A PARCEL-LEVEL ANALYSIS OF COASTAL HAZARD IMPACT ON MANATEE COUNTY'S RESIDENTIAL LANDS: AN INTEGRATED APPLICATION OF GIS, HAZUS-MH AND LAND USE PLAN

By

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To everyone who has ever inspired me or shaped my path

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LIST OF ABBREVIATIONS

BFE	Base Floor Elevation
CUTR	Center for Urban Transportation Research at the University of South Florida
FEMA	Federal Emergency Management Agency
FDEP	Florida Department of Environment Protection
SLR	Sea Level Rise
SS	Storm Surge

Abstract of Thesis Presented to the Graduate School
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This thesis intended to reveal how coastal hazard would affect the Manatee County's land development. It also answered the question about the strategies that can help improve the integration of land use planning and coastal hazard adaptation.

My study estimated buildings and building stock replacement value exposed to projected coastal hazard scenarios. Residential properties are most vulnerable to the attacks of coastal hazards. Hence, my study summarized future residential land exposures and associated existing land uses by scenarios. Land use exposures were categorized by spatial locations with respect to the magnitude of sea level rises and associated storm surges. My study also developed a methodology to present the projected storm water depth at the parcel level, and to identify the number of properties in each parcel.

For categorized future residential capacities, my study supported the community developments while also reduced their vulnerability to coastal hazards. Suggestions were made in views of county's land use plan, coastal elements, construction strategies and flood insurance. Existing residential land uses remaining residential must follow the

development strategy that focusing on maintenance of buildings' life-spans and the associated service infrastructure. Specified site development and purchasing-and-selling-back of development rights might be adopted for evacuation access and other urgent public services. Development opportunities in these areas are limited, but the county should focus on sustaining the stability between the communities and coastal environmental process. Vacant lands have more development potential. The county should involve flood insurance program, new constructions, and alternation of existing structures to meet the standards that the insurance company are willing to provide adequate coverage.

Apart from federal flood insurance policy, land regulatory tools integrated with coastal planning considerations should take the predominant position to prepare coastal hazard adaptations. An important goal is to involve local stakeholder's participation for the fulfillment of the plans and ordinances. Further coastal hazard-based studies should not only focus on convincing the stakeholders with sophisticated modeled results about hazards' impact, but also need to build guidance to lead the stakeholders to understand the adaptation process and to be willing to participate in implementations.

CHAPTER 1
INTRODUCTION

Background

Global warming, or climate change, is a subject that shows no sign of cooling down. (National Geography News, 2007) The U.S Global Change Research Program presented key findings about global climate change impacts. The program stated that the observed increase in global temperature is “due primarily to human-induced emissions of heat-trapping gases.” (U.S Global Change Research Program, 2009, p. 9) The facts demonstrated by the program include expected increasing climate-related impacts on energy, life-line utilities, induced public health issues and driving compelling water-sustainability issues. More importantly, the reports showed that “Coastal areas are at increasing risk from sea-level rise and storm surge,” (p. 12) the combination of coastal hazard risk ,wave heights and long-term beach erosions put properties and public infrastructure around Gulf Coasts and Pacific Islands are at a 90% probability of being impacted by coastal-hazard-driven flooding and erosion effects. Nowadays, it is necessary to aware the facts of increasing coastal hazard risks in the scope of urban planning, and to follow the trend of hazard mitigation. It is also important to integrate flood-hazard-related elements to develop better land use strategies. Last but not the least, it will be expected that the trend of using big data and customized hazard-based programs can lead to profound improvement of coastal hazard mitigation strategies.

Research Questions and Associated Objectives

This research reflects understanding of coastal flood hazards from an urban planning perspective. It also shows a view about how urban planning and management work in the coastal hazard adaptation process. The thesis is about to answer the following questions:

1. Will coastal flood hazards affect the county's land development?

    Here the way to affect land developments mainly refers to bringing damages to building stock, especially residential properties and associated lands. At first, it was assumed that a 100-year storm surge would happen in the year 2040. By summarizing physical and economic damages to the properties and lands within projected storm surge areas, my study produced general estimations of flood hazard impact. Manatee County, Florida, one of the counties at high risk of coastal hazards such as hurricanes and storm surges, was chosen as the study area.

    To answer the first question, this research used HAZUS-MH to generate estimations about building stock losses and related economic value losses caused by projected storm surges. In order to explore more details of the impact brought by storm surges, ArcGIS was used for an in-depth analysis of the property losses. This was based on the county's current land use codes, future land use plan, and coastal planning elements. In this way, the impact of coastal hazards on future land development was revealed with relatively detailed justifications.

2. What strategies can help improve the integration of land use planning and coastal hazard adaptation?

    The first valuable strategy identified by my study is integration of estimations from different viewpoints. As mentioned, my study used HAZUS-MH to generate building-oriented loss estimations, while also incorporating GIS technology to conduct a land-area-oriented loss assessment. Buildings and lands are tightly associated characteristics. Therefore, both building losses and land exposures were estimated under different storm-surge scenarios, for the sake of gaining comprehensive understandings about flood hazard impact.

    The second strategy is to integrate general and local estimations about coastal hazard impact on lands and properties. My study used both HAZUS-MH and ArcGIS to generate general loss estimations. However, the impact brought by storm surges onto each parcel or property varies for each individual building or parcel. In order to be more practical in the process of impact estimation, my study developed a property data preparation strategy to capture the details about storm-surge-caused damages to specific locations and properties. The strategy helped strengthen metadata for property data provided by the county's property appraiser, making the property data more available for direct application of the county's policies. My study examined discusses how to apply land use plan, costal elements, building codes and FEMA construction strategies to certain types of lands affected by storm water.

Significance of Research

My study can be regarded as a coastal hazard risk analysis intended to enhance county's coastal hazard adaptation policy through analysis of hazard impact. Data processing strategies and joint loss estimations are also part of the adaptation strategies. Coastal hazard analysis supports the maintenance and development of human life and properties, by mitigating the spatial conflict between built living environment and the nature's environmental and ecological process. Previous study showed that human habitation tends to concentrate near coastal zones: "The near-coastal population within100 km of a shoreline and 100m of sea level was estimated as 1.2 X 109 people with average densities nearly 3 times higher than the global average density, and average population densities are higher at elevation below 20m though the 100km width of the near-coastal zone". "The concentration of people and infrastructure along the nation's coastline has increased our vulnerability to severe coastal storms and other natural hazards." (Puszkin-Chevlin, et al., 2006, p. 7) Awareness of the risks living adjacent to potential hazard generators helps us develop proper avoidance strategies.

Second, through site-specific analysis and case studies, my study provides a method of capturing site-specific information about flood hazard impact. Numerous previous studies show the property damage, economic losses, and the on human living environment imposed by coastal hazards. In addition to generalization of land, population or economic value losses by a standardized land value estimation system, government officials and related departments need an overview for hazards impact and an understanding the spatial variation of the strength of impact. They also need to know which of the aspects (e.g., physical structures, economic characteristics) of the property will be affected. In addition, coastal hazard evaluation programs inevitably carry imprecision resulting from data deficiency and model assumption. My study adds to the comprehensiveness of coastal hazard planning by integrating the HAZUS-MH loss estimation strategy with the GIS property data preparation strategy.

