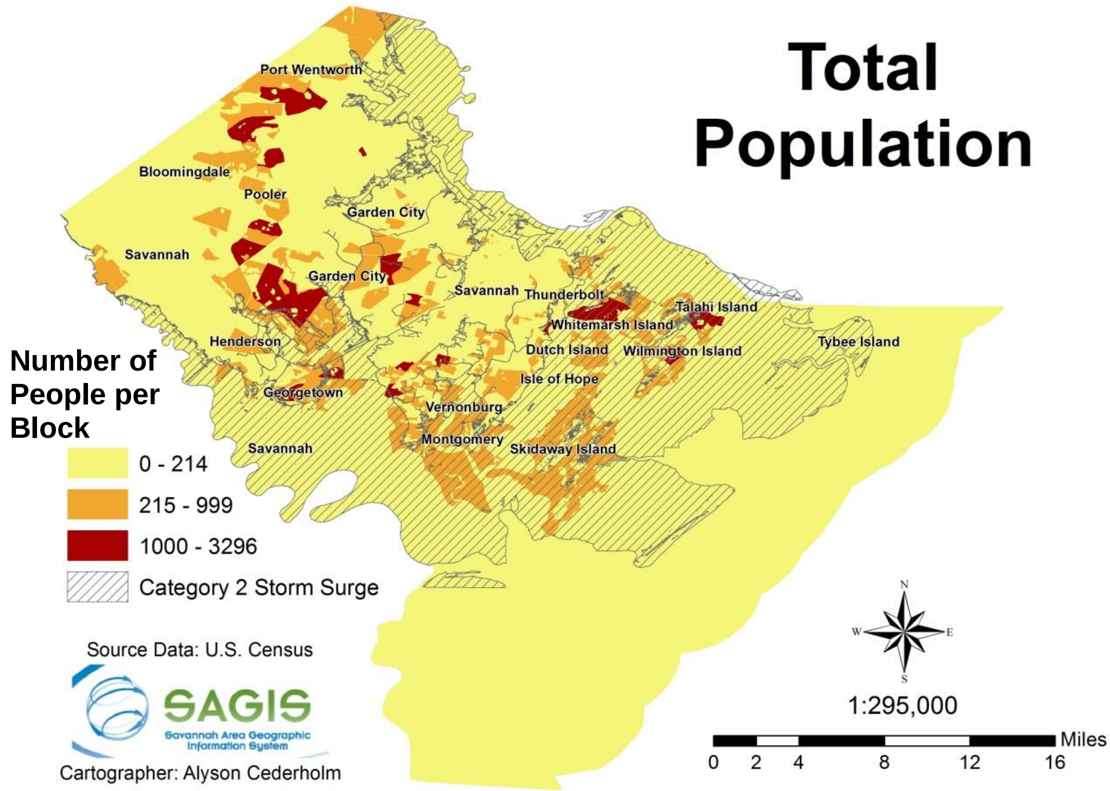
Category 2 Storm Surge Maps

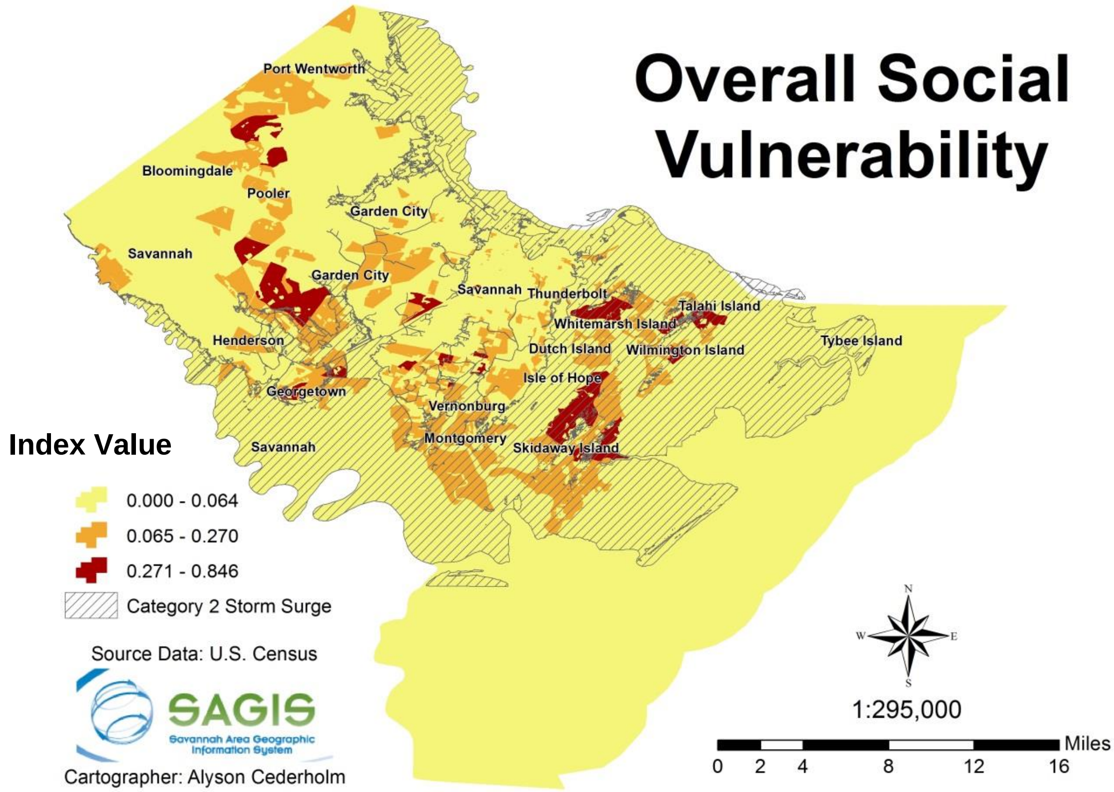

Women Headed Household Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 15
16 - 73
74 - 198
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

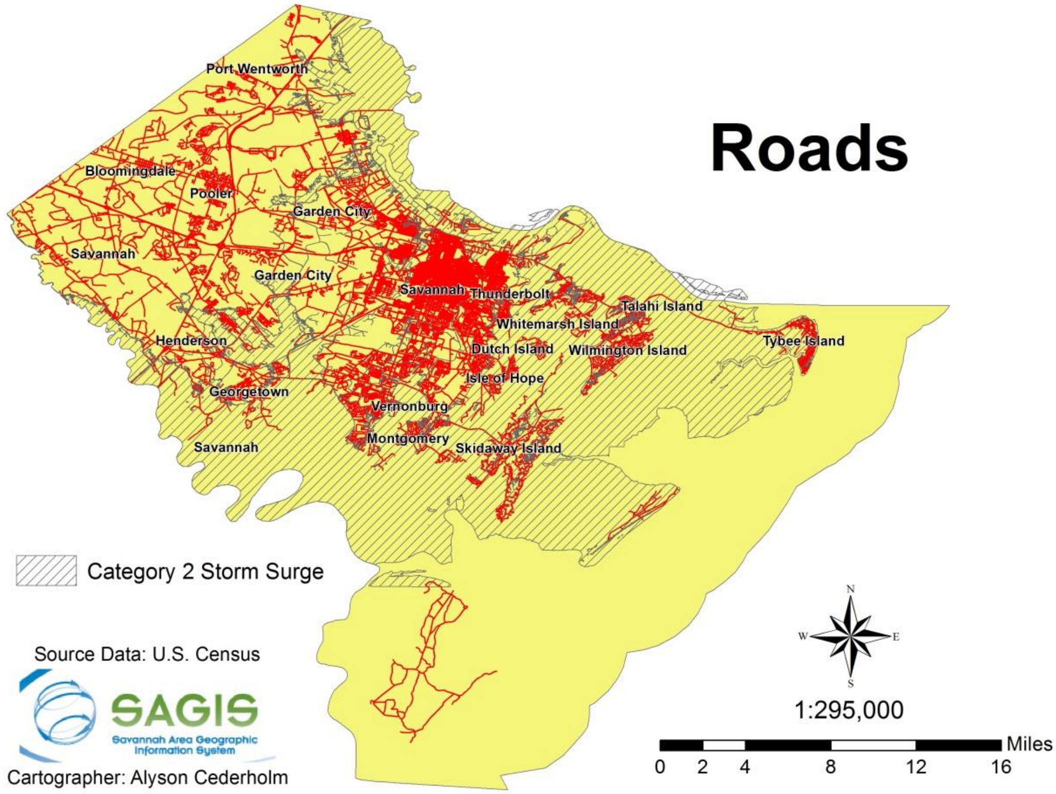

Children/Youth Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 50
51 - 259
260 - 905
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

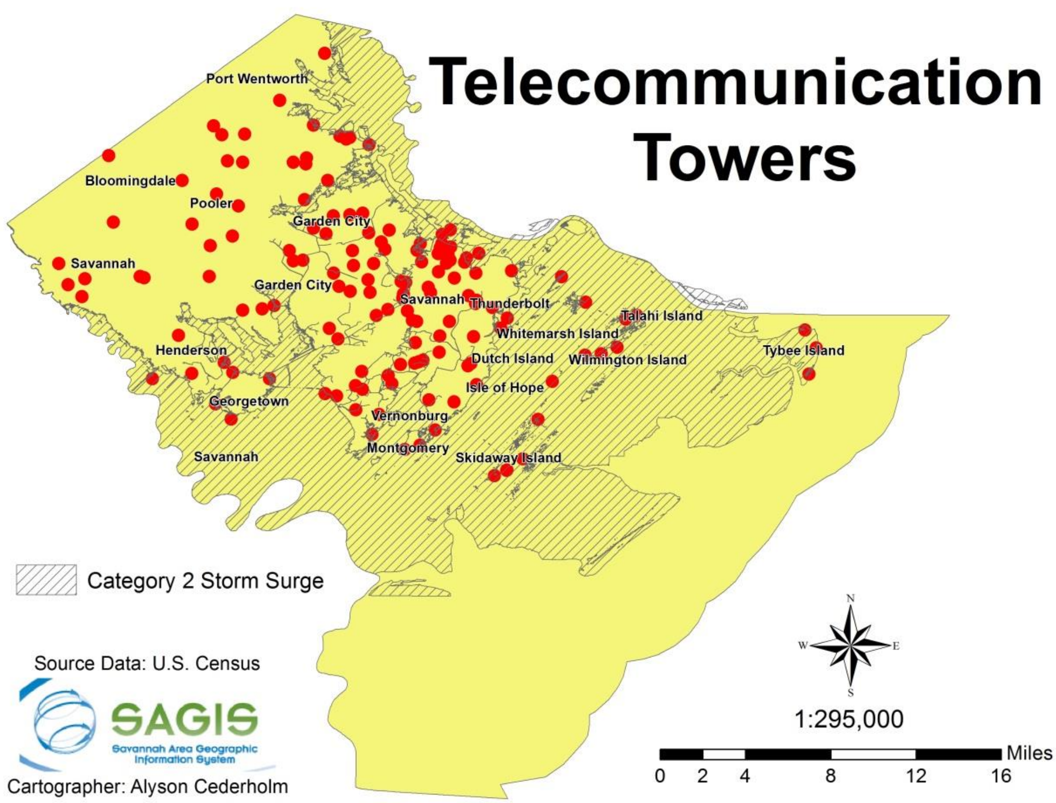

Elderly Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Number of People per Block
0 - 55
56 - 219
220 - 575
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0
2
4
8
12
16

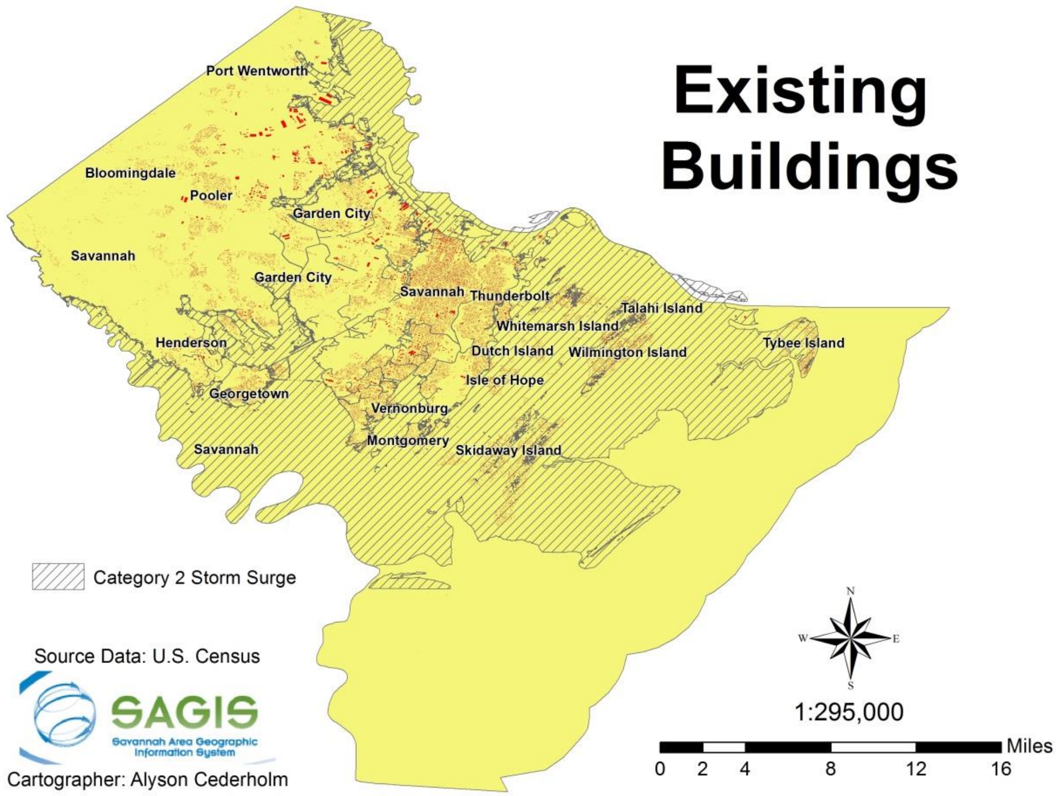

Renter Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Number of People per Block
0 - 67
68 - 274
275 - 591
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0
2
4
8
12
16

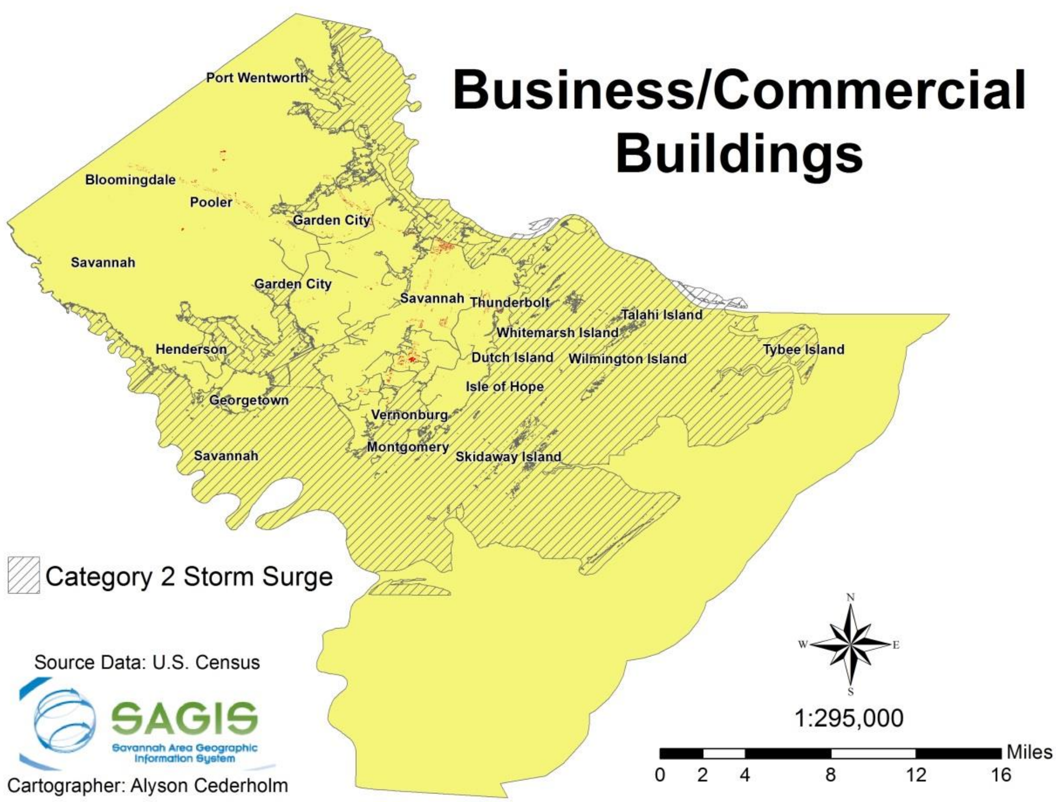

Total Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Number of People per Block
0 - 214
215 - 999
1000 - 3296
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

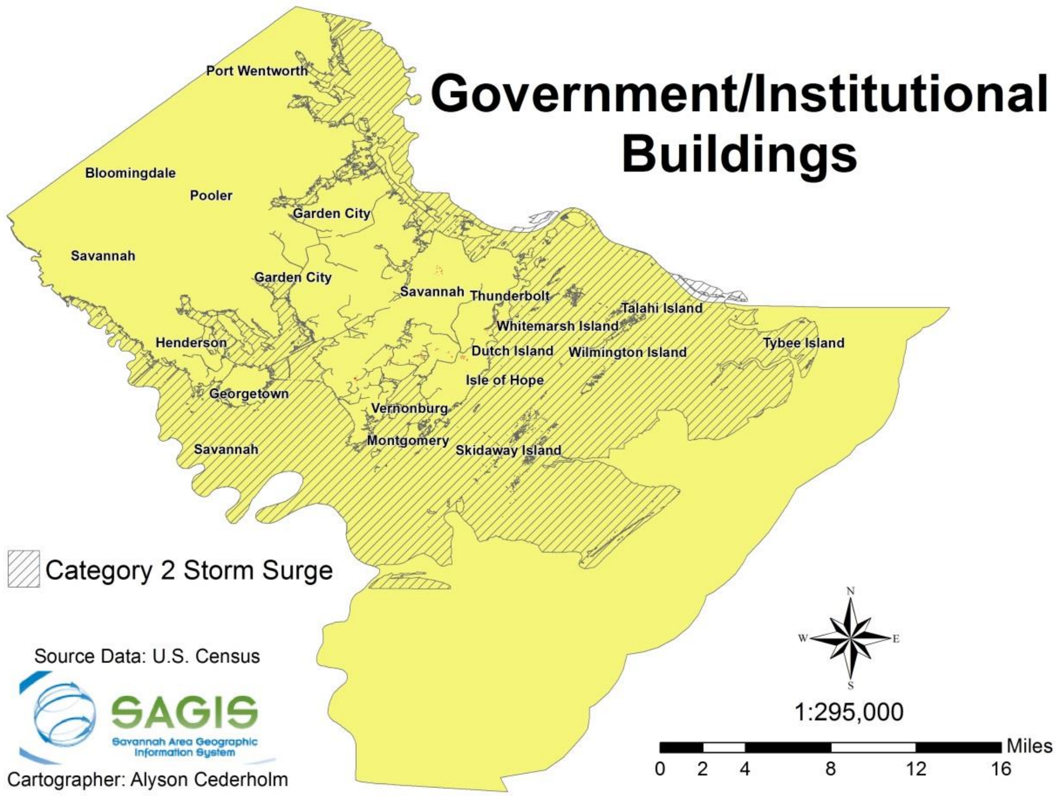

Overall Social Vulnerability
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Index Value
0.000 - 0.064
0.065 - 0.270
0.271 - 0.846
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

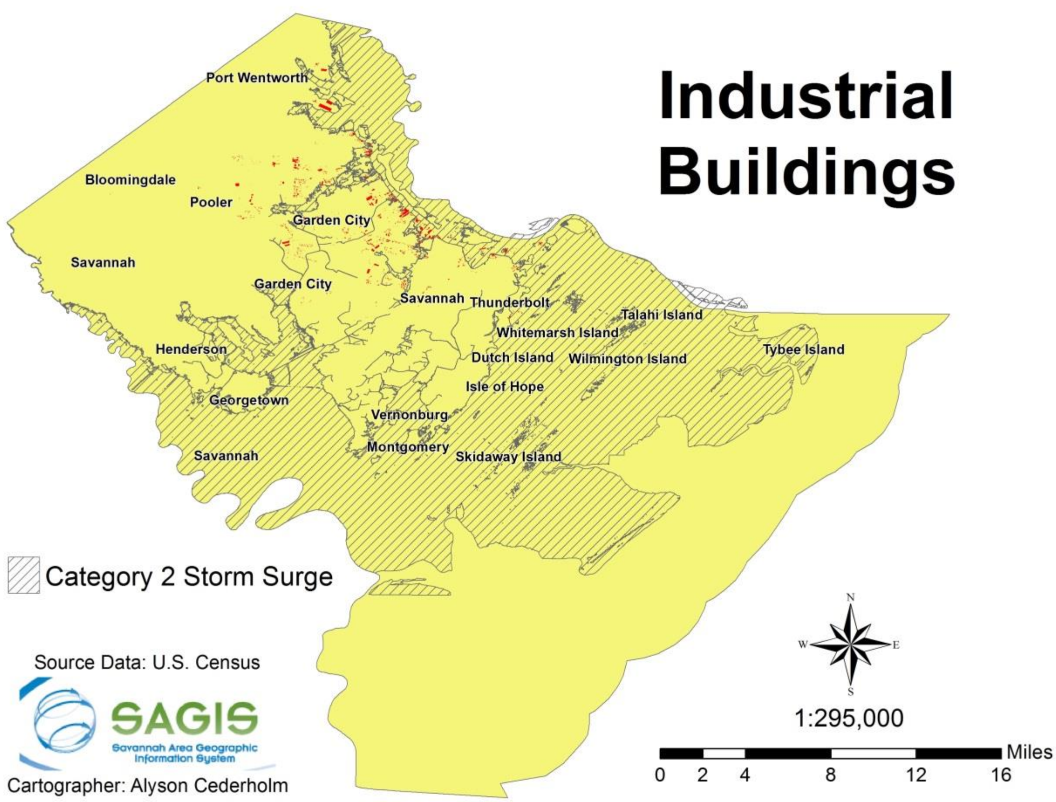

Roads
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

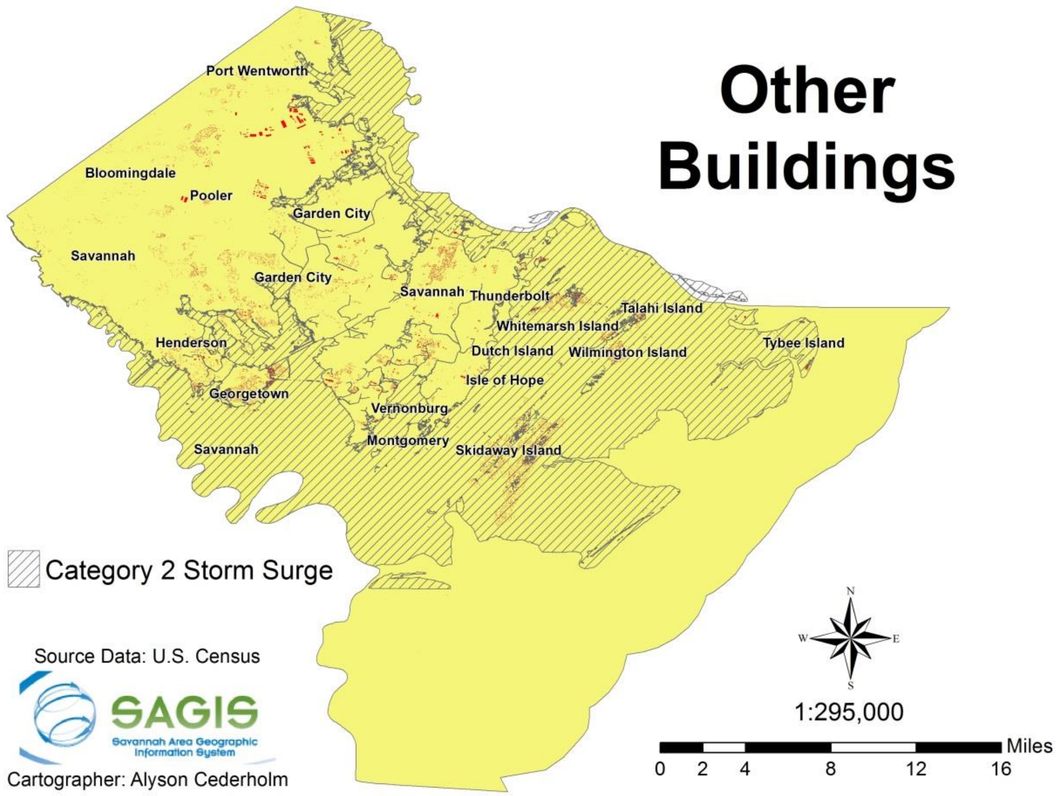

Telecommunication Towers
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

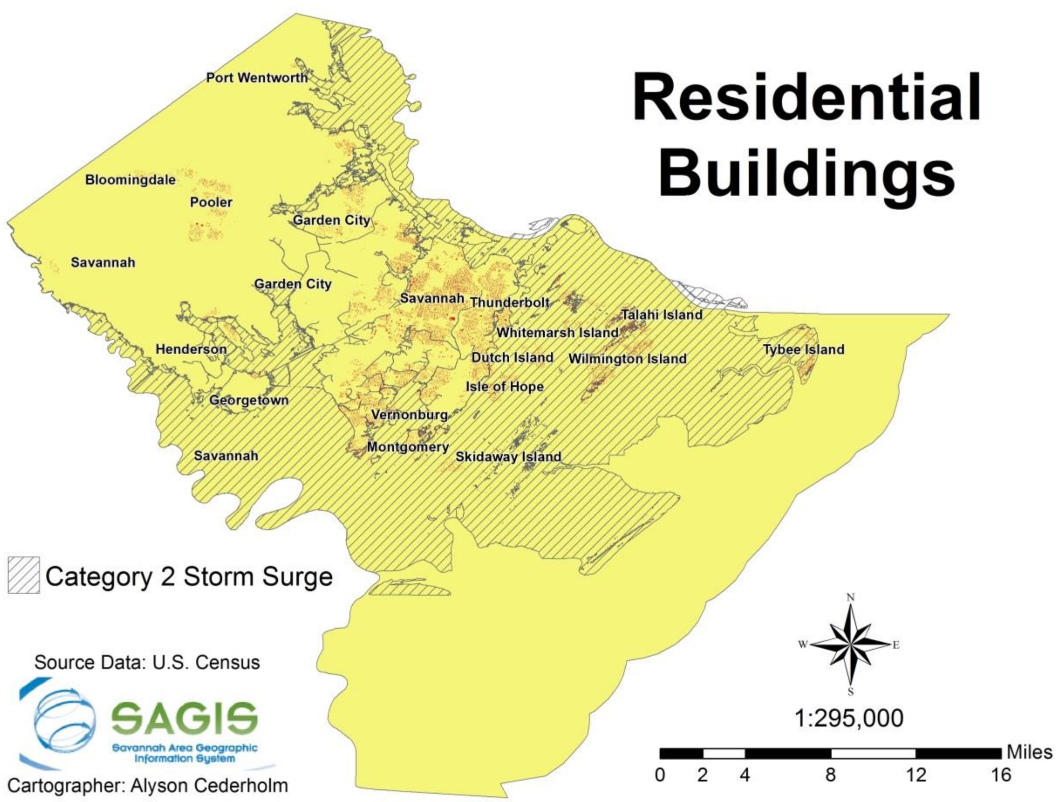

Existing
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

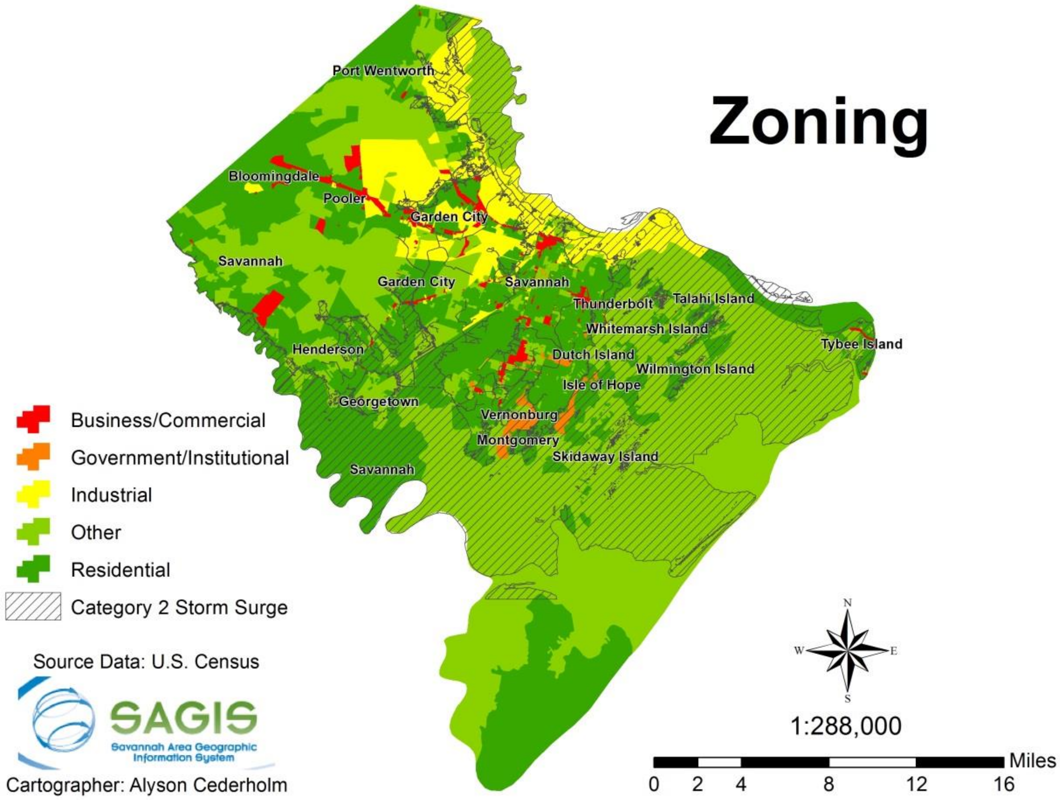

Business/Commercial
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16


Government/Institutional
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16


Industrial
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

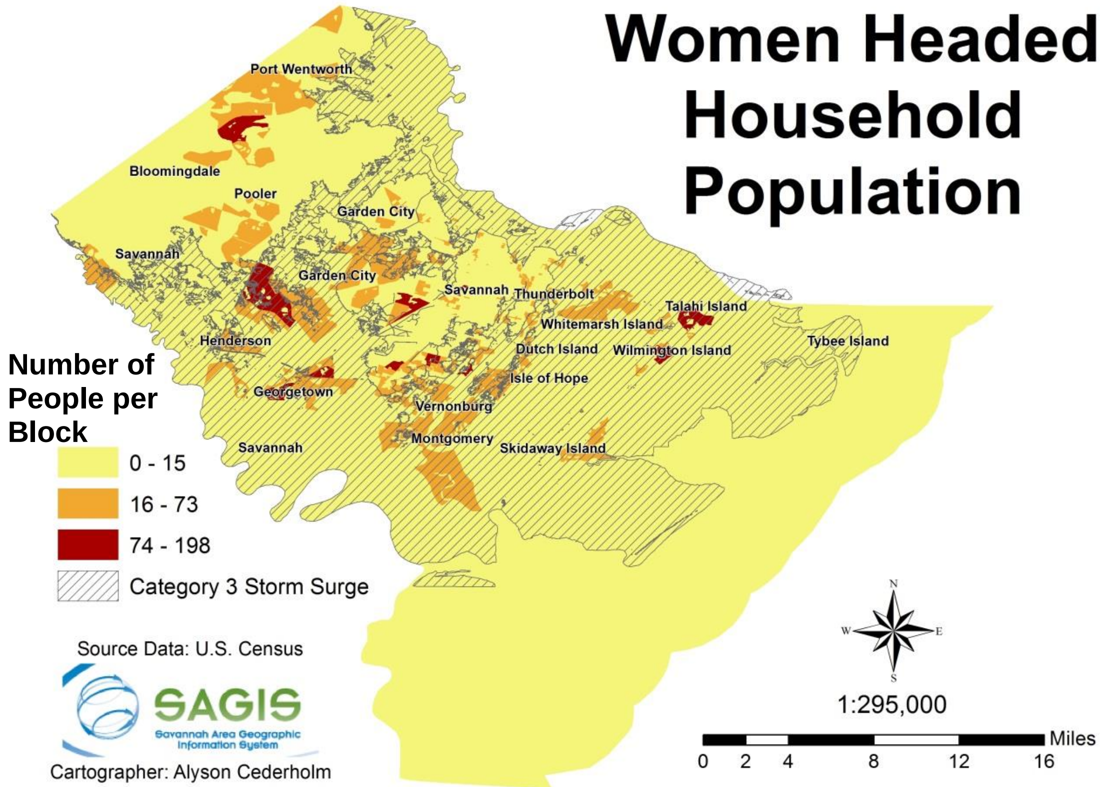

Other
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

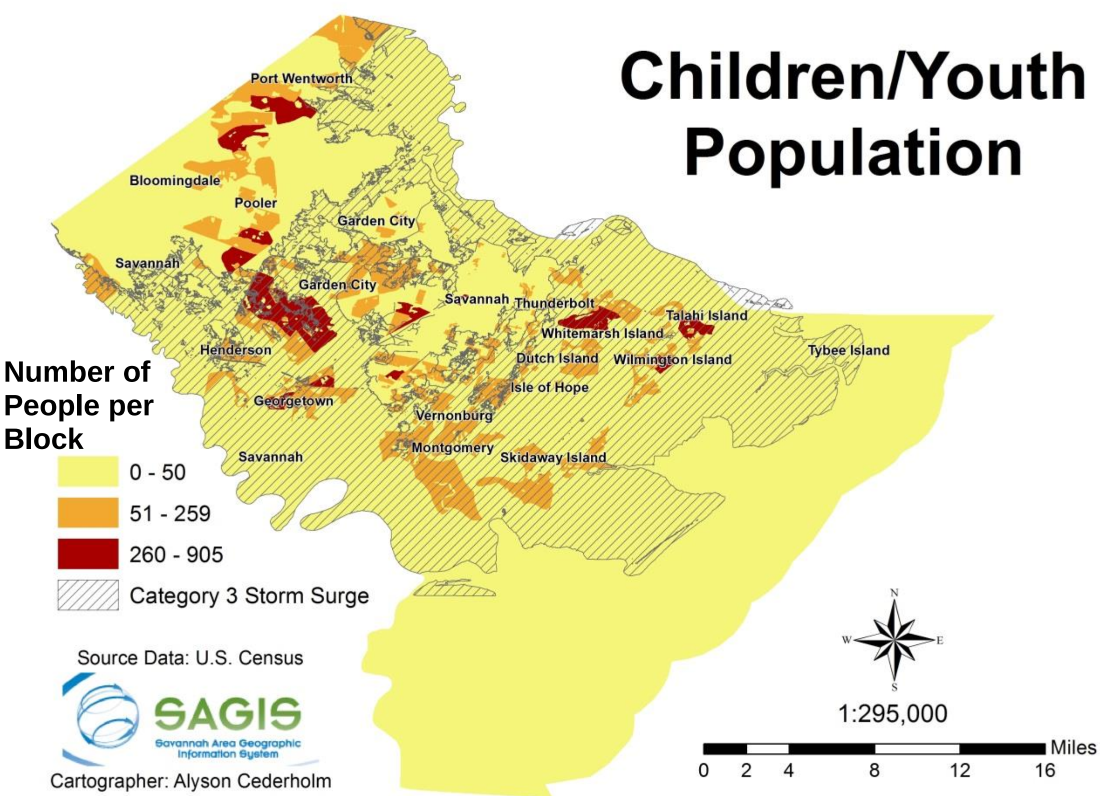

Residential
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

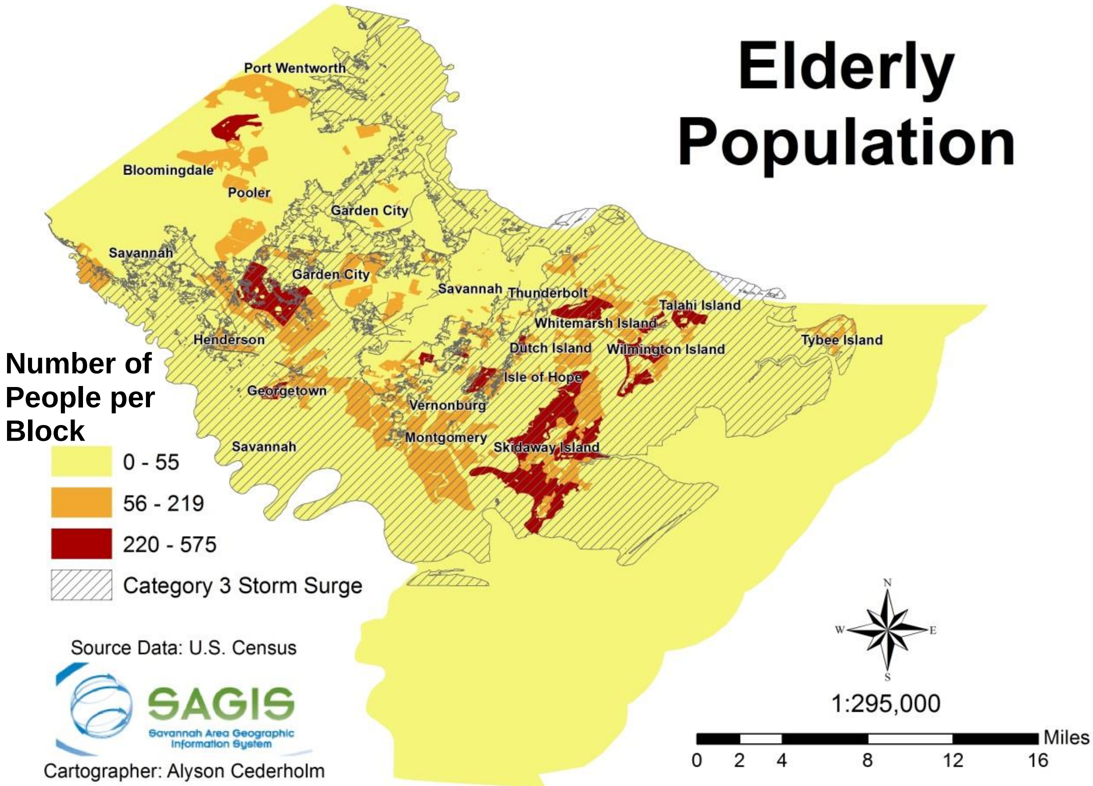

Zoning
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Business/Commercial
Government/Institutional
Industrial
Other
Residential
Category 2 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:288,000
Miles
0 2 4 8 12 16