Methodology

The entire research process relied on using HAZUS-MH flood hazard modeling and ArcGIS basic Geoprocessing tools. ArcGIS was mainly used for secondary data or property data process. The Geoprocessing tools were widely and flexibly adopted in compiling, transforming, aggregating and disaggregating geophysical, demographic and economic information into the data stored at various regional levels. One important steps: identifying number of parcels stacked atop each other, was also done by ArcGIS. HAZUS-MH was used for generating storm surge depth grids and Hazard Event Reports of direct and indirect losses on building stocks, other infrastructures and utilities. Importantly, building characteristics defined in HAZUS-MH (such as structural types and foundation distributions) were largely adopted in case studies for parcels with multiple stacked polygons. Interactive use of the two software programs built the workflow of the sequential analysis, the parcel data were prepared to have attributes such as acreages, market value, and land-use codes. These attributes were built on various regional levels (Census Block Group level, future land use level and parcel level). HAZUS-MH produced storm surge depth grids. The grids were intersected with parcel data in ArcMap for summarizing the statistics about affected land areas and associated land use codes. Together, HAZUS-MH loss estimation “Hazard Event Report”, along with the GIS statistical summaries provide the contents and scope for coastal flood hazard impact analysis. This is because lands exposed under projected storm surges can be displayed visually by different categorizations, such as storm water depth or land use descriptions. This provides a variety of ways to convey the information about storm-surge-cased impacts simultaneously.

Apart from the methods listed above, three case studies were incorporated to deal with site-specific issues and data inconsistency. Cases also helped illustrate the fact that the GIS-based property management process and the flood-based customized program can be integrated to provide damage estimations and to initiate further detailed analysis.

Results

HAZUS-MH Hazard Event Reports show that 99% of buildings facing different levels of storm-water-caused damages are residential buildings. From the perspective of direct and indirect economic loss, residential buildings are still the primary group, and also the largest group to be affected by the 100-year storm surge projected in the year 2040. A half-meter sea-level-rise causing associated storm surge will substantially increase damaged building stock.

Considering that residential properties make up the biggest group exposed to future storm water, the following GIS analysis discusses the existing condition of future residential lands. Most future residential areas comprise current residential lands, followed by current vacant acreage and Greenfields. Vacant lands in the 100-year storm surge area with a one-meter sea-level-rise make the most capacity for future residential developments, The government must give each of these land categories different land use treatment, according to their spatial location and associated potential land development opportunities. Finally, we examined the joint utilization of future land use elements and costal elements in the current comprehensive plan, coastal-planning-related land use tools, and FEMA-suggested construction strategies.

CHAPTER 2
LITERATURE REVIEW

My study undertook flood hazard risk analysis and sought to enhance the process of hazard adaptation. Specifically, the risk analysis consists of risk (hazard) modeling and future land use based hazard scenario analysis. Studies in a variety of coastal-hazard based scenarios estimated related hazard impact and explore the mitigation solutions from planning , building construction and environmental engineering. However, the past studies showed there are deficiencies in researches about the ways to build connections between coastal hazard impact assessment and applications of land use planning strategies, especially strategies in the view of future land use planning.

Coastal Hazard

Rising mean sea level is a significant indicator of global climate change. (Barnett, 1983, p. 287) As generally considered result of thermal expansions and polar ice discharge, the impact of sea-level-rise has been studied extensively around the world. Meanwhile, the global sea level rises are also well-established consequences of global warning. According to Climate Central’s Florida costal hazard vulnerability report (2012), the global sea level has risen around the doubled speed as it did during the past centuries (p. 12). It has been acknowledged that the global mean sea level rose at an average rate of 1.7 mm per year during the 20th century, and the satellite measurements even suggests an increased rate by 3.2 mm/yr. (Maryland Climate Change Commission, 2013, p. 3) (Church and White, 2011, p. 585) The report estimated that coastal sea level rise has been a persistent trend and over eight millions people live in areas at risk to coastal flooding. A coherent pattern of increasing Relative

Sea Level (RSL) was found to exist on average at all stations analyzed between the years of 1903 to 1969. (Etkins and Epstein, 1982, p. 287) Gonitz (1991) also predicted that “A rise of sea level between 0.3 and 0.9 m” by the end of this century. (p. 379) In fact, every coastal flood today is already wider, deeper and more damaging because of the roughly 8 inches of warming-driven global sea level rise that has taken place since 1900. (Climate Central, 2014. p. 11) The latest projected sea level rise range from U.S. Army Corps of Engineers Guidance showed that among the year 2050 the sea level rise will reach 0.5 to 1.5 feet(Climate Central, 2014, p.11) and in the year 2100 there will be at most 5 feet of sea level rise around the country’s coastal area(Frank, 2014).

Coastal areas are also vulnerable to increases in the intensity of storm surges. Generally, the Climate Central’s research indicated that a storm surge drives extra water tidal level (p.16), which concurrently works with the tidal level at a given time. In the meantime, sea level rise contributes extra baseline component, with all the base level and extra time added up would be the water level elevation at the time of flood hazard. “Sea level rise could magnify the impacts of storms by raising the water level that storm surges affect”. (EPA, 2014)

Coastal Hazard Risk Analysis

Numerous studies revealed the magnitude of coastal hazards, an increasing number of researches tried to adopt the results for strategy development, to set the risk as a level of estimation for the severance and impact of coastal hazard. Broadus (1996, p 313) conducted a potential economic impact assessment resulted from the absence of mitigation for coastal hazards. It emphasized the “human adjustment” for the potential capital lost.

More specifically, In order to present the damage brought by coastal hazards, measurements of property and infrastructure value loss and other economic costs under coastal hazard scenarios were conducted on varied purposes. As Leatheman (1984) and nine other scholars stated, potential Sea Level Rise impacts have been studied to “address adverse effects on low-lying ecosystems, properties, critical infrastructure, and population. (Zhang, 2011, p. 130) We could conclude that this quantitative analysis lay the foundation for any further analysis testing the future land use plan by scenario comparison. A previous study of the San Francisco Bay area (Gleick and Maurer, 1990,) concluded that a 1-meter sea-level-rise would threaten existing commercial, residential and infrastructures in a cost of $48 billion (in year 1990 dollars) (p. 79). The study of potential impacts of increased coastal flooding in California (Heberger, Cooley, et al. 2011) analyzes the threats to California’s coast from increased flooding and erosion caused by climate change induced sea-level rise, together with the associated storm and wave effects (p. 229), and it evaluates the current population, infrastructure and property threatened by projected sea-level rise using a joint analysis of GIS and HAZUS (p. 235) considering if no protecting actions are taken. A case study in Wisconsin’s Lower Fox river basin (Kousky, Olmstead, et al., 2011) tried to identify the quantity and location of land that should be protected under flood hazard .This research used HAZUS to estimated expected flood damages associated with current land use to demonstrate how flood-prone local communities can use HAZUS as a planning tool and go about the business of calculating benefits and costs of alternative land-use scenario to reduce the risks of flooding. (p. 3) Similarly, in the year 2012, a research about the Southeast Florida Regional Climate Change Compact developed a regionally-consistent methodology for sea-level-rise inundation mapping and vulnerability assessment about physical features, property values, and future land use acreage loss. The vulnerability was visualized through regional comparison. However, this study mainly aims at developing finer technical strategy for SLR mapping and analysis methods. (pp vi, B-22)