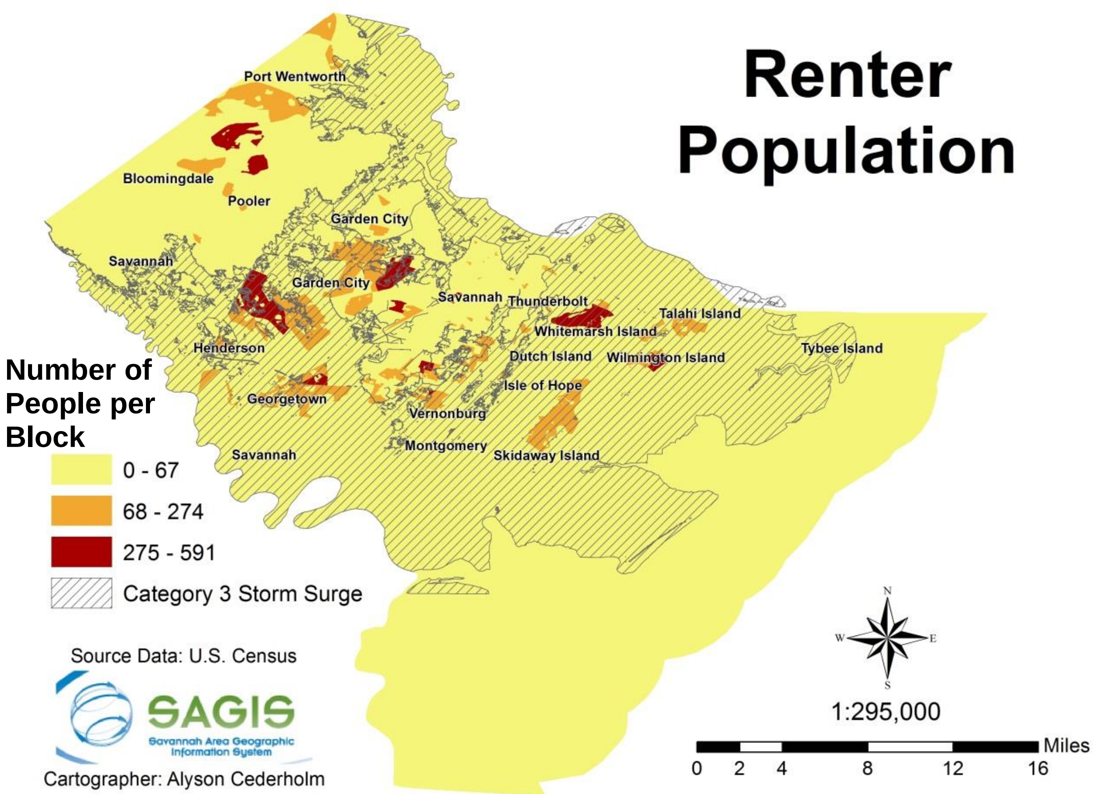
Appendix 5

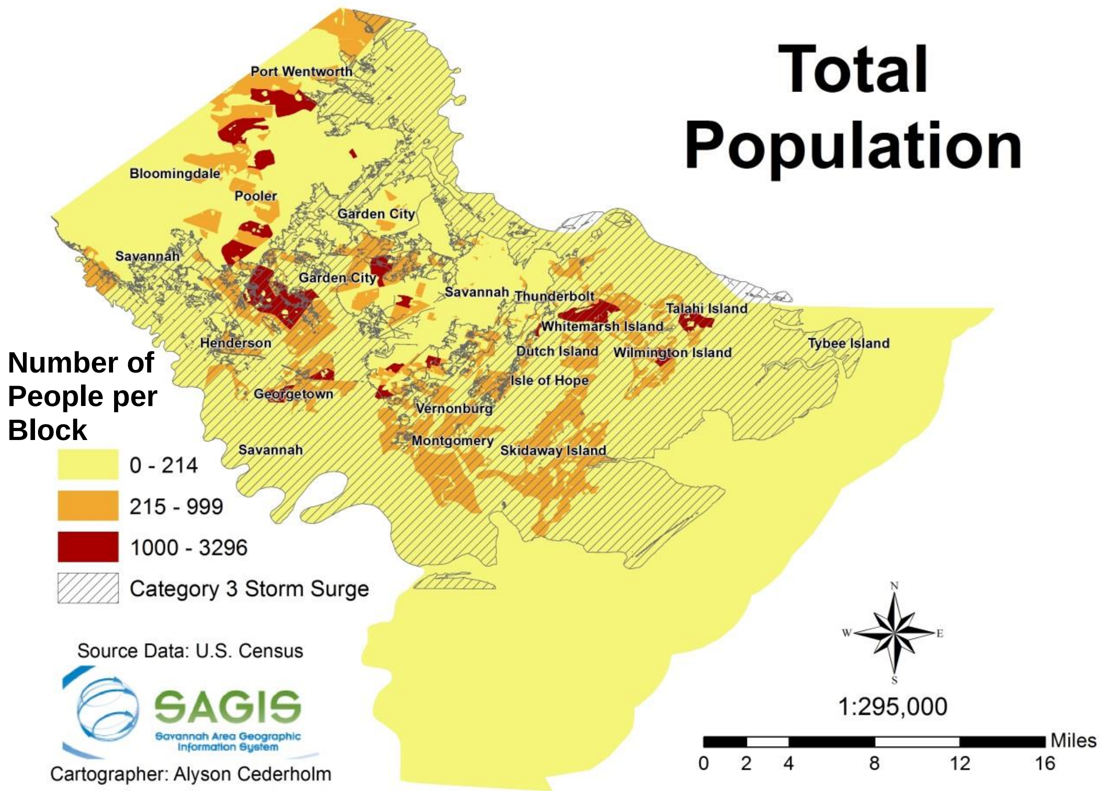
Category 3 Storm Surge Maps

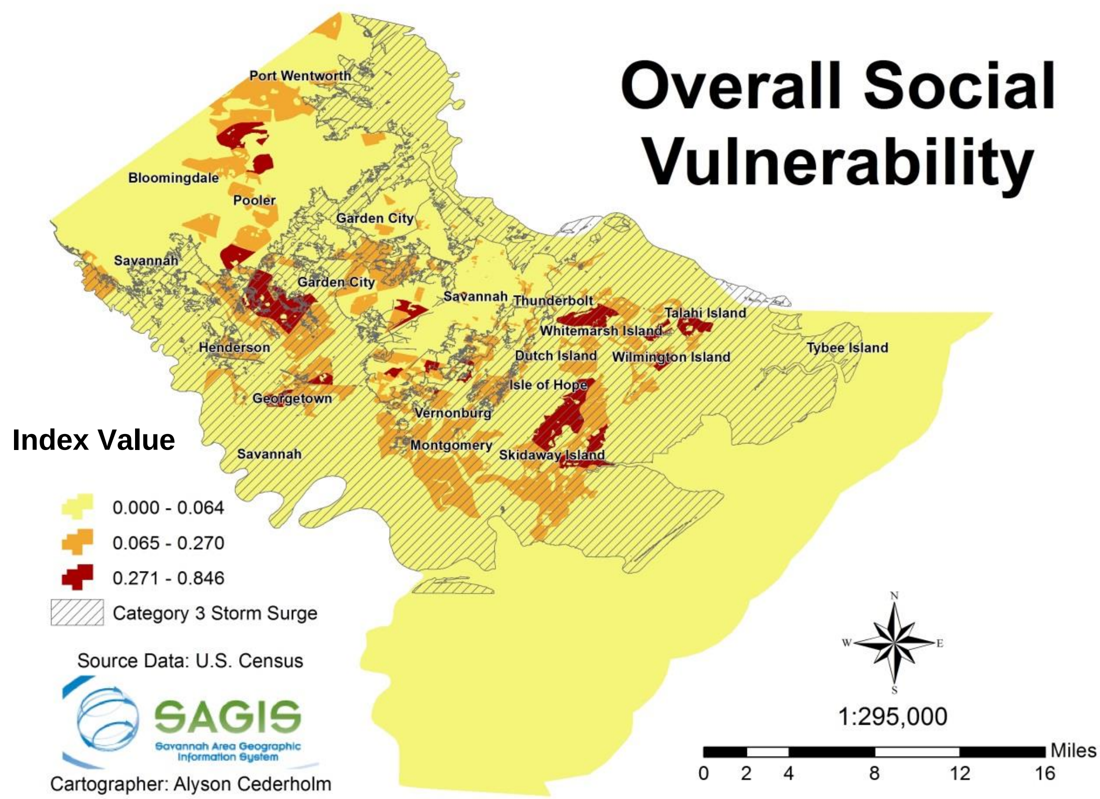

Women Headed Household Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Number of People per Block
0 - 15
16 - 73
74 - 198
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
0 2 4 8 12 16 Miles

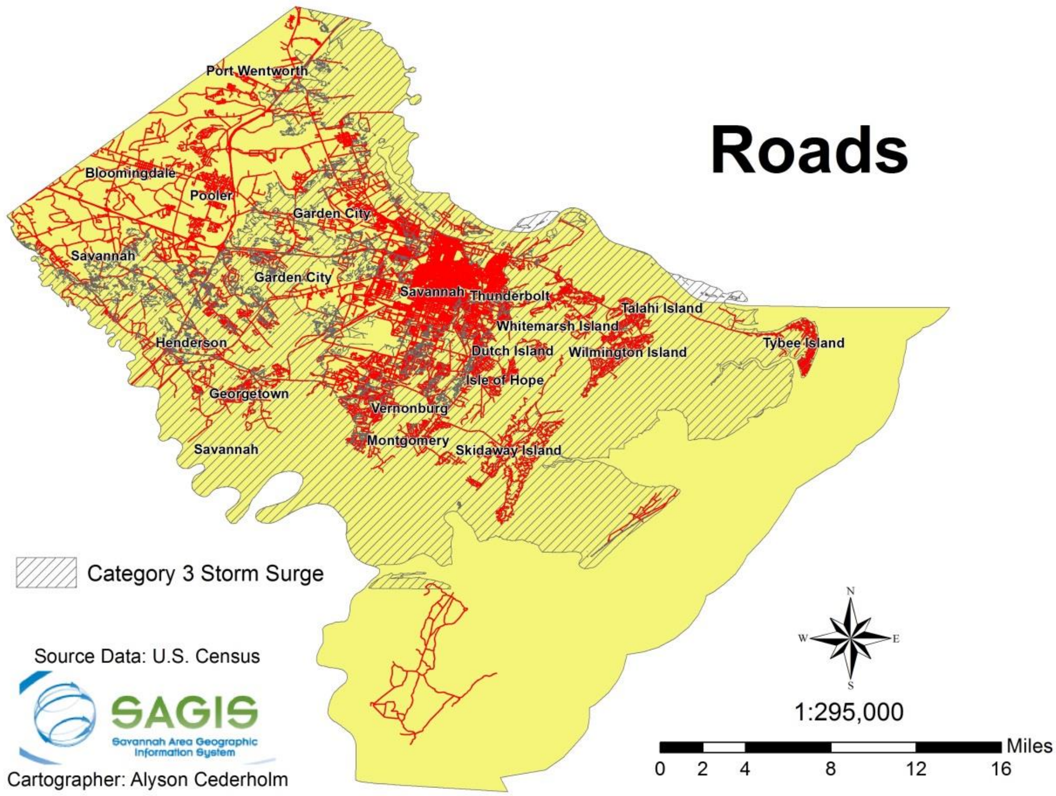

Children/Youth Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Number of People per Block
0 - 50
51 - 259
260 - 905
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
0 2 4 8 12 16 Miles

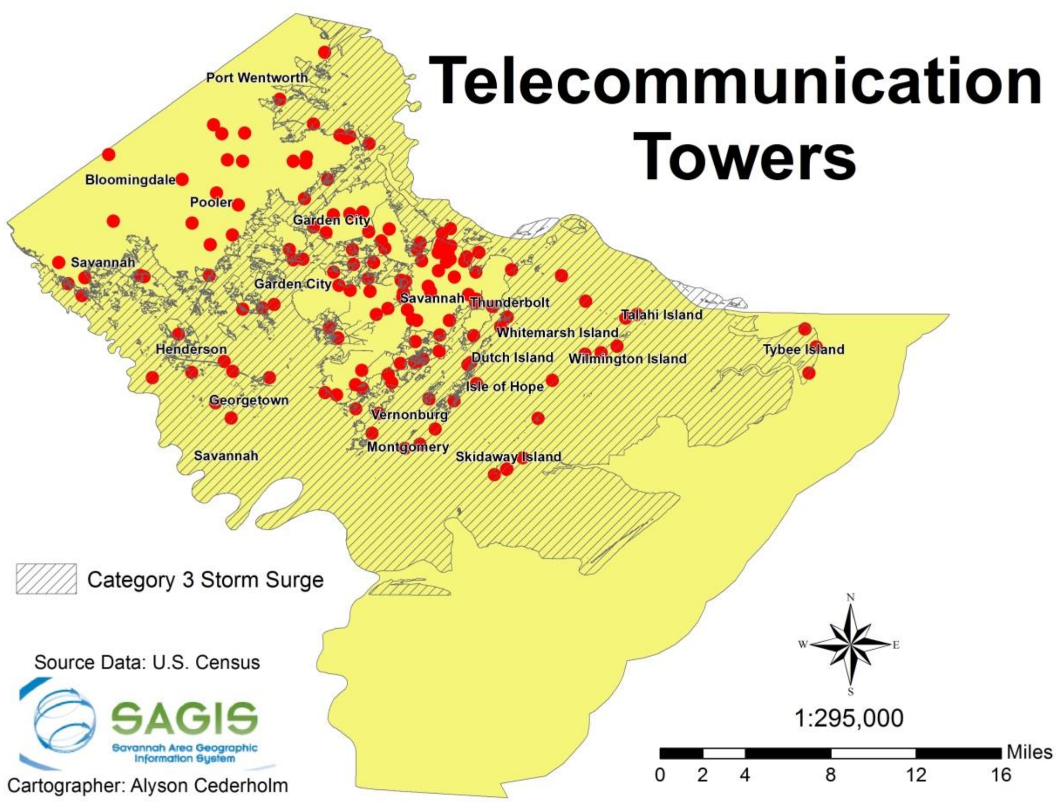

Elderly Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Number of People per Block
0 - 55
56 - 219
220 - 575
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

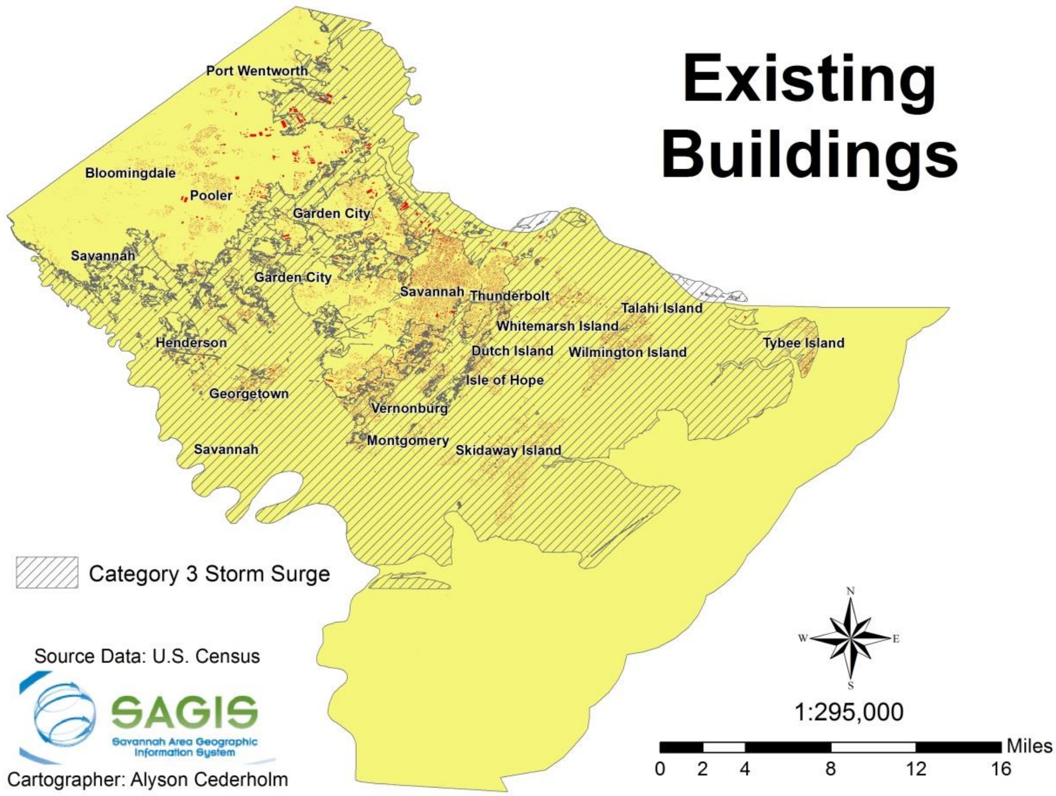

Renter Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Number of People per Block
0 - 67
68 - 274
275 - 591
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

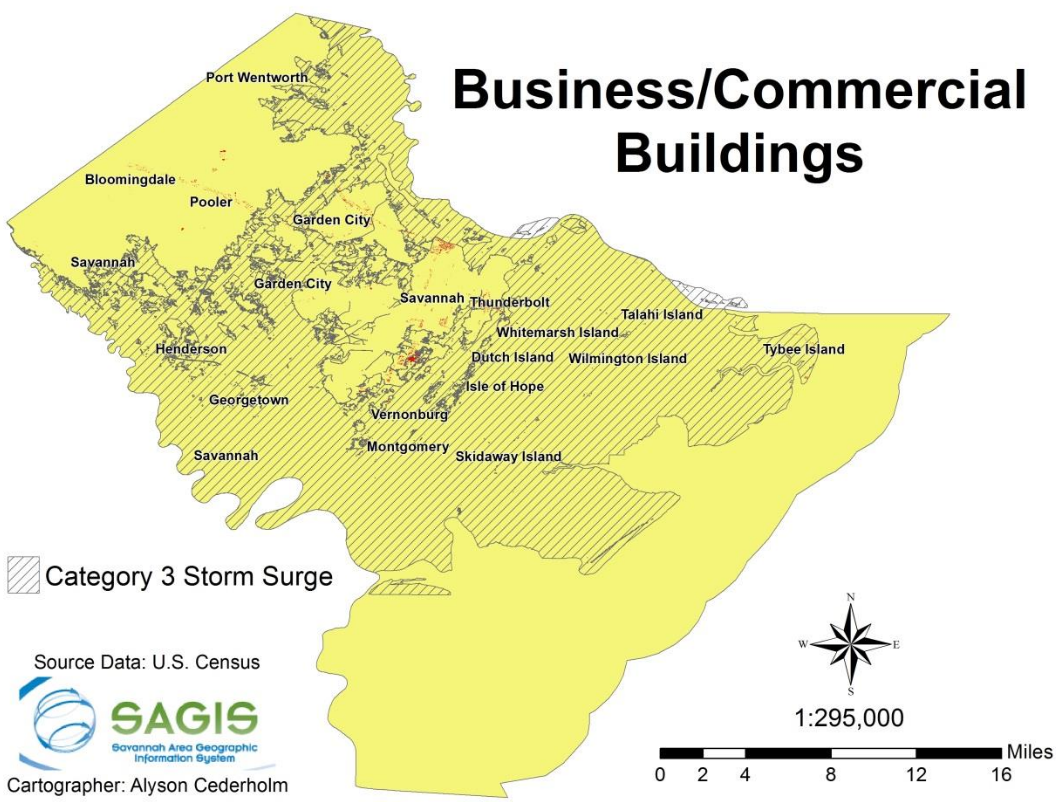

Total Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 214
215 - 999
1000 - 3296
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
0 2 4 8 12 16
Miles