Study Area

Demographic

Located in Tampa Bay area, Manatee County has a moderate density and total population in state of Florida. 2012 Census TAZ data shows the average population density within each TAZ jurisdiction is around 3.91 per acre. According to the population projection from Bureau of Economic and Business Research, in a medium level, the county population will reach 469,800 in the year 2040, based on current number of 330, 302. The result of higher-level projection is 568, 500.(Smith and Rayer, 2013, p. 6) The annual growth rate of residential and employment population is growing as well: according to Manatee County’s transit development plan (Fiscal year 2008 – 2017), population would rise from 327,544 in the year 2010 to 358,412 in the year 2017 with the annual growth rate at 1.59%, which is higher than the annual growth rate in the year 2010 (at 1.21%). (CUTR, 2008. pp. ES-25 & 5-5), the employment growth rate in the year 2015 would be 3.37% and the working population will be 211,611 in that year. Being adjacent to 3 of the most densely developed county (Hillsborough, Pinellas, and Sarasota), Manatee county will possibly take the charge of part of the population overflow resulted from adjacent counties’ population growth. The County will face an overall population appreciation.

County Coastal Hazard Profile

The State of Florida Enhanced Hazard Mitigation Plan ranked Manatee County as one of the most risky county for severe storm and flood hazard occurrence (Florida Division of Emergency Management, 2013, pp. 3.5 , 3.93). According to 2011's Manatee County's Flood Insurance Study (p. 12), "Flooding in Manatee County results primarily from tidal surge and associated wave action (caused by hurricanes and tropical storms in the coastal areas of the county and from overflow of the streams) in other areas. (FEMA, pp. 23–24)" Additionally, overlaying SLOSH Storm Surge Data prepared by Manatee County with current parcel data shows that the land use types that are under the surge areas are mainly medium-low density residential, along with a large proportion zoned for planned-development residential. In the future land use plan map, it is expected that several medium-density residential or mixed-use development will be affected by storm surge.

County Coastal Hazard Planning Profile

In 1992 when City of Bradenton was under site study for its trend of shoreline recession led by sea level rise, results showed that apart from the eroding barrier shorelines, and also temporal and spatial variability along shoreline positionand the county plans are afoot to address the diverse problems. Site-specific plans are still among principle guidelines for authentically addressing coastal hazard issues (Daniels, et al., 1992. p. 5-44). In Florida, the local governments' comprehensive plan set forth goals and objectives to reduce in in a community's vulnerability of coastal hazards and land development (Florida Department of Community Affairs, 2005, p. 18). Manatee County's comprehensive plan followed a series of coastal hazard zone designation from FEMA, to scale and envision coastal development and land use development elements.

The county already classified flood risk levels and designated evacuation zones in parcel level. The County-processed GIS property data incorporate flood zones according to base flood elevations and probabilities of the occurrence of a 100-year flood. So far the county already designated coastal hazards elements in comprehensive plan. Land use and construction limitation were divided according to the overlay districts.

The Coastal High Hazard Area (CHHA) refers to areas below the Category-1 storm surge line and Overland surge lines under SLOSH Hurricane model according to the county's comprehensive plan to manage the development of the land exposed to coastal hazards. Public expenditures and population concentration therein are limited (Manatee County, 2005 A, p. 107). FEMA defined special flood hazard zones "Zone A" and Zone V" according to zonal flood types, wave height, direction and the extent of possible inundation. CHHA categorizes lands in a similar way that "Zone A" and "Zone V" were defined (FEMA, 2005, pp. 1–5). The county noticed that more precise determinations can override the CHHA because CHHA is an approximation. Consequently, analysis within CHHA or in specific related locations would be beneficial to the modification and delineation of CHHAs. Apart from CHHA, the county also identified Coastal Evacuation Area (CEA, which refers to the areas within the evacuation zones for a Category 1 hurricane as established by the County Emergency Management Division) (Manatee County, 2005 A, p. 155) and Coastal Planning Area (CPA, Zones from Category 1, 2, 3 within Hurricane Evacuation Zone A) based on the level of severity of hurricane hazards based on the SLOSH Model.

Regarding coordination of land use elements and coastal hazard concerns, the county planned to limited the density of new residential development and the placement of industrial and public infrastructures in the FEMA V-Zone and intended to lead a clustered development inside CHHA (Manatee County, 2005 B, p. 342) area and maintain minimum construction setback lines to be consistent with Coastal Construction Control Line (CCCL). However, integration of land use elements and coastal elements are limited as conceptual, thus, land categorization within the CHHA according to the locational coastal hazard characteristics and the level of hazard impact will be further required for better implementation of the elements inside the county plan.

Overall, Manatee County is exposed to the risk of coastal hazard. Nevertheless, the county land use development enforcement has already been strategically managing the risk mitigation and addressing adaptation issues. The county government and planning department must take further steps to facilitate the coordination of coastal hazard mitigation concern and the application of the elements in future land development.

GIS and HAZUS-MH Modeling for Risk Analysis and Impact Assessment

GIS has already being serving as a traditional technology for coastal hazard risk analysis, especially at the level of modeling “coastal morphodynamics” (or in geophysical level) (Gambolati & Teatini, 2001, p. 964). It has been acknowledged that GIS with a digital elevation model is a “very promising tool for the analysis, control and effective management of low-lying coastal areas.” (p 972) In early years, GIS was also an important auxiliary tool for “decision-support system” (El-Raey, 1998, p. 39) in future development planning.

HAZUS-MH can work with ArcGIS to map and display hazard such as hurricane winds, flooding, and earthquake. An important function of HAZUS-MH is to estimate the impact of different hazards. Developed by the Federal Emergency Management Agency

(FEMA), Hazards U.S. Multi-Hazard (HAZUS-MH) is a methodology and software program that contains models for estimating potential losses from natural disasters. HAZUS-MH is widely used by states and communities economic loss scenarios for risk analysis. It uses data provided with the software or user-provided local data to estimate the type and extent of damage for specific hazard. It performs for certain natural hazards. It also supports rapid impact assessment and disaster response.