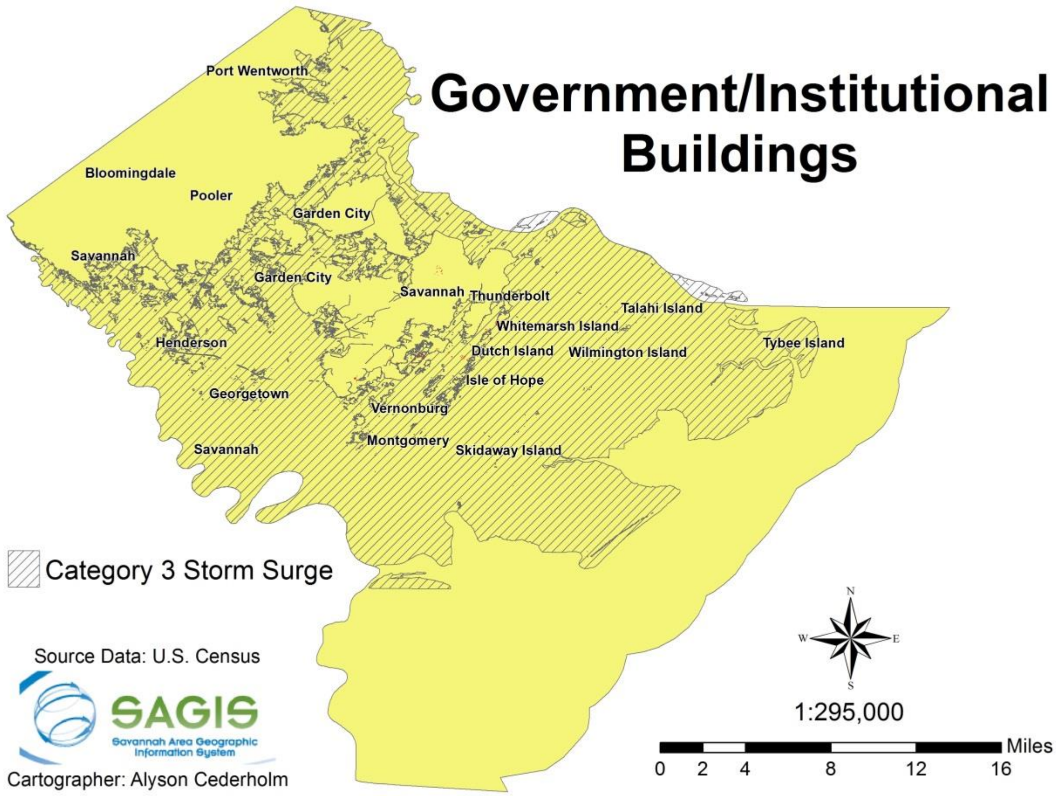

Overall Social Vulnerability
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Index Value
0.000 - 0.064
0.065 - 0.270
0.271 - 0.846
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
0 2 4 8 12 16
Miles

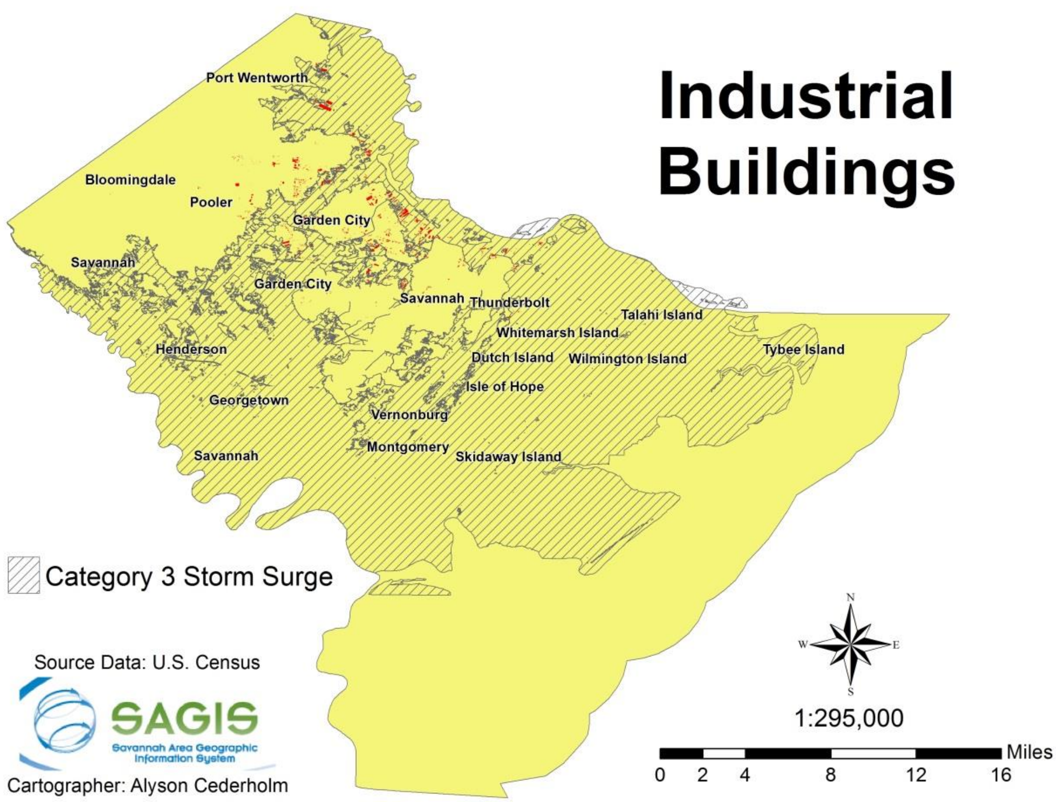

Roads
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

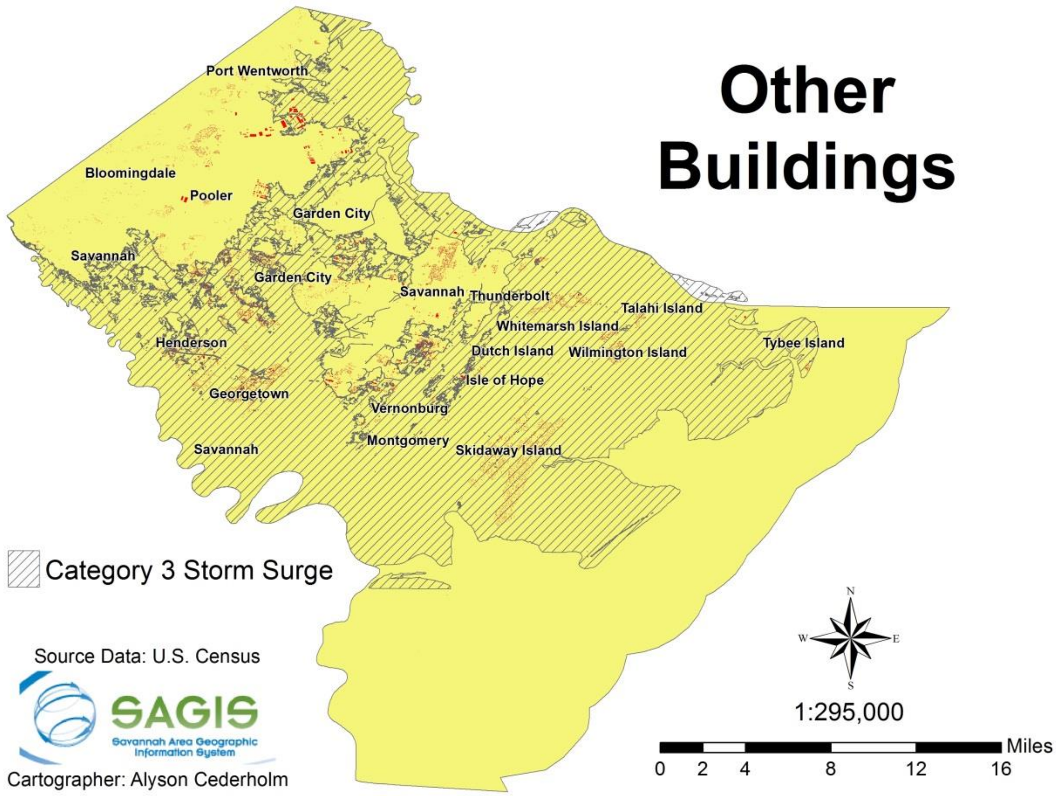

Telecommunication Towers
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

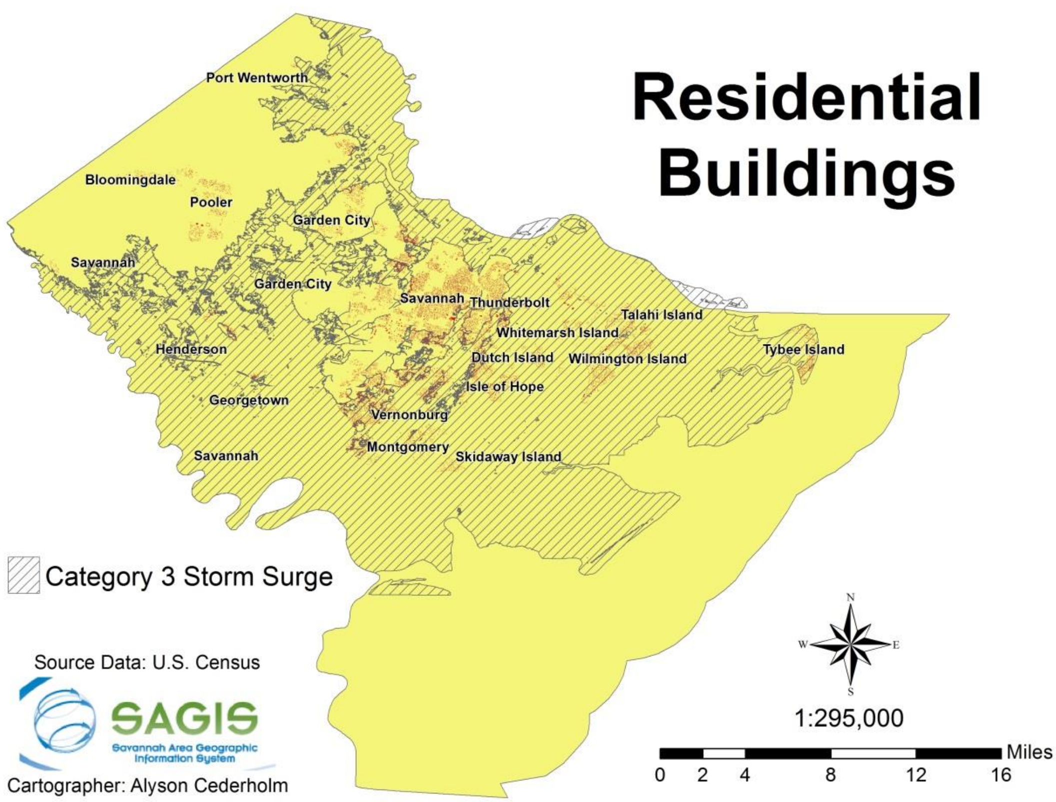

Existing
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

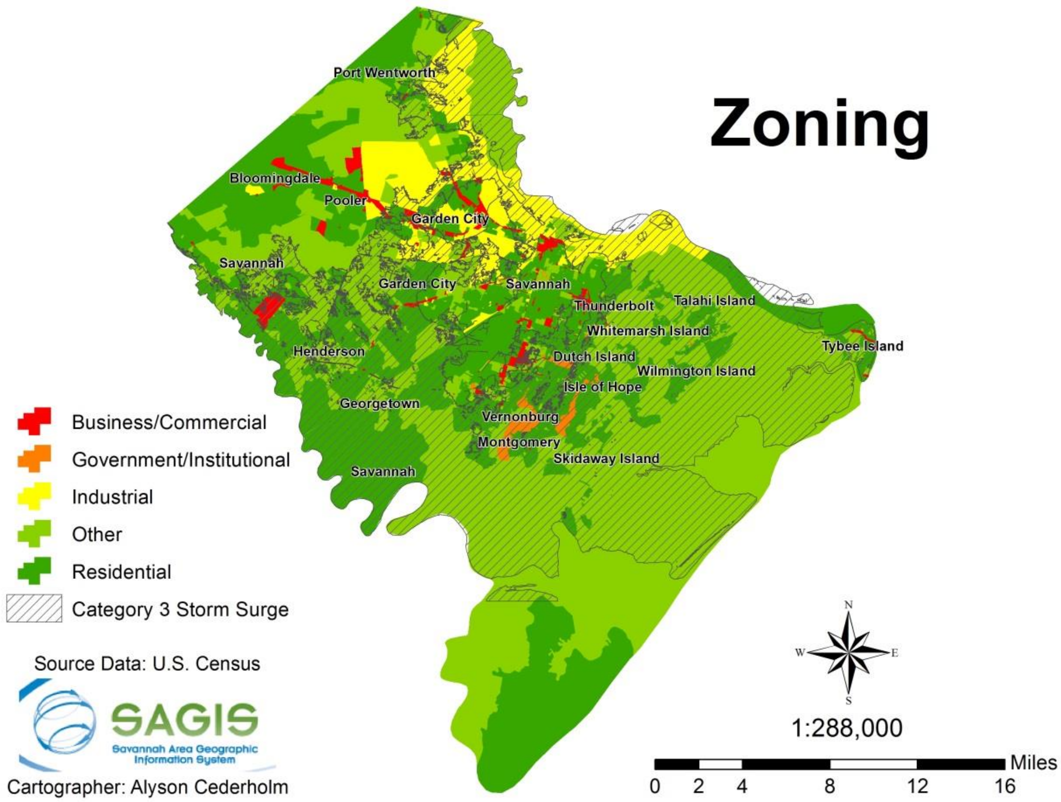

Business/Commercial
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16


Government/Institutional Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 3 Storm Surge
Source Data: U.S. Census
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16


Industrial Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 3 Storm Surge
Source Data: U.S. Census
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

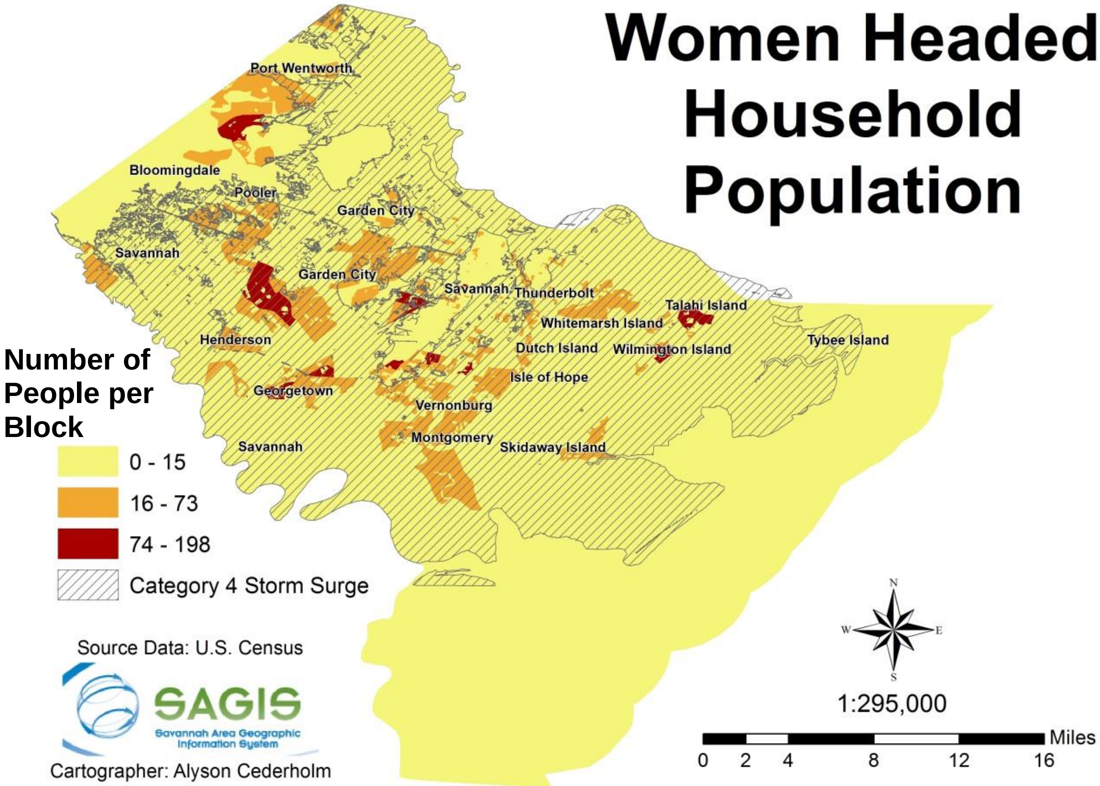

Other
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

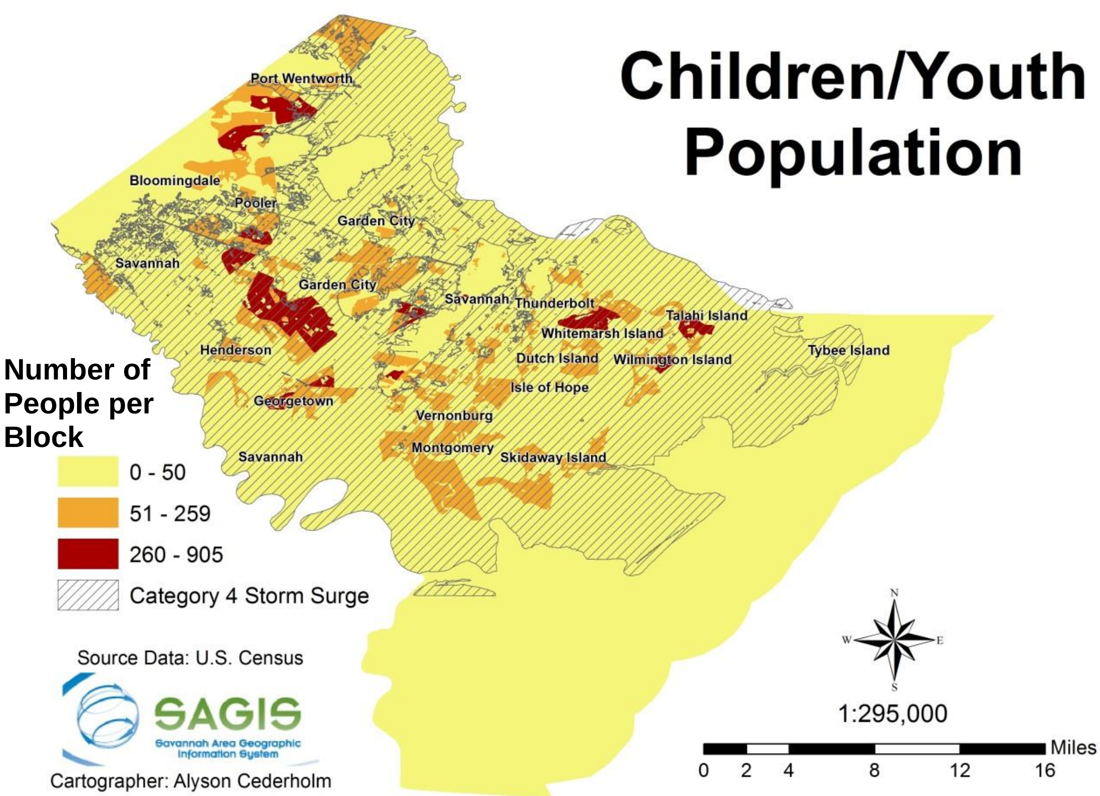

Residential
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

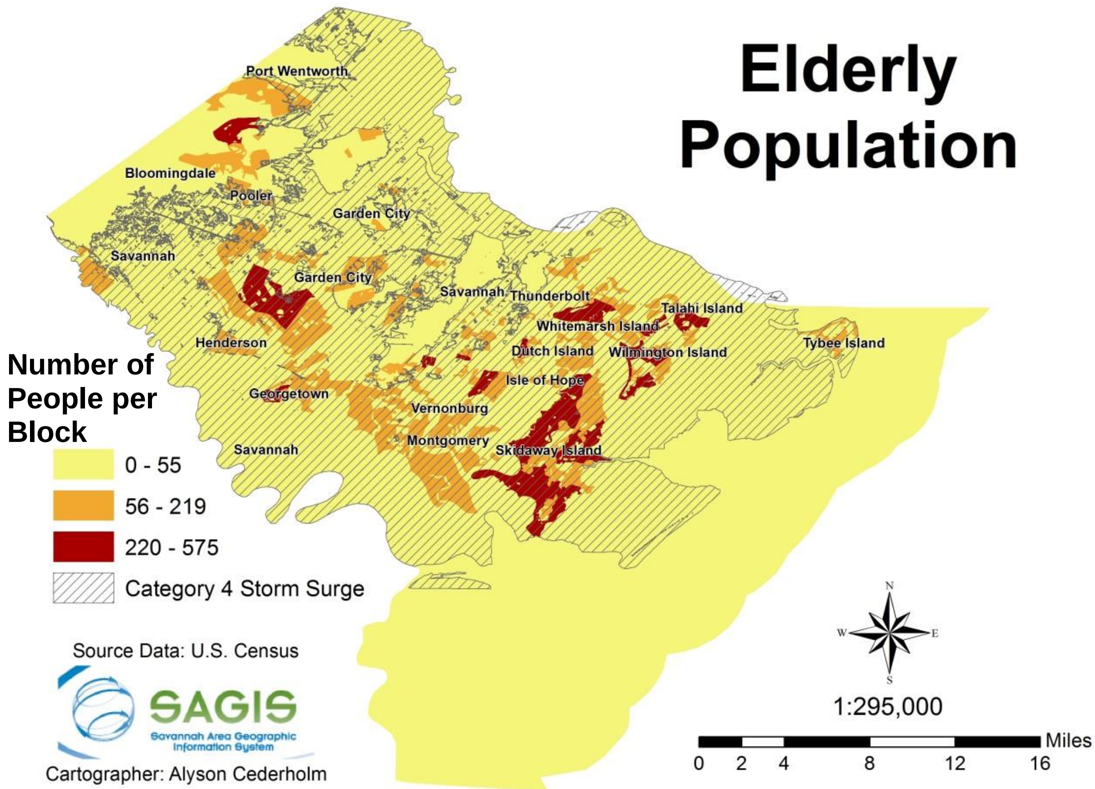

Zoning
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Business/Commercial
Government/Institutional
Industrial
Other
Residential
Category 3 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:288,000
Miles
0
2
4
8
12
16