HAZUS-MH provides different level of analysis. Level 1 involves using HAZUS-MH 2.1 provided hazard and inventory data with minimal outside data collection or mapping. Analysis in level 1 uses the inventory and hazard data provided with HAZUS-MH 2.1. For coastal hazard analysis, only digital elevation model, 100-year Stillwater area and Stillwater elevation are required. Level 2 integrates the HAZUS-MH provided hazard and inventory data with more "localized" data for the study area. Level 3 adjusts the built-in loss estimation models for hurricane loss analysis. Considering the data availability, my study only performed Level 1 analysis. (FEMA, 2014, pp. 2-8 – 2-9)

Future Land Use Planning and Coastal Hazard Mitigation

As hazards and associated impacts are revealed and assessed, "coastal managers are beginning to think about and tackle these increasing management challenges." (Moser & Tribba, 2006, p. 35) They would like to know more about inundation or damage risks that could be forecasted in the future. One way is to look at their future land use strategy, taking hazard loss assessment as a level of estimation for their level of the preparedness in their future land development.

Considering how well of future land use plan incorporates concerns about coastal hazard mitigation, a HAZUS-based analysis was done in Volusia County (Zou, 2012 p. 11). Zou's study quantified the impacts of sea-level-rise. It showed how quantitative hurricane hazard models work in future land use decision making process. Additionally, Zou's study envisioned the long-term impacts of storm surge and sea level rise on infrastructure, property parcels and other public and private resources by land use types. Although Zou's study valued the linkage between storm surge modeling and future land use planning, it did not determine the possible solutions in future land use plan, or modify the associated decision-making strategy. However, Glynn County, Georgia emphasized that with suitable response to existing coastal hazard vulnerability, "a comprehensive plan affords an opportunity to mitigate long-term risks by promoting suitable development patterns". (Georgia Department of Community Affair, 2013, p.2). Glynn County's study identified connections and gaps between county hazard mitigation plans and local and regional comprehensive plans by a series of detailed comparisons. They showed the importance of incorporating land use mapping in hazard mitigation plans and coordinating land use mapping and natural hazard analysis to reduce damage. One result recommended a parcel-based future land use development map that includes floodplain categories. This research made potential property and economic value loss as a precondition for implementing the mitigation with land use and policy options. Nevertheless, neither of the study considers an implementation strategy in response to property loss and vulnerability measured with a quantitative model within land use categories.

It has been acknowledged by Department of Florida Community Affairs that Florida communities need additional initiatives to "better integrate hazard mitigation policies into the comprehensive plan and its implementation" (Department of Community Affairs, 2005, p.26). Previous studies show that Manatee County coastal planning policy is already well-rounded. Through a comprehensive view, the county proactively incorporated advanced planning and engineering techniques to identify coastal planning areas. However, since the county was generally designating the land use elements and characteristics in terms of CHHA and CPA, it is necessary to examine the policy application through detailed categorization by Designed Flood Elevation and coastal high hazard zones to examine the effectiveness of county plan elements and integration. According to my literature review, land use resolutions based on coastal hazard mitigation or adaptation characteristics are inadequate to coordinate the diverse conflicts among hazard adaptation activities and land development. Therefore, in coastal hazard mitigation process, site-specific inspection of the land development within coastal planning, evacuation and high hazard areas can help develop linkage of coastal hazard planning and land use tools. And the cooperation of land use planning and coastal hazard management will hopefully strengthen the effectiveness of coastal hazard planning processes.

CHAPTER 3
DATA AND METHODOLOGY

Data Description

GIS Data

Table 3-1 and Table 3-2 show important values considered for the first-step parcel preparation and subsequent analysis. Manatee County provides parcel data that incorporates multiple flood control attributes, such as flood zones, flood ways, and evacuation zones. Parcel data have 214180 records. Different value categories also provide the chance to develop a sound damage-evaluation system. Additionally, parcel attributes include a field called "FLULABEL", which links each parcel with associated future land use characteristics. Further steps of analysis focus on future land use, so a specific future land use shapefile was used in order to explore more details.

HAZUS-MH Inventory Data

HAZUS-MH inventory data can be used when users cannot supply sophisticated data. Inventory data are a composite of building stock and associated facilities with high–level loss probabilities. Buildings and facilities are classified and stored indifferent categories. In HAZUS-MH, listing the inventory data constitutes data presentation and one step of the model operation process. A simple description of inventory data and categorization is provided as follows:

1. "General Building Stock" (GBS). GBS are buildings stocks that are assumed as evenly distributed through each census block. (FEMA, 2012 A, p. 3-1)

2. Occupancy mapping schemes. Occupancy mapping schemes are different mapping schemes that display different valuation parameters, exposure and values by multiple matrixes, which can emphasize various proportion of building and damage characteristics. (i.e., first floor elevations or occupancy types). (FEMA, 2012 A, p. 3-2)

3. Essential facilities and high-potential loss (HPL) facilities (FEMA, 2012 A, pp.3-33, pp. 3-38): essential facilities include medical care facilities, and emergency response facilities. Being similar to general building stocks, essential facilities are also classified based on building structural and occupancy classes. HPL facilities are vital and sensitive infrastructures such as dams and militarily facilities. HAZUS-MH automatically incorporates essential facilities and HPL facilities in its inventory data display. However, my study will mainly focus on building stocks and associated classification systems, inventory presentations, and loss estimation and analysis.

4. Hazardous materials (FEMA, 2012 A, pp. 3-59): Hazardous substances are defined by different degrees of danger. The materials include substances that might be toxic, radioactive or flammable, leading to significant property or life damage once being released.

5. Demographics: Census housing and population statistics on block level. Like the census block data used for GIS parcel preparation, each block division is coded by a unique 15-digit number. However, in the HAZUS-MH dataset, census block attributes with relatively homogeneous characteristics (such as income level, age and races) are grouped as factors for estimating social loss due to household replacement , temporary housing and other factors which will be discussed in the methodology chapter.

Methodology

GIS Data Preparation

Analysis began with creating a parcel-based dataset storing all of the analyzable attributes into one GIS parcel shapefile. The created parcel also serve as the "container" for the future calculated inundated areas, population, densities and associated information. The entire data disaggregation and transformation process was accomplished with ArcMap.

To analyze the information attributes in the parcel dataset required both global-view-based statistic summaries, such as the total count of the inundated parcels, and site-specific information, such as the number of affected floors in a certain parcel. Point GIS data is a good way to store the count of parcels without too much processing. Correspondently, parcel polygons were mainly used for precise information processing. Basically, parcel points and polygons must possess the same attribute fields that store the data in a consistent way. Processing polygon and points was accomplished in different approaches. The technical process of property data preparation is listed below. The preparation process also shows basic issues for which imprecision or uncertainty of data can impede the research, when processed data are not consistent with each other. These issues are real-world problems that always happen in GIS property management processes.

Setting up unique identifications

A unique ID was added to the parcel polygon data, calculated using ObjectID. (named according to user preference). A unique ID is an identifier that keeps track of a certain record. For instance, in a parcel dataset, "ObjectID" instead of the field "parcel ID" or pin code stands for the unique identifier, the "Object ID" is generate by system instated of by human designation. However, a new field was built to copy the "Object ID" to make this field more discernable. After this step, parcels were converted into points, and a unique ID was added for the ease of keeping track of the data.