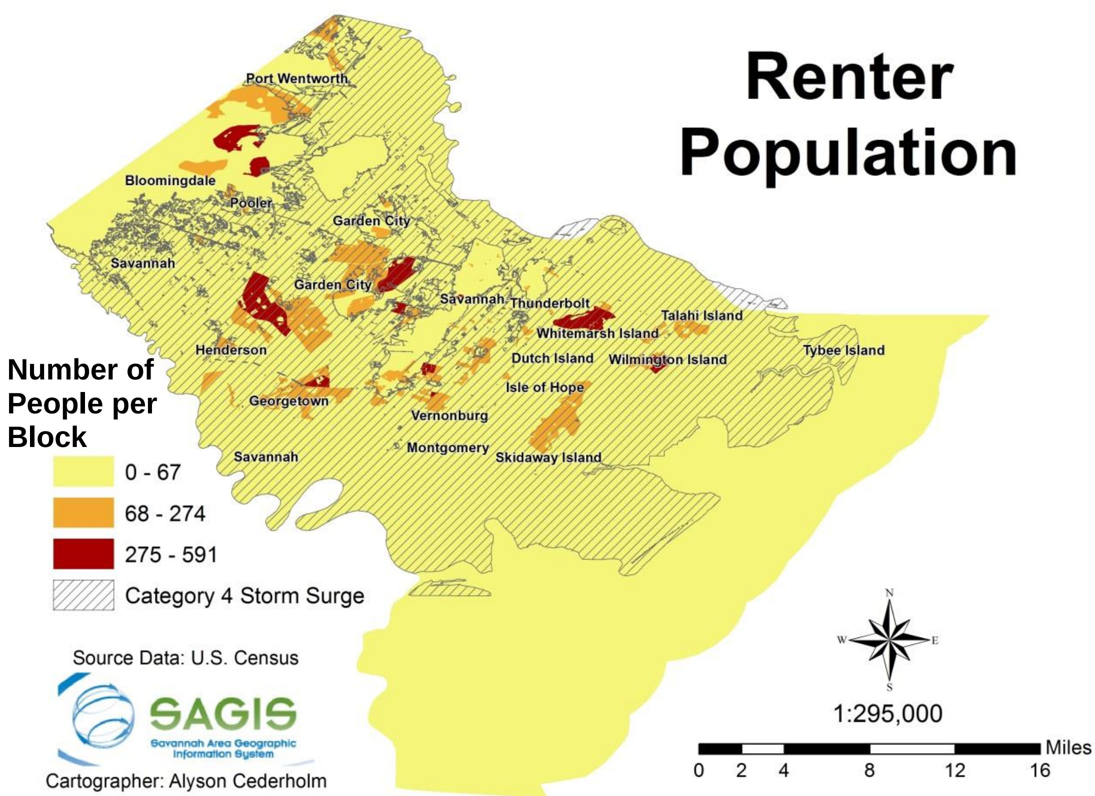
Appendix 6

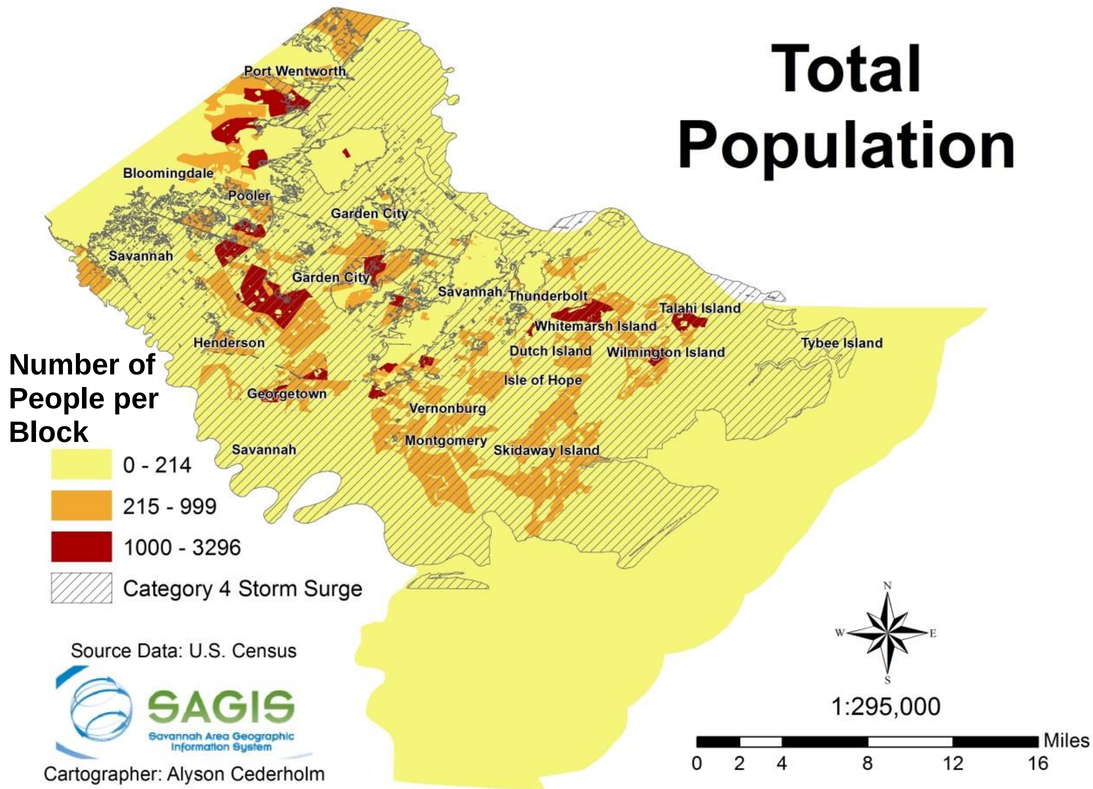
Category 4 Storm Surge Maps

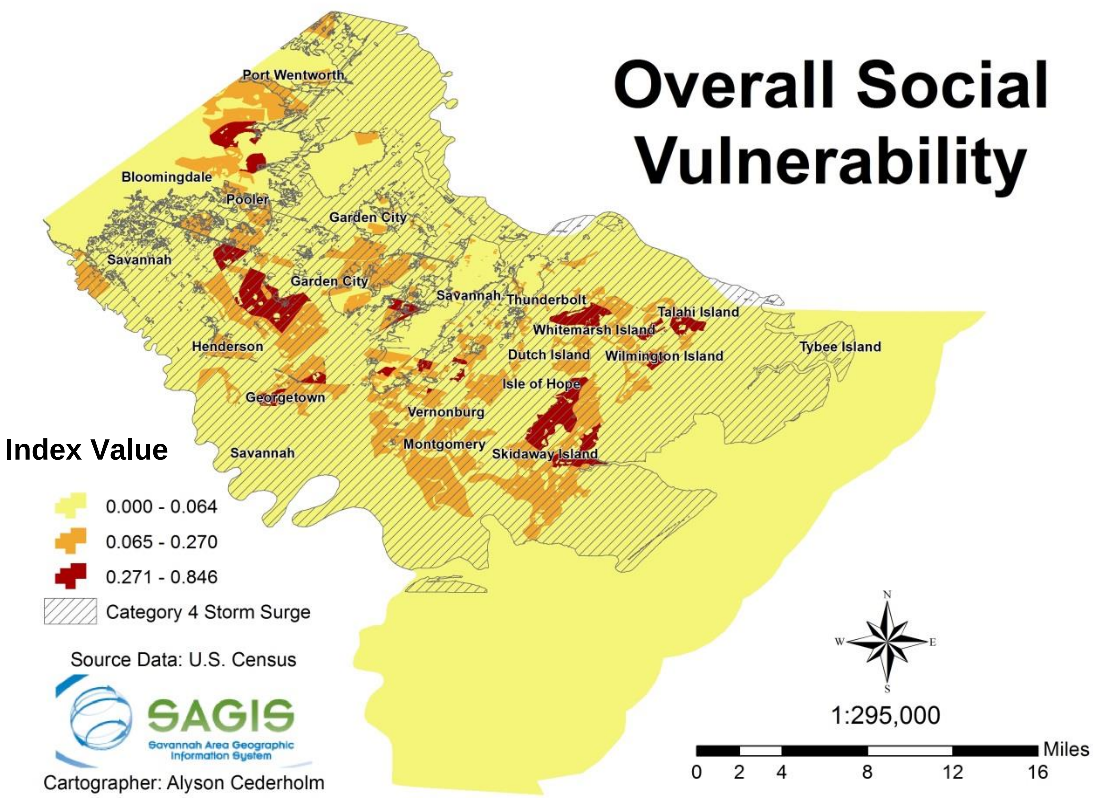

Women Headed Household Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Number of People per Block
0 - 15
16 - 73
74 - 198
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

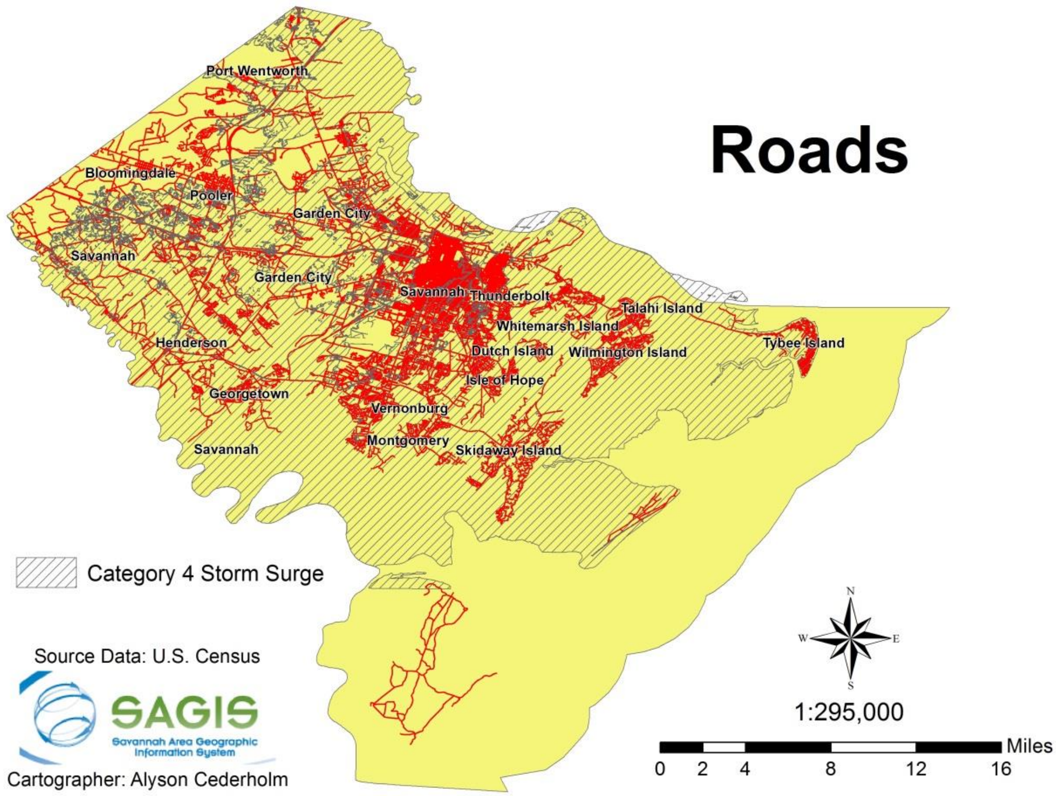

Children/Youth Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Number of People per Block
0 - 50
51 - 259
260 - 905
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

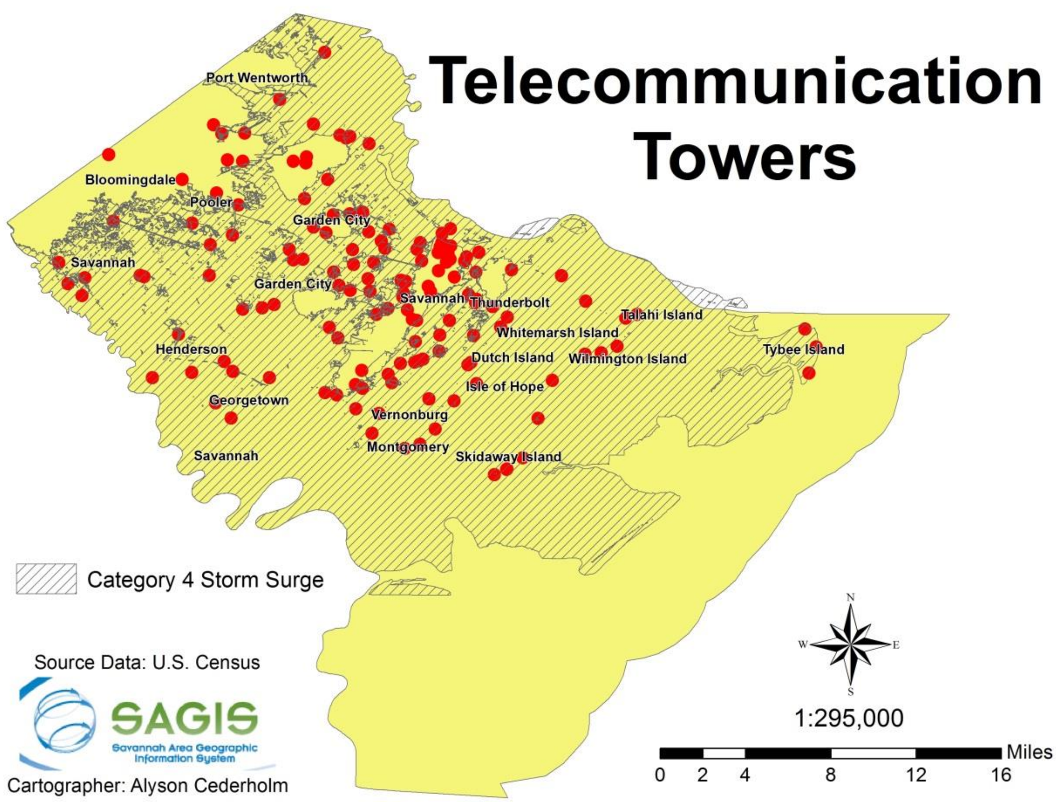

Elderly Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Number of People per Block
0 - 55
56 - 219
220 - 575
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

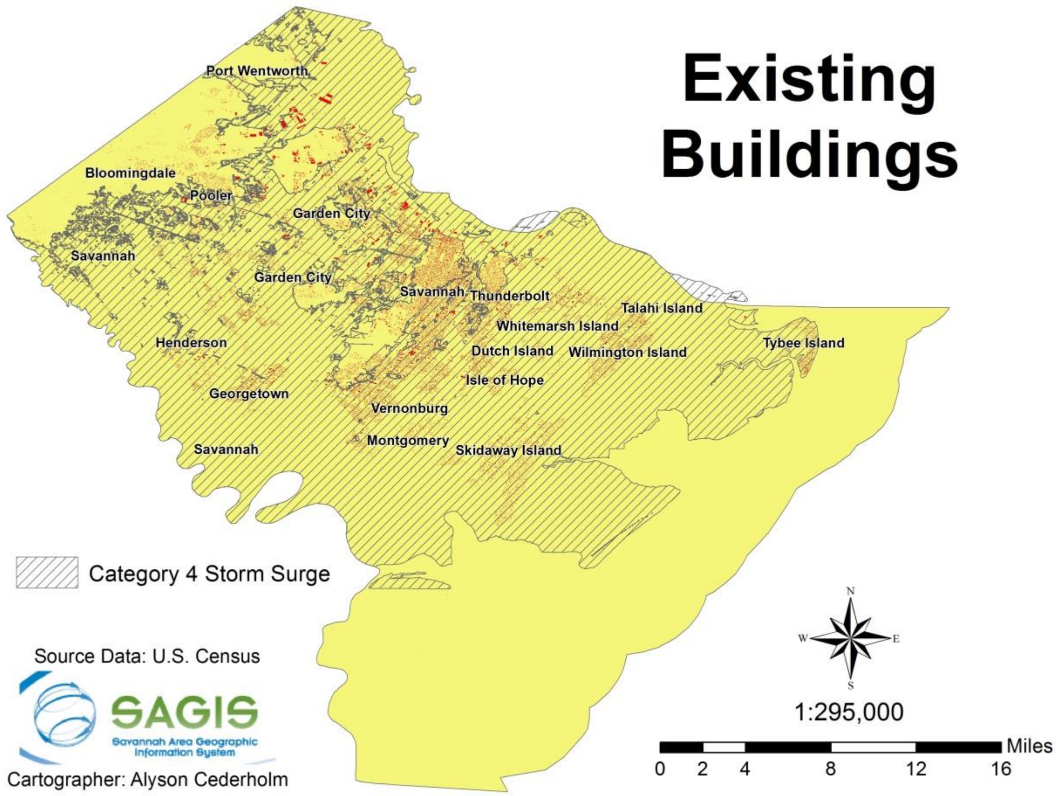

Renter Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Number of People per Block
0 - 67
68 - 274
275 - 591
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

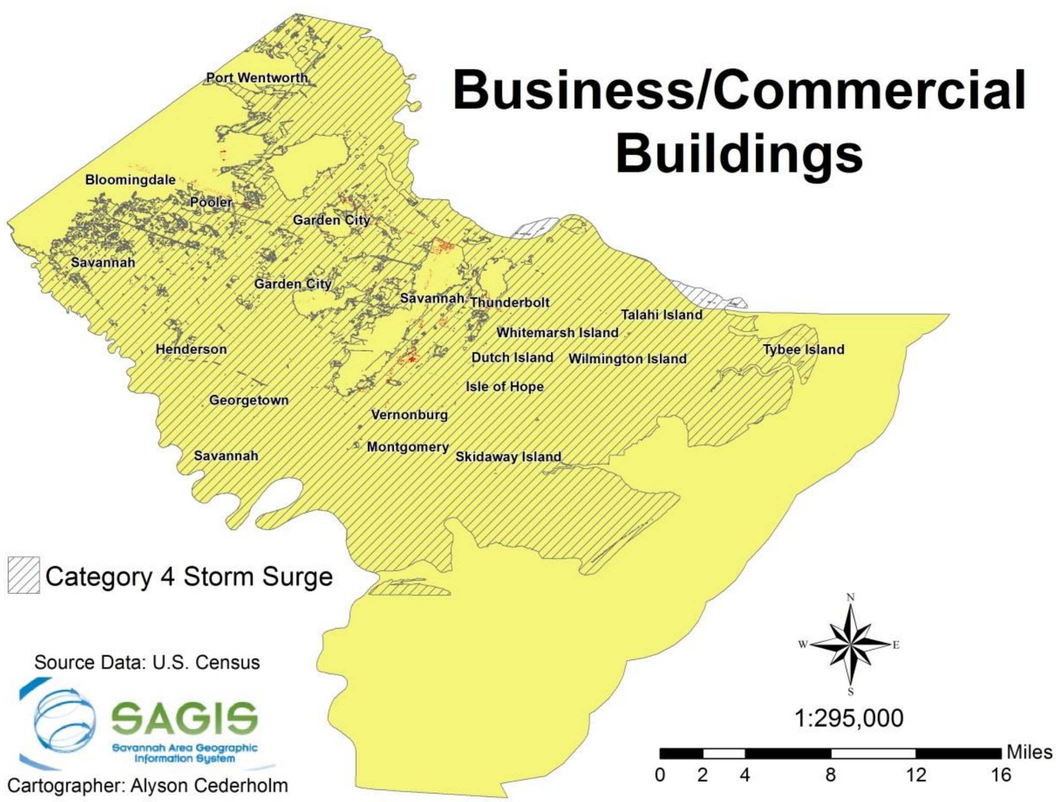

Total
Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of
People per
Block
0 - 214
215 - 999
1000 - 3296
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

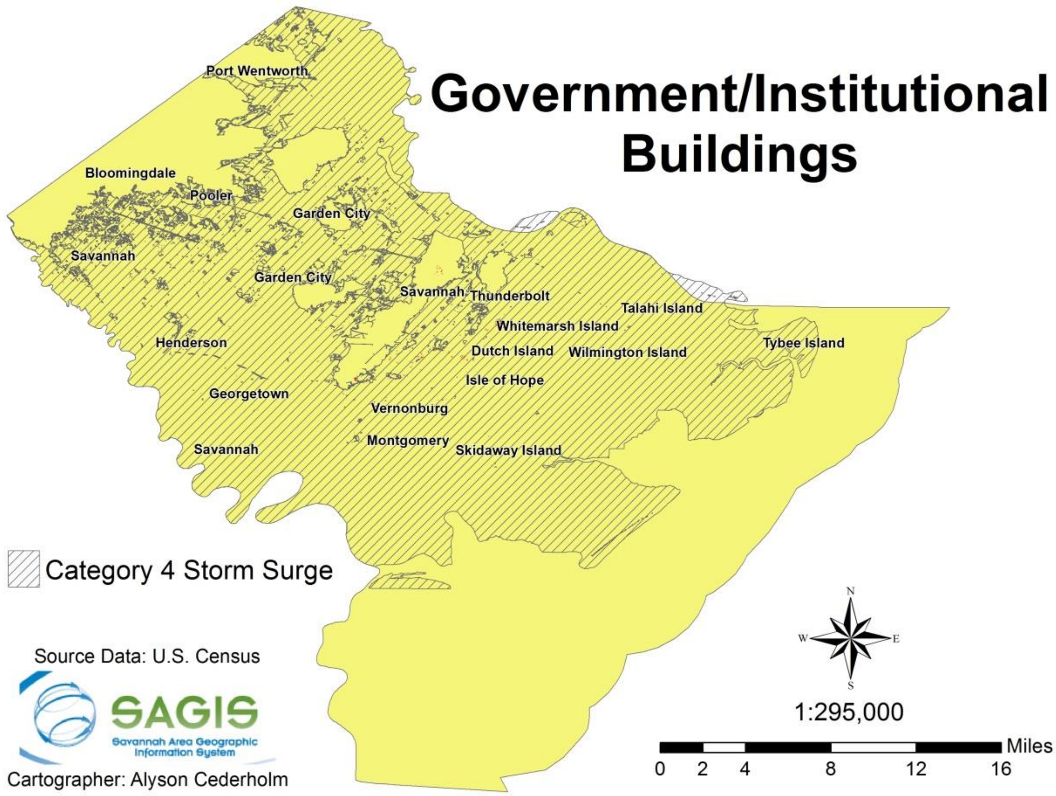

Overall Social
Vulnerability
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Index Value
0.000 - 0.064
0.065 - 0.270
0.271 - 0.846
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

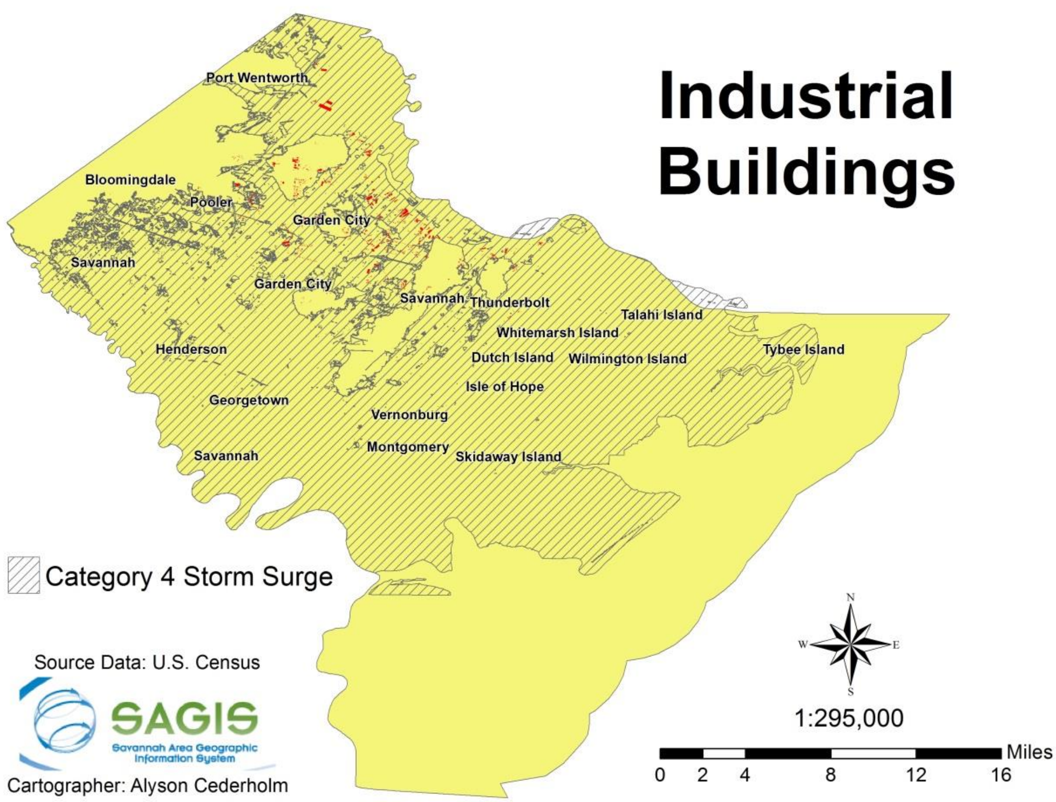

Roads
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

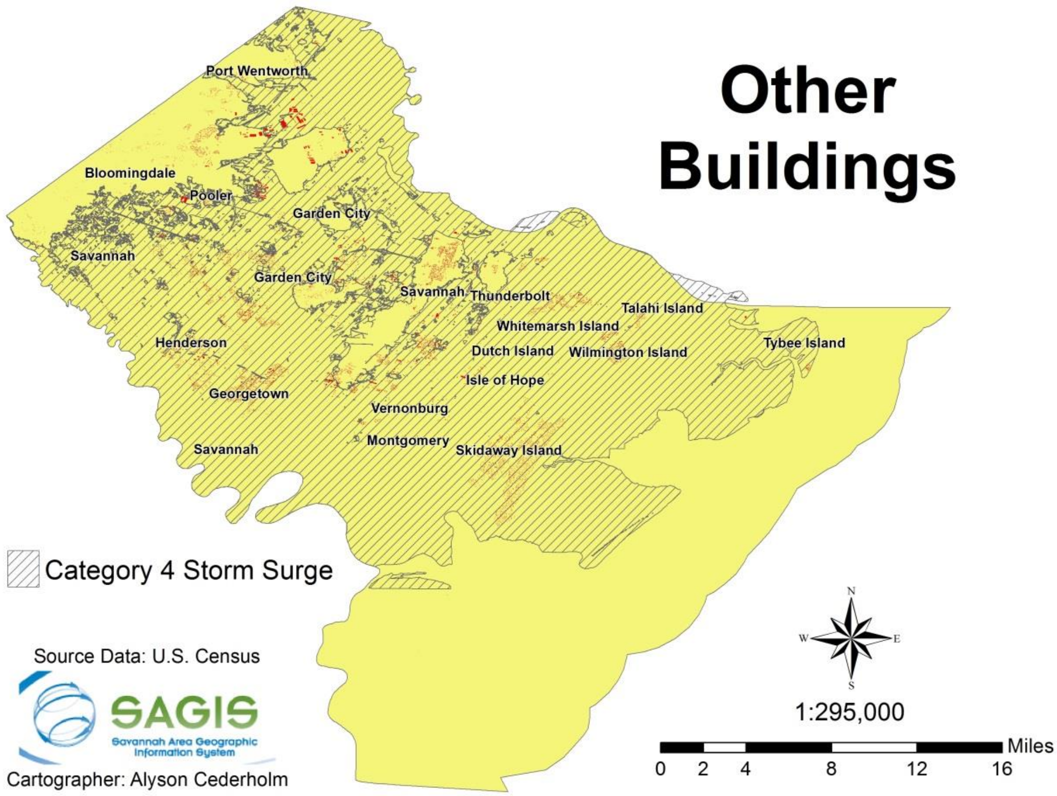

Telecommunication Towers
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

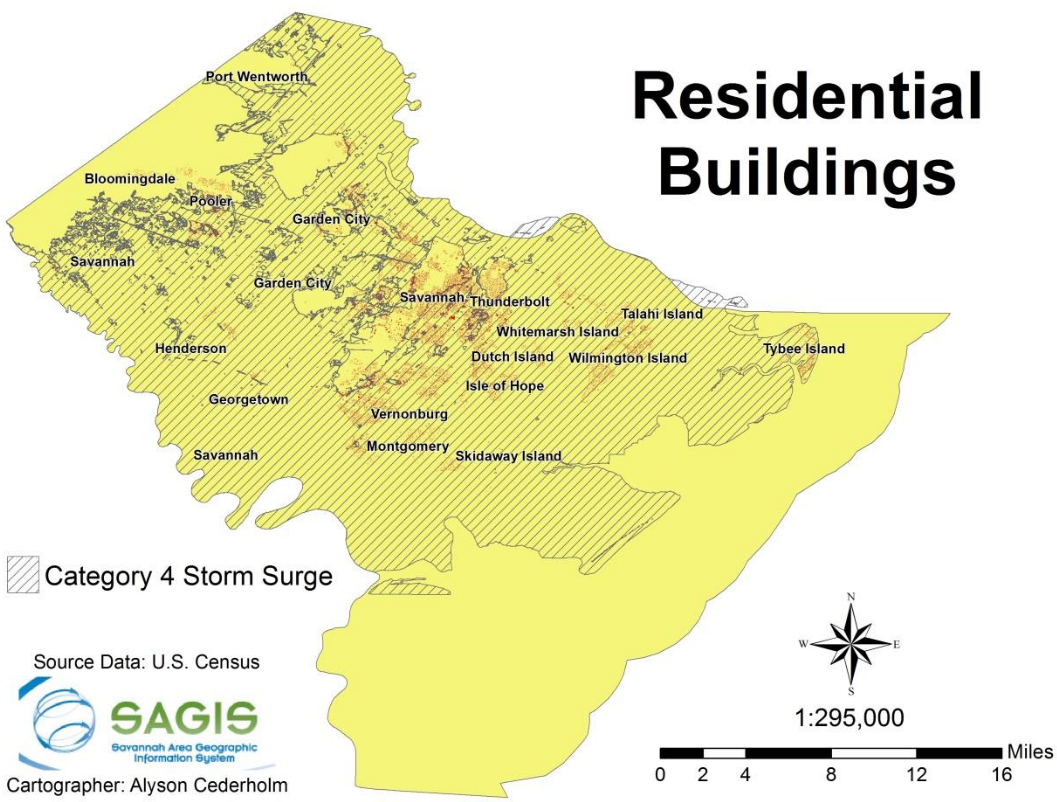

Existing
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

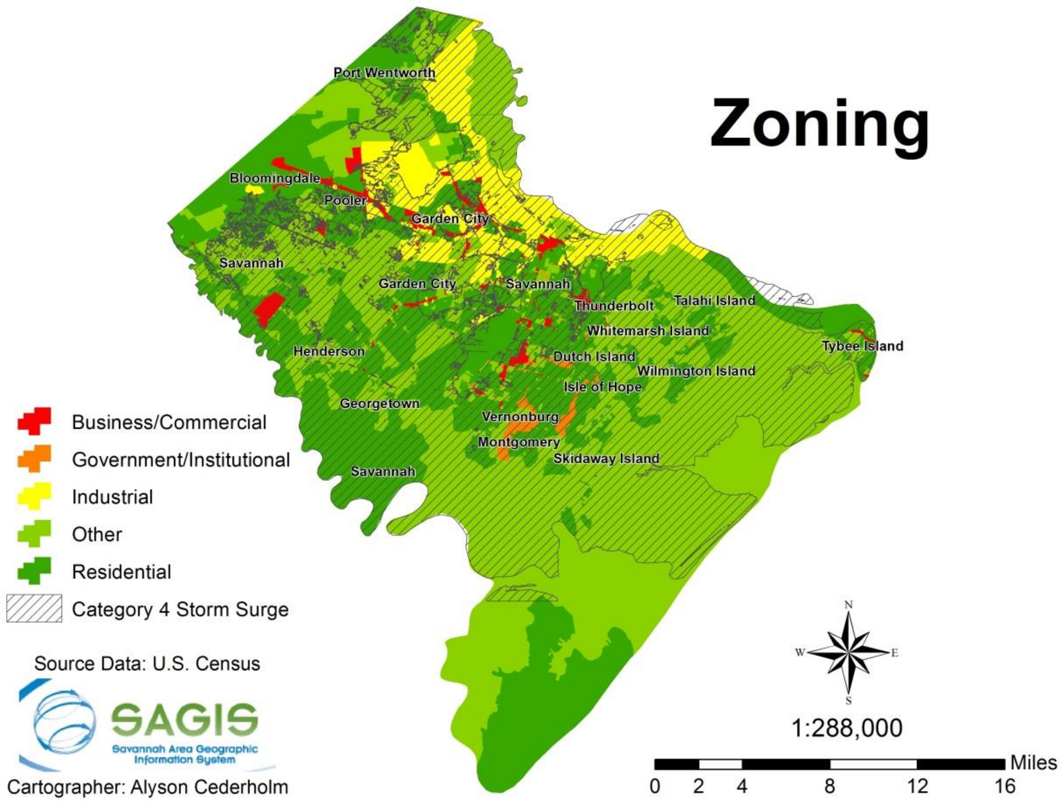

Business/Commercial
Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16


Government/Institutional Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Dutch Island
Wilmington Island
Tybee Island
Henderson
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16


Industrial Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Dutch Island
Wilmington Island
Tybee Island
Henderson
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