Combine parcel and future land use data

This step aimed at disaggregating the census block data and future land use into each parcel, on which all the further analysis will be conducted through the joint consideration of the multiple attributes. Technically, ArcMap operated through the following process:

1. Loaded parcel and future land use shapefile into ArcMap
2. Combined parcel data with future land use data: use ArcMap "Spatial "Join" tool to join parcel and future land use polygon data. This step joined attributes from the future land sue dataset to parcels based on spatial relationship. Future land use attributes were added to the output parcel data. "JOIN_ONE_TO_ONE" was chosen to ensure no repetitive parcel features in the output feature class. However, it is necessary to choose "Have their center in" for spatial relationship, to prevent

unnecessary attribute aggregation. if “JOIN_ONE_TO_ONE” is chosen, attributes from both parcel and future land use are aggregated to the output data, wiping out the original information on both datasets. “Keep All Targeted Features” was checked to ensure all the features are written to the parcel. After the new point dataset was created, use the field “FID_Parcel_Point” to join important parcel records such as Acreage, Total Under Roof, Units. Similarly, it is also necessary to involve attributes such as “FLULABLE” and “FLUDESC” into the dataset.

“Collecting Events“

This step eliminated stacked parcels and set the foundation of the analysis based on “single-count” parcels and parcels with multiple registered properties stacked atop of each other at exactly the same geo-spatial location. This step specifically serves to reorganize the parcel data prepared by Manatee County. The parcel data provided by Manatee County are grouped or divided by primary address and property ownership. Each parcel would be coded by a unique parcel ID. In other words, the parcels are not divided only on a geometric plane surface. If one piece of parcel is designated for Condominium land use, this parcel can be split into multiple individual properties. However, all properties share one primary address, meaning a number of parcels are geo-coded in exactly the same location. The result is stacked parcels. Figure 3-1 to 3-3 show the situation: 64 pieces of parcels are located at “100 61th Street.” sharing a same owner. On the map, the 64 piece of properties are overlapped to only two polygons. The geo-coded parcel acreage is 5.66. However, this represents the floor area of each private property, rather than the actual land area of the parcel it belongs to. Additionally, the points converted from parcels still possess the same problems, although their attributes have been processed. In order provide resolution, we must identify frequency of parcels in the same location. The “Collect Events” tool is used to identify coincident “events”. Specific technical process was listed below:

1. In the “Spatial Statistics” toolset, open “collect events”. In the “Input Incident Features”, enter the converted parcel points. This step generated a new output feature class containing all of the unique locations found in the parcel points. A field named “ICount” was added to hold the sum of all incidents at each unique location. Output features were displayed in categorized symbols. The larger the ICount, the bigger the points. Hence, it is easy to visually distinguish area with overlapping points (Figure 3-4).

2. In the 214,180 pieces of parcel properties, only 129,227 parcels are standing by their own. The remaining 84,953 “parcels” formed somewhat repetitive pattern. The next step is to find overlapping parcels and assign them actual land values.

3. Set a 3-meter buffer for each event points, including the event point with only 1 coincident number.

4. This step spatially captures the attribute value from the parcel points into the event points. The 3-meter buffer is to make sure no points are missing from any slight spatial discrepancies.

5. Select buffers with ICount field larger than 1. This step specified locations where parcels were repetitively drawn in exactly the same place.

6. Used “Identity” in the “Analysis” Geoprocessing tool to incorporate the ICount field into the parcel point, using the selected buffered event data. ” Identity” can be used to factor the spatial location of “coincident” parcels.

Implementation of the HAZUS-MH 2.1 Level 1 Flood Model

One of the important features of HAZUS includes designing its scenarios in deterministic approaches and generating its scenarios based on probabilistic approaches. However, the two approaches give the analysis an integrated scope. Although the flood hazards are strictly defined, widely tested and inspected, they are still interpolated natural phenomena. Duplicated characteristics of flood hazard provide a flexible research context for analysis, while adding uncertainty for the results.

As a flood vulnerability quantification system, HAZUS-MH sees the flood damage from engineering and science viewpoints. Flood depth, duration, and water velocity in the flood area are the predominant factors into the process of loss estimation. The relationship among model parameters, data, and databases are strictly identified.

HAZUS-MH provides analysis scope for both riverine and coastal flood hazard. My study focused only on coastal flood hazard analysis. Figure 3-1 shows the overall schema of the HAZUS-MH Flood model. The figure descripts the conceptual workflows of HAZUS-MH modeling.

1. Identify the flood hazard and determine hazard velocity
2. Identify direct physical damage
3. Interpolate induced physical damage (i.e., debris-induced damage)

HAZUS-MH runs the flood hazard model through three phases to produce the estimations. First, it conducts velocity-based measurement of direct physical damage, which includes a succession of essential physical infrastructures, vital systems, and facilities described in inventory data. Second, HAZUS-MH evaluates damage induced by lower-floor damage of general building stock: debris damage. By joint consideration of direct damage and induced damage, HAZUS-MH finishes its model preparation and goes into the next step: generating direct socio-economic losses. This estimation measures demand for shelters, temporary housing, and transportation. More importantly, economic losses assessment includes repair and relocation expenses. Finally, the model assesses the indirect socio-economic loss: it generally accounts for future expenses on hazard-mitigation-related policies and the establishment of hazard prevention systems.

For direct losses, users can view the results either from maps or from the hazard event report conveyed by the system. The ArcGIS mapping tool displays accurate spatial distribution of damage states, and users can actually see the joint effects of default settings and flood scenarios. The maps follow the same mapping schema as ArcMap and cannot display multiple valuation parameters at once. Hence, the tool is only powerful in revealing the performance of individual or limited building parameters (i.e., economic loss of Residential Occupancy). Besides, HAZUS-MH summary reports present quantified losses due to building and contents damage but also include monetary losses resulting from the loss of function.

Technical Process of Creating Flood Hazard Scenario

The technical process was used in my study. However, it is the general process of HAZUS-MH loss estimation. Three scenarios were created in my study to reflect different magnitude and intensity of flood hazard. Basically, the scenarios were categorized by the probabilities of storm surges and sea-level-rises.

1. Stillwater scenario (Scenario 1).This scenario describes the areas that have a 1 percent or greater chance of experiencing storms surges in any given year before the year 2040. The projected storm surges will happen without accompanying sea-level-rises.

2. A Half-meter SLR scenario (Scenario 2). This scenario describes the areas that have a 1 percent or greater chance to experience storm surges in any given years before 2040. The storm surge will occur with (or induced by) a half-meter sea level rise. The sea level rise has 1 percent probability to happen in any year till 2040. Thus, the probability that this scenario happens in the period before the year 2040 is 0.01 percent.

3. A Full-meter SLR scenario (Scenario 3). This scenario describes the areas that have a 1 percent or greater chance to experience storm surges in any given years before 2040. The storm surge will occur with a one (full)-meter sea level rise. The sea level rise has 1-percent probability to happen in any year till 2040. Thus, the probability that this scenario happens in the period before the year 2040 is 0.01 percent.