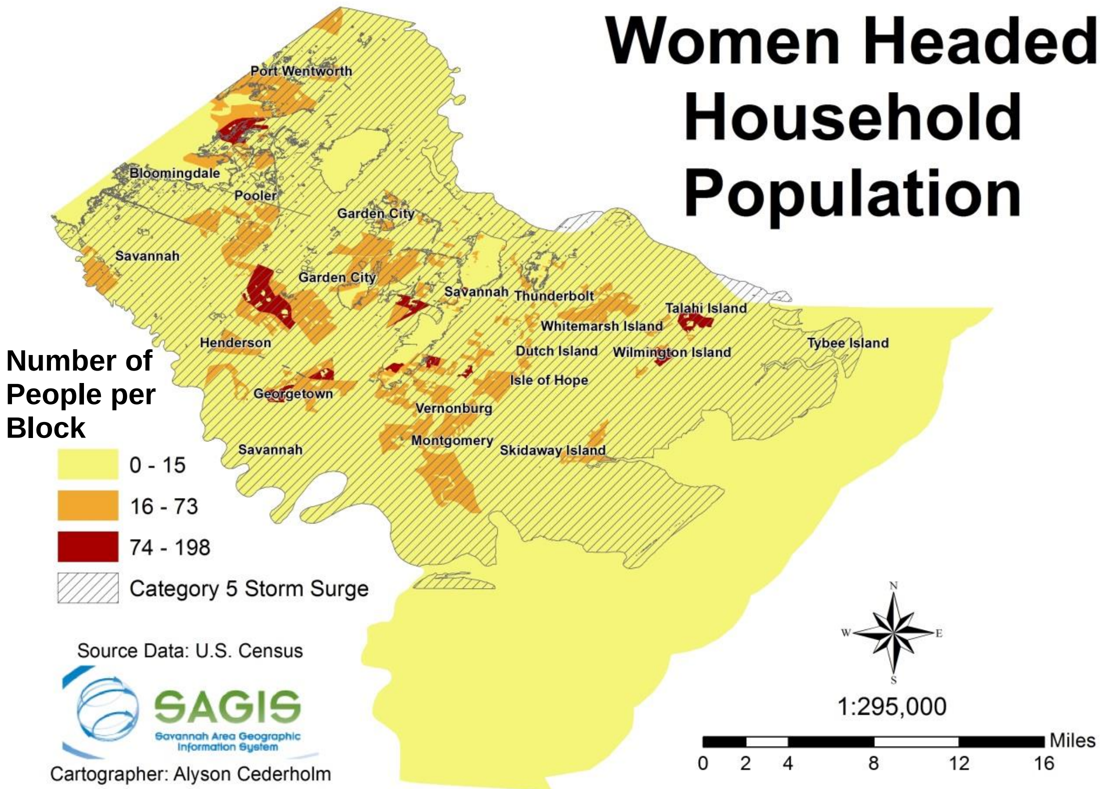

Other Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

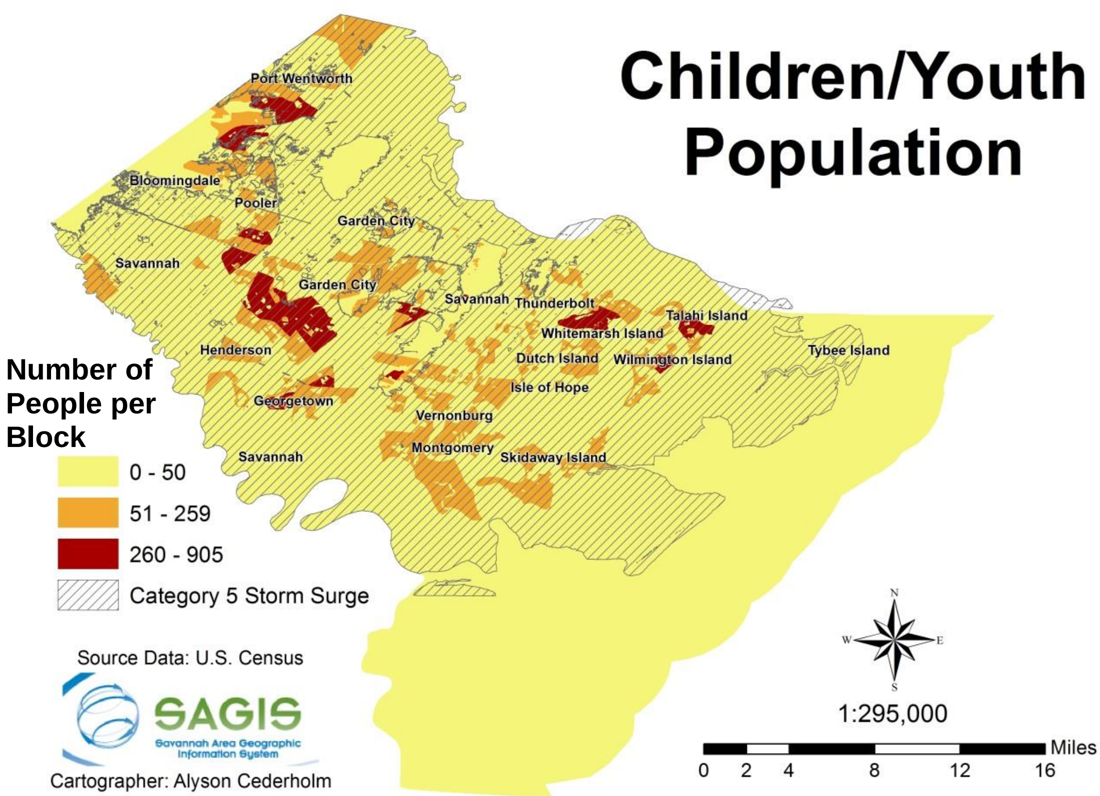

Residential Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

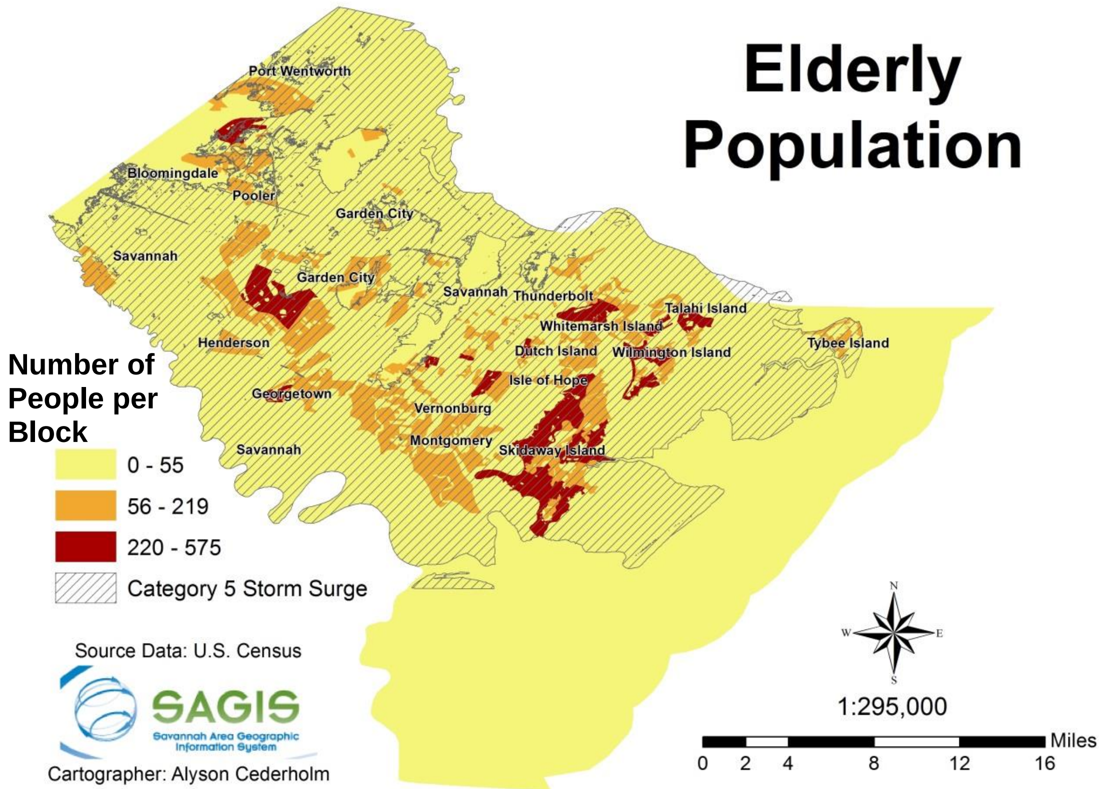

Zoning
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Business/Commercial
Government/Institutional
Industrial
Other
Residential
Category 4 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:288,000
0 2 4 8 12 16
Miles

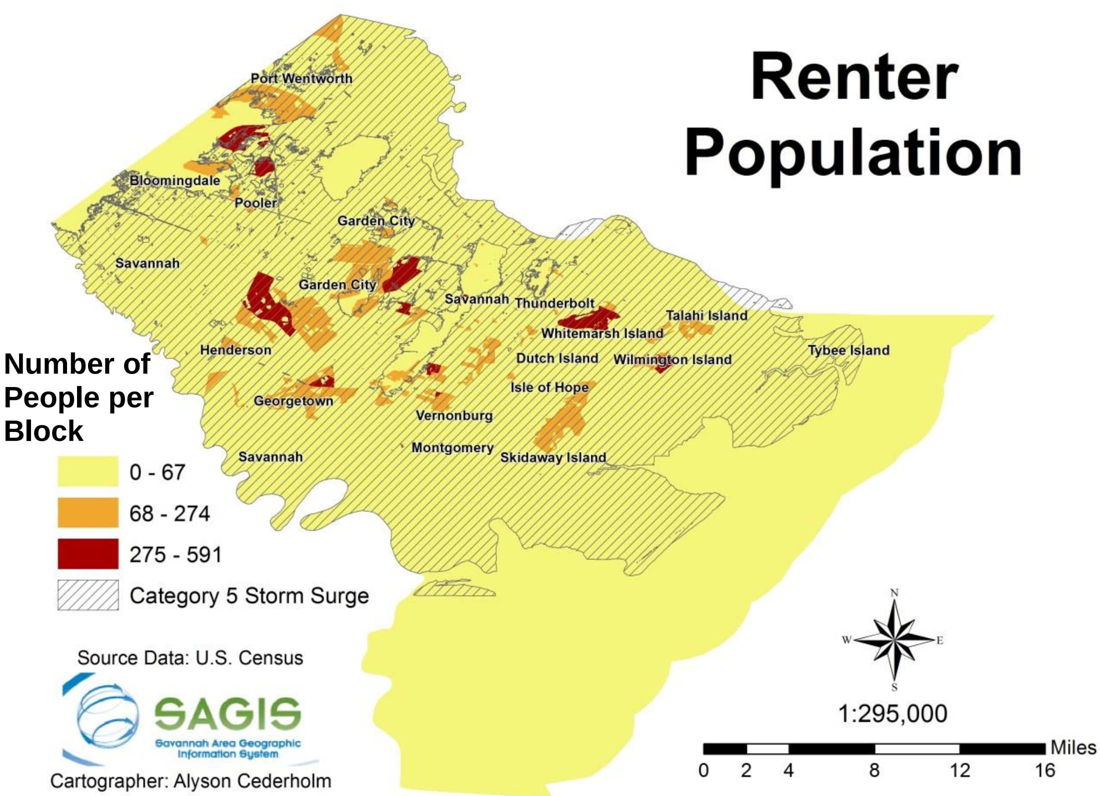
Appendix 7

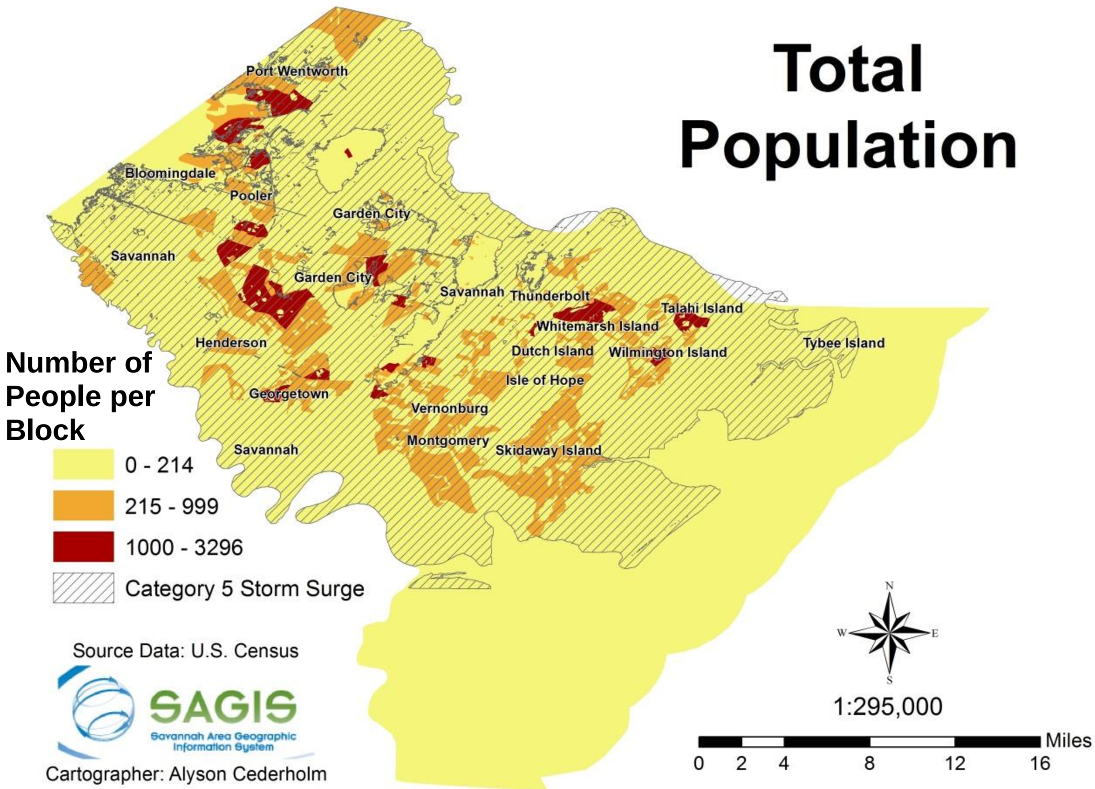
Category 5 Storm Surge Maps


Women Headed Household Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Number of People per Block
0 - 15
16 - 73
74 - 198
Category 5 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

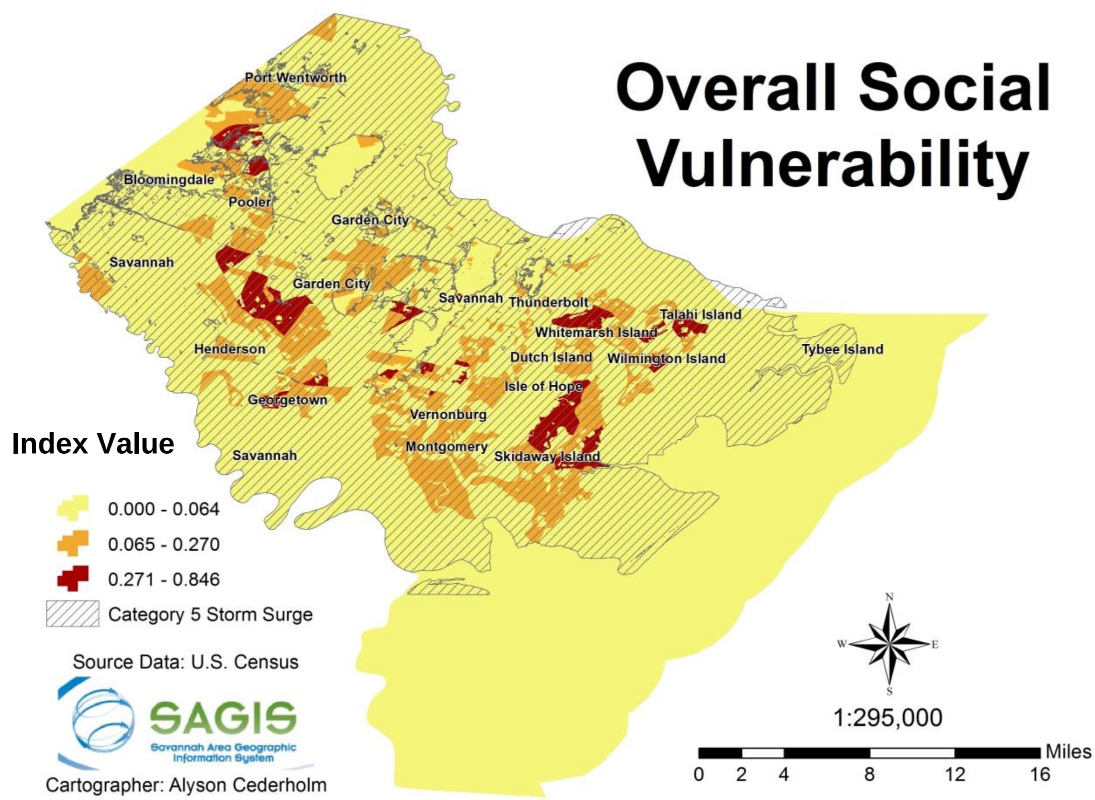

Children/Youth Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Number of People per Block
0 - 50
51 - 259
260 - 905
Category 5 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16


Elderly Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Tybee Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 55
56 - 219
220 - 575
Category 5 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

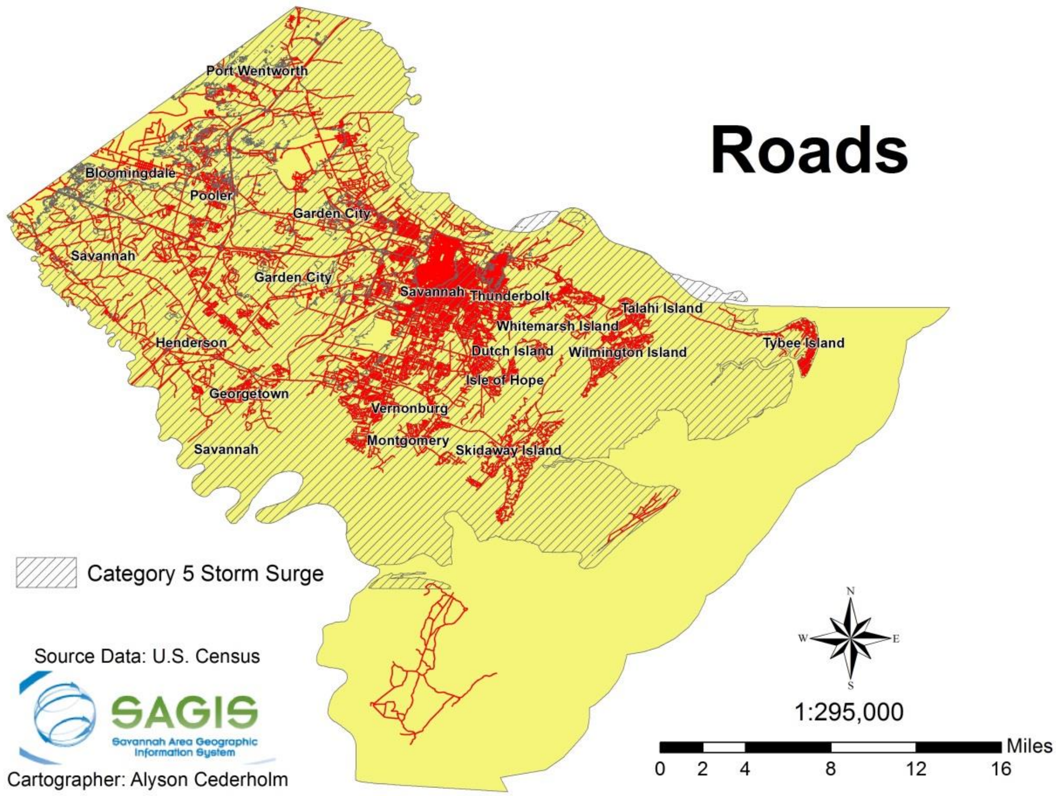

Renter Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 67
68 - 274
275 - 591
Category 5 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

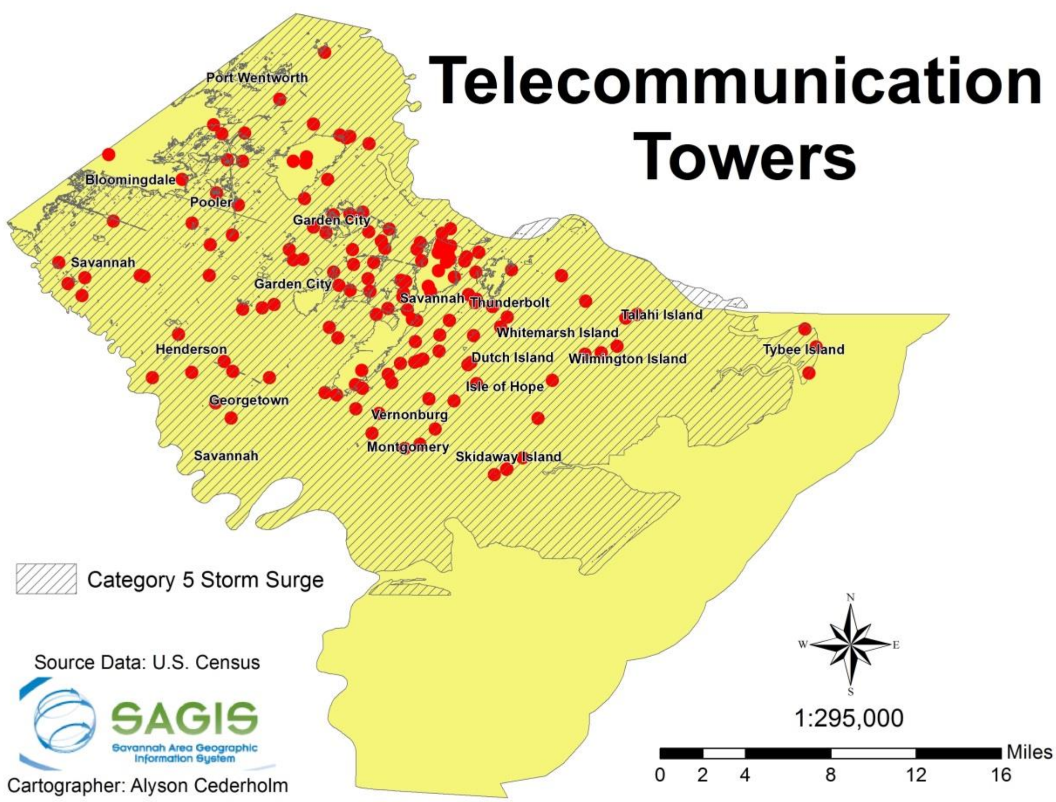


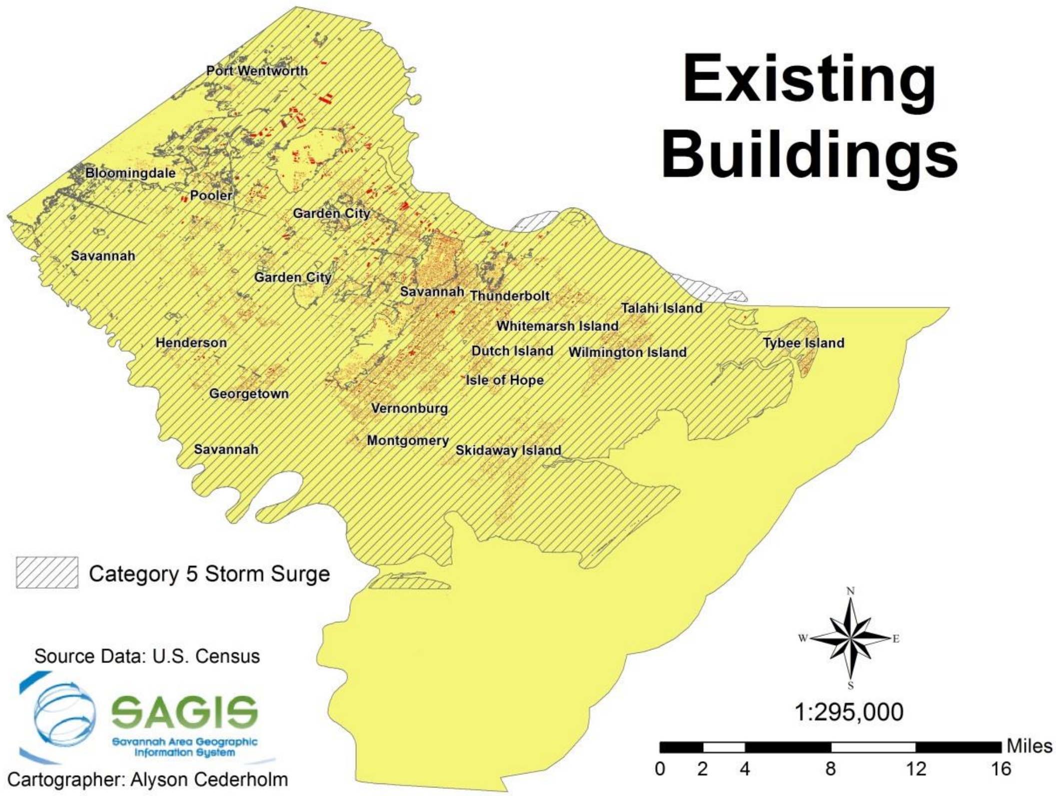
Total Population
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Number of People per Block
0 - 214
215 - 999
1000 - 3296
Category 5 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