Define the study region

Open HAZUS-MH, in the StartUp interface, choose “Create a New Region.” After the model is set up and scenarios are created, each time of opening HAZUS-MH, choose “Open a Region” in the StartUp Interface

1. Examine the inventory data: Capture the profile of the inventory data composition. In HAZUS-MH, menu items include lists of inventory and compile built-in calculation parameters. HAZUS-MH provides the function of mapping the inventory data one at a time. For example, choosing “Inventory” on the menu bar will show every inventory dataset in one list. After that, choosing “General Building Stock → Square

Footage → Map" will display the magnitude of square footage of general building stock by detailed occupancy type. A simple description of each parameters and their storage type in the inventory list is presented as follows.

Square footage: displayed in occupancy type.

Building count: displayed by Census Blocks along with the number of buildings. Assigned to each category of general occupancy

Valuation parameters: a combination of views including replacement cost, location factors, garage distribution, and height distribution.

Depreciation parameters: median age of the census block and buildings help determine the depreciated exposure of each census block.

Occupancy types mapped by building types: named as "general occupancy mapping scheme," the building type distribution (building structures and materials) is classified by occupancy types.

First Floor Elevations: elevations are defined by different foundation types.

2. Identify the hazard: As it has been stated before, my study focused on Costal flood hazard. Hence, on the menu, choose Hazard → Flood Hazard Type → Coastal Hazard Only.

3. Deriving digital elevation model: In the first-level analysis, only t system default data were adopted. HAZUS-MH automatically incorporated the Digital Elevation Model from its dataset. To accomplish this step, continue navigation through the listed process:

   Hazard → User Data → DEM → Determine Required DEM Extent → Navigate directly to the NED Download → Download the 1/3 arc Data and extract it to HAZUSData → Navigate to Region → MyFolder → RegionDEM

   To import the data: Navigate to User Data →DEM → Browse → Import the data (At this step, choose the Vertical Datum as NAVD88).

Coastal hazard scenario creation

HAZUS-MH allows users to create multiple scenarios regarding hazard type and study region. It also allows combination of multiple hazards. For each of the parameter composition HAZUS-MH can create a unique scenario. In my study at the first-level analysis, a 100-year storm surge based scenario was created. A half-meter and a one-meter sea-level-rise were added to the Stillwater elevation at the time point, the year

2040. Table 3-1 shows the Stillwater elevation input for three scenarios. The scenario of one-meter sea-level-rise with storm surges stands for the worst case. To complete these step, navigate to Hazard → Scenario (create a new scenario) → Add to selection, save and click "OK." However, to enrich the scenario with flood information and associated property-related parameters, flood surface visualization needs to show the magnitude and directions of floods.

1. Delineate coastal floodplain: In this step, HAZUS-MH was used to prepare the flood surface data, to confine the shoreline limitation, and to model the direction for flood to proceed. Since my study is a level-1 analysis, it is not necessary to identify the start and end point of shorelines across the coastal line where flood hazard is projected (FEMA, 2012 A, p. 3-83).

2. Shoreline characterization with default dataset: This step differentiated scenarios. In this step, the 100-year Stillwater elevation was entered as mandatorily input. Stillwater elevation stands for the vertical distance between the Stillwater flood surface and bottom (FEMA, 2012 A, p. 4-85). Magnitude of coastal hazard was determined by the "tidal wave" at that given time, plus the extra wave height generated by sea-level driven surges. Hence, in this step, the Stillwater elevation was decided by entering the average number of 1-percent Stillwater Elevation. Gulf of Mexico, Tampa Bay and Sarasota Bay area are all considered in order to acquire a relatively unbiased number. Lakes and Rivers are not substantially considered. The input elevation is listed in Table 3-3. (The vertical datum must be NAV88).

3. Check the flood surface characteristics: Navigate to Scenario → Coastal → CaseOutput folder→Transects and Wave Heights.

   Specifically, transects are shown as perpendicular to the shoreline. This is the step where HAZUS-MH calculates its wave setup and dune erosion effects. Transects are drawn automatically by Coastal Flood Model at around 1000-feet intervals along the shoreline (FEMA, 2012 A, p. 4-85). Any coastal flooding beyond transects is assumed to be Stillwater. As being used for dune and flood characteristics estimation, transects can be divided into two proportions. Accessing the details of transects helps users to get better understand about the patterns and trends where the flood propagates.

Table 3-1. Manatee County Parcel Metadata

Name of Attributes	Description
ACRES	Acreage
LUC	Land Use Code
LUC_DESCRIPTION	Land Use Code Description
ZONING	
FUTURE_LAND_USE	
HIST_NAME	
FLOOD_ZONE	FEMA flood zone
FLOOD_WAY	FEMA flood way(Yes/No)
FLOOD_PANEL	Flood map panel
OVERLAYS	Any planning overlays
WATERSHED	Watershed Districts if any
FLOOD_WAY	FEMA flood way(Yes/No)
FLOOD_PANEL	Flood map panel
OVERLAYS	Any planning overlays
WATERSHED	Watershed Districts if any
HISTORIC	
FIRE_DISTRICT	
EVACULATION_ZONE	
IMPACE_FEE_DIST	
SPECIAL_AREAS	Planning Dept. Special Areas(If any)
SCHOOL_SVC_AREA	
FRONTAGE	Frontage of lot feet
PARCEL_ID	Different than select pin-code
IMPVAL	Improvement Value
JUSTVAL	Estimated market value as determined by the PAO less than cost of the sale such as Realtor fees, surveys, points, etc.
LANDVAL	Land value
ASSESVAL	Assessed value
SFLA	Square footage living area
YRBLT_RES	YB residential
YRBLT_COM	YB Commercial
TUR	Total Under Roof
UNIT	
CODE_ENF	Code Enforcement

Table 3-2. Manatee County Future Land Use Metadata

Future Land Use Label	Future Land Use Category	Maximum Potential Density(Dwelling Units per Gross Acre)	Net(Dwelling Units/Net Acre)	FAR(Maximum Potential Intensity
CON	Conservation Lands	0.00	0.00	
AG/R	Agriculture/Rural	0.20	2.00	
ER	Estate Rural	0.20	1.00	
RES-1	Residential-1 DU/GA	1.00	2 or 6 (see pace land use policy page 20)	
RES-3	Residential-3 DU/GA	3.00	6.00	
UF-3	Urban Fringe-3.0 DU/GA	3.00	9.00	
RES-6	Residential-6 DU/GA	6.00	12.00	
RES-9	Residential-9 DU/GA	9.00	16.00	
RES-12	esidential-12 DU/GA	12.00	16.00	
RES-16	Residential-16 DU/GA	16.00	20.00	0.25
OL	Low Intensity Office	6.00	12.00	0.23
OM	Medium Intensity Office			0.30
ROR	Retail/Office/ Residential	9.00	20.00	0.35
IL	Industrial-Light	1.00	1.00	0.75
IH	Industrial-Heavy	0.00	0.00	0.50
IU	Urban Industrial	0.00	0.00	1.25
MU	Mixed Use	9.00	20.00	
P/SP(1)	Public/Semi-Public(1)			
P/SP(2)	Major Public/ Semi-Public (2)			
AT	Major Attractors			
R/OS	Major Recreation/Open Space	0.00	0.00	0.00
MU-C(MU-C/AC-1)	Mixed Use Community	6 -- 9	20 (Max)	1.00

Table 3-2. Continued

Future Land Use Label	Future Land Use Category	Maximum Potential Density(Dwelling Units per Gross Acre)	Net(Dwelling Units/Net Acre)	FAR(Maximum Potential Intensity
MU-C/AC-2	Mixed Use Community	6 -- 9	20 (Max)	0.35
MU-C/AC-3	Mixed Use Community	3.00	9(Max)	0.23
MU-C/R	Mixed Use Community	3.00	9(Max)	0.23
MU-C/RU	Mixed Use Community	9.00	16.00	0.23
	Future Land Use Overlay District			
HR	Historic Resources			
WO	Potable Water Reservoir Watersheds			
CHHA	Coastal High Hazard Area			
CEA	Coastal Evacuation Area			

Table 3-3. Coastal Hazard Scenario Creation: Entering 100-year Stillwater Elevation

Flooding Source and Location	100 – year Stillwater Elevation
Stillwater	10.03333333
Half Meter	11.67375328
Full Meter	13.31417323

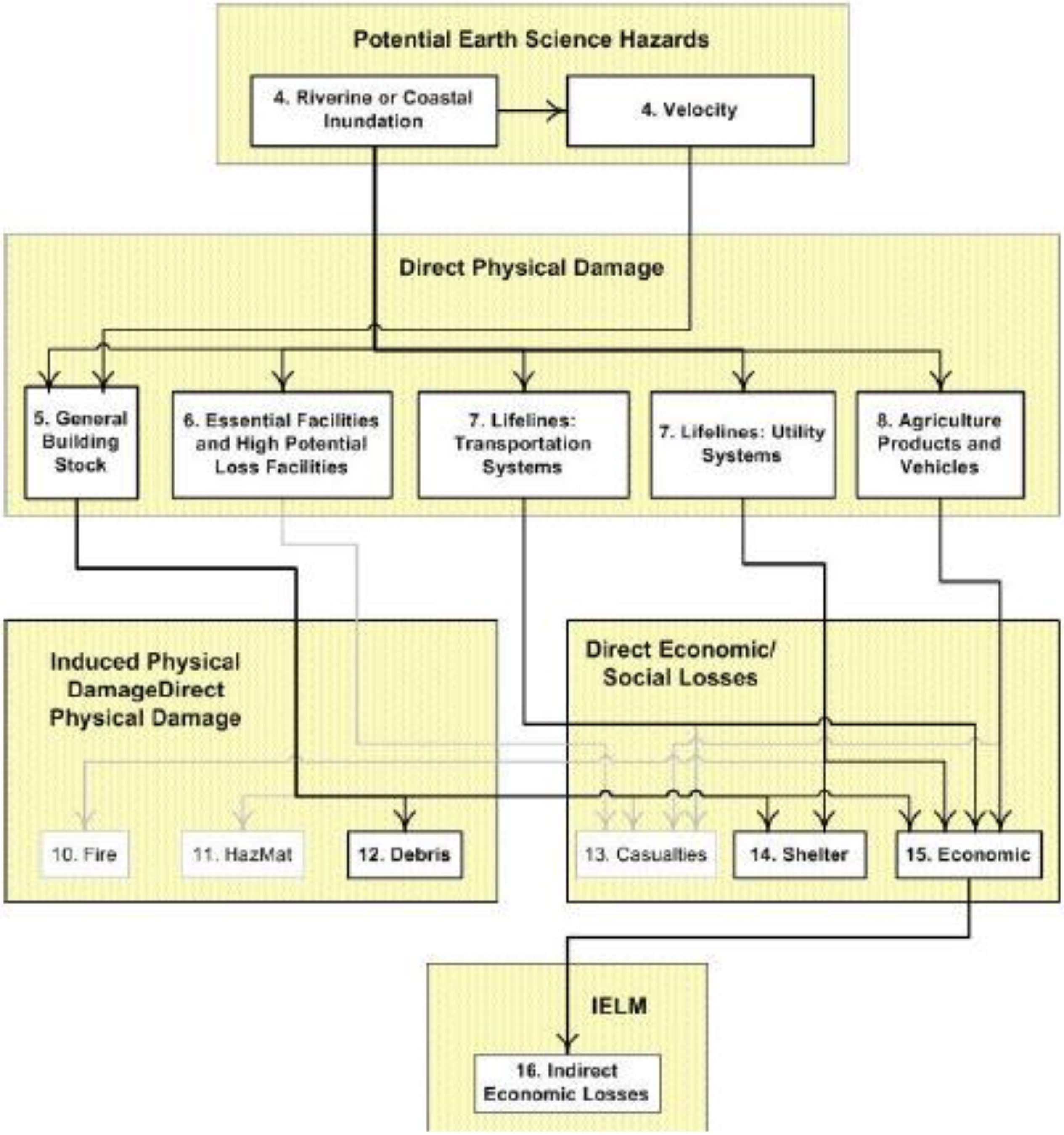


Figure 3-1. HAZUS-MH Implementation Process

OBJECTID *	Shape *	SELECTPIN	OWNER	PRIMARY_AD
82775	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
82867	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
90622	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
92529	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
94611	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
99175	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
107141	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
114977	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
115012	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
123629	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
123634	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
127975	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
130045	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
140533	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
143069	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
144059	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
145199	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
145223	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
147444	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
155192	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
155797	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
156306	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
166900	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
168302	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
168912	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
169829	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
172097	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
176281	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E
177117	Polygon	2244510000	FISHERMANS COVE RESORT LLC	100 61ST ST E

45 (64 out of 214180 Selected)

Figure 3-2. The attribute table of stacked parcels

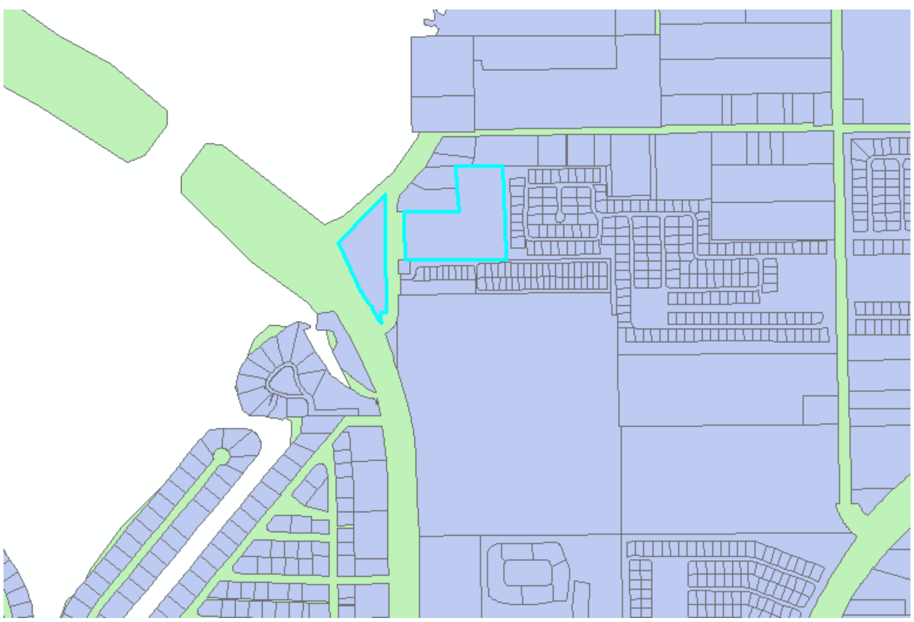


Figure 3-3. Stacked polygons.