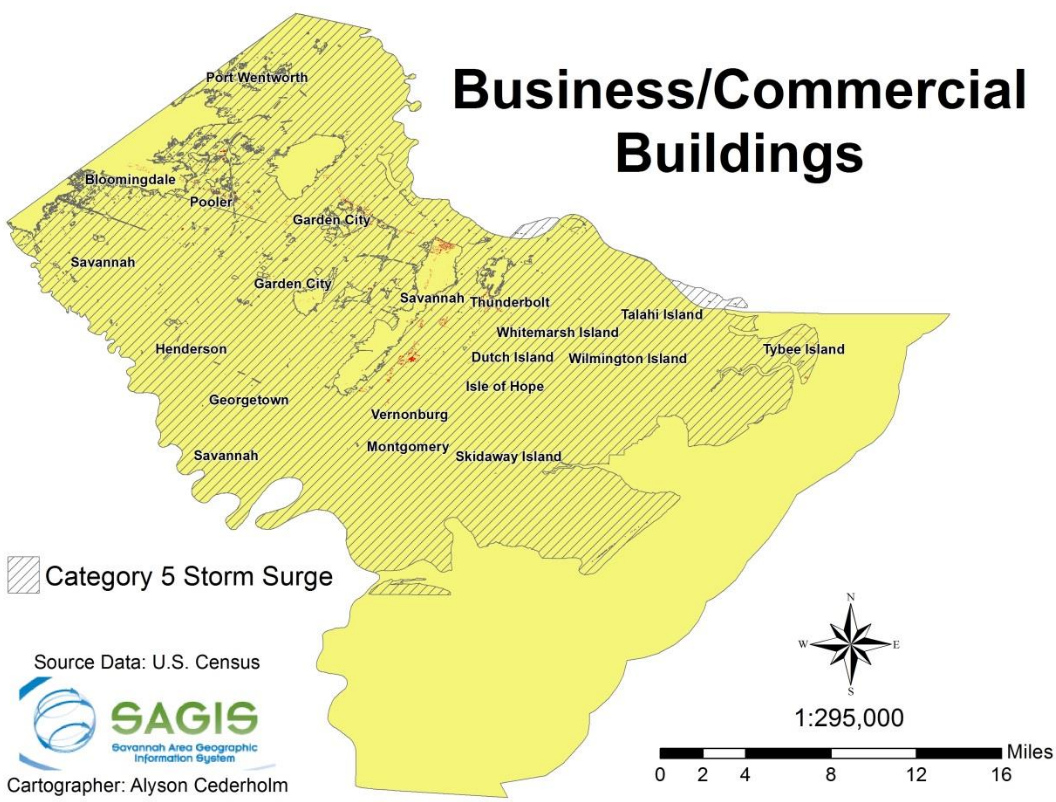


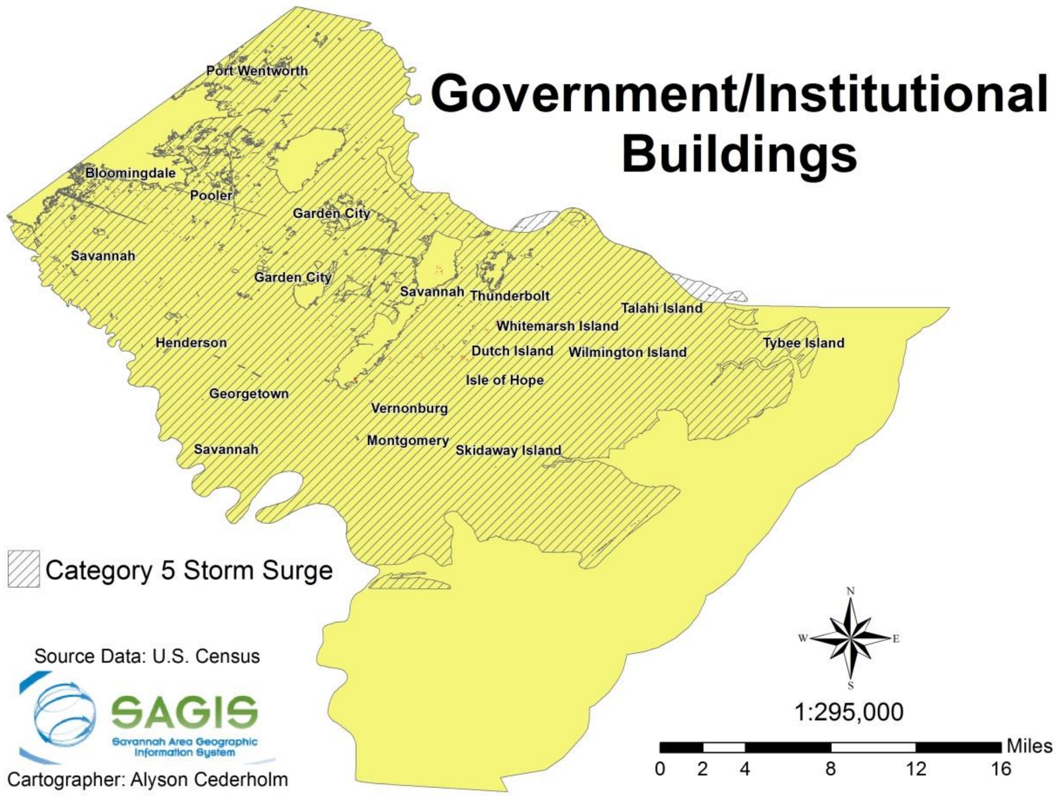
Overall Social Vulnerability
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Index Value
0.000 - 0.064
0.065 - 0.270
0.271 - 0.846
Category 5 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:295,000
Miles
0 2 4 8 12 16

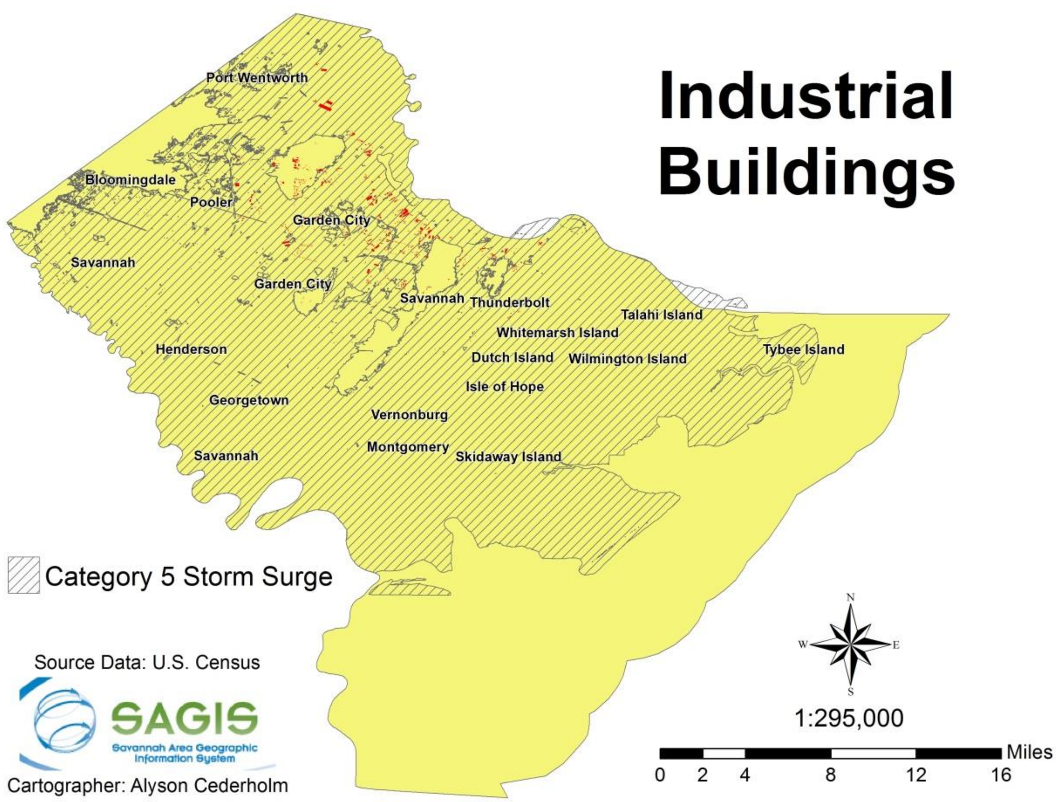

Roads
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Category 5 Storm Surge
Source Data: U.S. Census
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

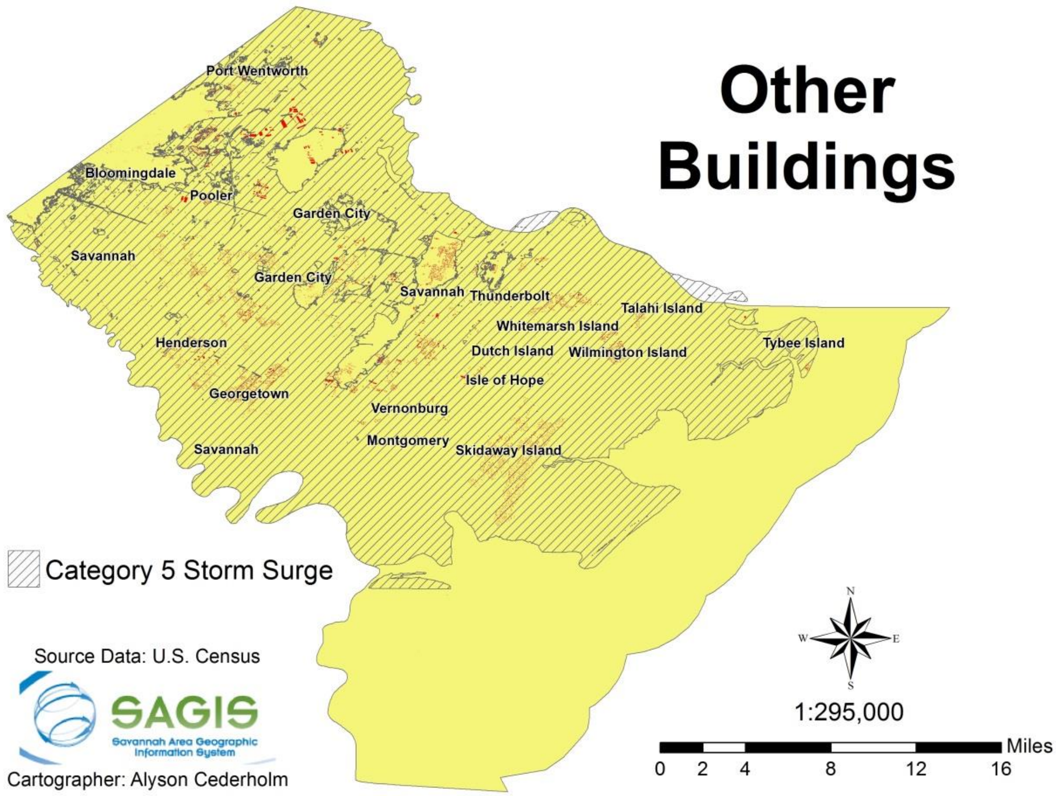

Telecommunication Towers
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Category 5 Storm Surge
Source Data: U.S. Census
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16

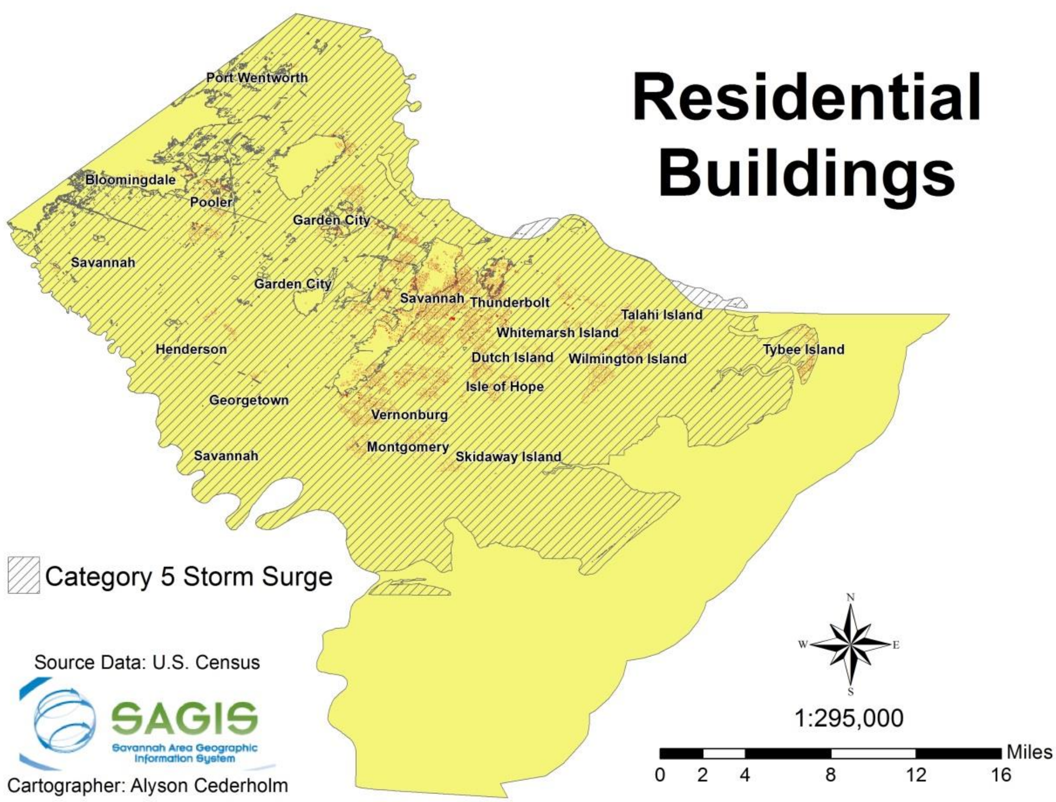

Existing Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Dutch Island
Wilmington Island
Tybee Island
Henderson
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 5 Storm Surge
Source Data: U.S. Census
1:295,000
Miles
0 2 4 8 12 16
Cartographer: Alyson Cederholm

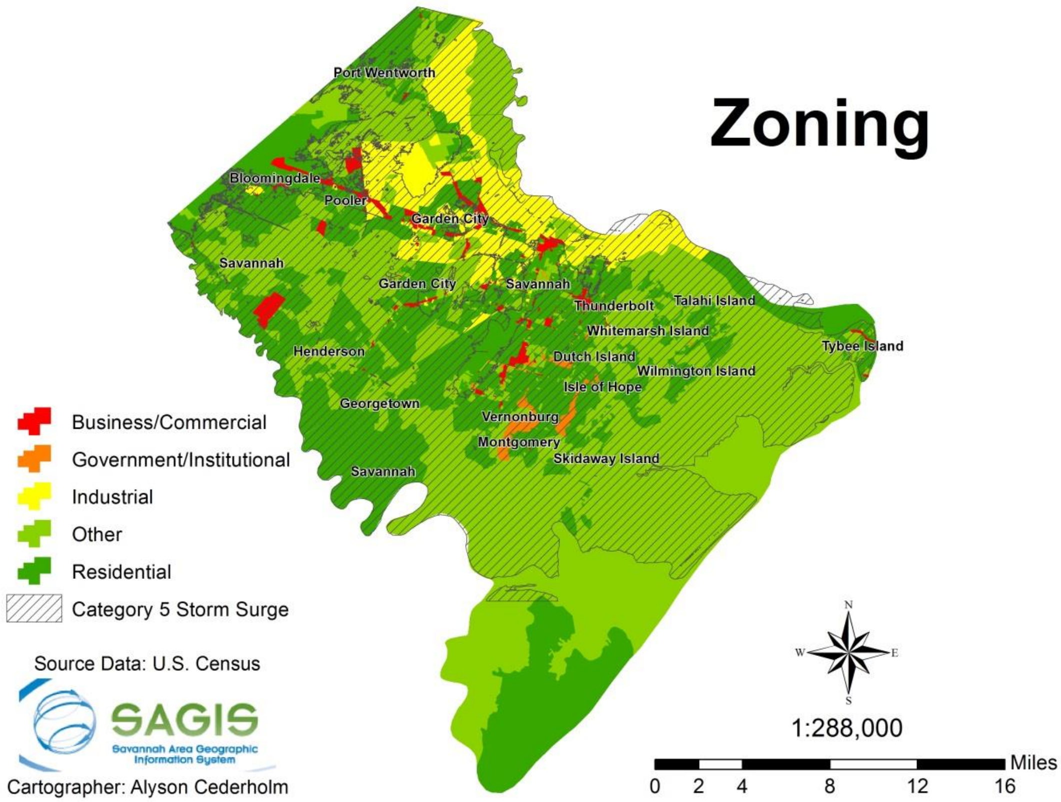

Business/Commercial Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Dutch Island
Wilmington Island
Tybee Island
Henderson
Isle of Hope
Georgetown
Vernonburg
Montgomery
Savannah
Skidaway Island
Category 5 Storm Surge
Source Data: U.S. Census
1:295,000
Miles
0 2 4 8 12 16
Cartographer: Alyson Cederholm


Government/Institutional Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Category 5 Storm Surge
Source Data: U.S. Census
Cartographer: Alyson Cederholm
1:295,000
0 2 4 8 12 16 Miles


Industrial Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Category 5 Storm Surge
Source Data: U.S. Census
Cartographer: Alyson Cederholm
1:295,000
0 2 4 8 12 16 Miles


Other Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Category 5 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16


Residential Buildings
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Henderson
Dutch Island
Wilmington Island
Tybee Island
Isle of Hope
Georgetown
Vernonburg
Savannah
Montgomery
Skidaway Island
Category 5 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
1:295,000
Miles
0 2 4 8 12 16


Zoning
Port Wentworth
Bloomingdale
Pooler
Garden City
Savannah
Garden City
Savannah
Thunderbolt
Talahi Island
Whitemarsh Island
Tybee Island
Henderson
Dutch Island
Wilmington Island
Isle of Hope
Georgetown
Vernonburg
Montgomery
Skidaway Island
Savannah
Business/Commercial
Government/Institutional
Industrial
Other
Residential
Category 5 Storm Surge
Source Data: U.S. Census
SAGIS
Savannah Area Geographic Information System
Cartographer: Alyson Cederholm
N
W
E
S
1:288,000
0 2 4 8 12 16 Miles