Parcel_Point_CollectEvents

Shape *	ICOUNT	OBJECTID *
Point	281	18668
Point	288	78430
Point	290	46076
Point	290	85300
Point	292	113763
Point	293	60013
Point	298	20176
Point	299	5960
Point	317	14594
Point	322	76066
Point	337	11549
Point	339	84000

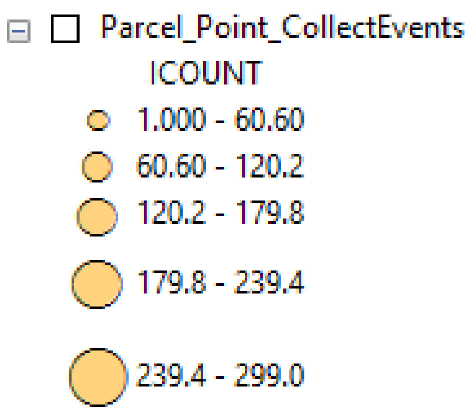


Figure 3-4. The categorical symbols of collected events

CHAPTER 4
ANALYSIS AND DISCUSSION

HAZUS-MH Hazard Event Reports indicate that the majority of damage will happen to buildings of residential occupancy type as the projected storm surge happens. This is because 99% of the buildings facing different levels of damages were expected to be residential buildings. The dollar values related to expected residential building exposure account for over 78% in all the three scenarios. From the building-related loss estimation, my study considered residential land use as the predominant land use that must be studied and analyzed.

HAZUS-MH Hazard Event Report Analysis

HAZUS-MH not only produced general descriptions of the damage expected for building and infrastructure properties but also provided summarized damage states for estimated inventories and multiple parameters under different scenarios. The program produced Hazard Event Reports that comprehensively interpret results. The hazard event reports consist of building inventory dollar-value loss estimation, building damage estimation, and associated facilities damage estimation. The report also included debris damage induced by flood hazard, social impact assessment and one of the most important parts, building-related economic loss. Considering the GIS data availability and structural consistency of this thesis research, results interpretation and analysis were mainly conducted using occupancy-based statistics.

Building Inventory: General Building Stock

As showed in the HAZUS-MH event report and the Table 4-1, HAZUS-MH estimated that there are 132,349 buildings in the study region which have an aggregated total replacement value of 20,681 million. The summary reports present the relative distribution of the value with respect to the general occupancies by Study Region and Scenario respectively. The General Building Stock (GBS) includes residential, commercial, industrial, agricultural, government, and education buildings. The "output" is an estimation of the damage to the buildings at a given depth, which can be expressed as "a percentage of the replacement cost of the structures, and later translated into a dollar value using its estimation module" (FEMA. 2012 A, p.5-2). In each of the three scenarios, the buildings exposed to the storm wave are defined in Table 4-1. Residential dwellings originally dominated portions of the entire building population, followed by those of commercial and industrial abodes.

Building dollar value exposure by occupancy categories (Table 4-2) varied according to different storm surge-based scenarios. Basically, through the three scenarios, the actual residential value exposures followed a trend that increased, as did commercial, industrial and other building values. Under the circumstance that residential building stock value was still mostly exposed to the rising water depth, as the water level increased, the percentage taken by residential buildings went down from 79.3% at Stillwater elevation to 78.1% at the full-meter level. Conversely, the commercial building dollar exposure went up proportionally with the rising water level, from 14.2% at Stillwater level to 14.9% at the one-meter sea level scenario.

The building value exposure increased at a lower speed at increments between the three scenarios. For instance, the residential building value exposure only increased 9.25% when the storm water level rose from a half-meter to a full-meter, which was less than 11.17% when the scenario switched from Stillwater to a half-meter, compared to the commercial building value exposures. We considered three value categories that are about to be exposed, residential (always around 78% to 79%), commercial (around 14% to 15 %) and Industrial (around 3.3% to 3.4%), we took a closer look at these three categories and noticed that the commercial building value exposure increased the least as water levels went up, while the industrial buildings almost maintained the same level of exposure from scenario to scenario. One conclusion would be that Residential and Commercial building construction inclines to locate close to shorelines and wave exposure areas, while industrial buildings tend to be built away from flood-sensitive areas, or they may be scattered around the study areas.

General Building Stock Damage

HAZUS-MH estimated the number of buildings that will be damaged at different levels. Damage states were derived from the percentage of damaged buildings (1 – 10% damage is considered slight, 11 – 50% damage is considered moderate, and 51 – 100% is considered substantial damage). Moderate damages are also classified with a 10% increment. Table 4-3 and Table 4-4 present the counts and the percentage of buildings in each damage state by occupancy and structural types.

Generally, HAZUS-MH estimated that the number of buildings that will be at least moderately damages grew from 19,306 to 27,231 as the scenario changes from “Stillwater” to a full-meter sea-level-rise with associated storm surge. These numbers take 14% to 17% of the total number of buildings as the scenario changes.

From Table 4-3 it can be observed that residential building damage in different scenarios are most close to each other when the damage levels reach around 11% to 30%. We noticed that as the storm water depths grow, the major proportion of damaged buildings changes through categories that represent different extents of damage. For instance, in the Stillwater scenario, 9.265 residential buildings 41% to 50%

damaged, but that number rises sharply to 10,374 as the water level went up half a meter. It dropped to 8,865 (which is even less than the 9,265 in the Stillwater scenario) in a 1-meter sea-level-rise scenario. This indicates that the number of buildings that will be substantially damaged actually grew drastically between the half-meter scenario and the full-meter scenario, from 7,321 to 12,631. Additionally, the damage level“41% to 50%” also reflected the largest residential and industrial building damage, and among “31% to 50%” level of damage, building exposure kept an increasing trend. A fair indication from this trend is that the flood hazard induces medium-level or substantial damage for residential areas. The number of affected residential buildings peaked around the 41% to 50% affected rate.

Table 4-3 shows that generally, the number of exposed industrial buildings never exceeded 10 in any scenario. However, although the total number of affected industrial buildings was relatively small, under the full-meter scenario, there are 46.15% industrial buildings under different levels of damage. This means that almost half of the industrial operation in the county might be affected once a one-meter sea-level rise happens.

Building-Related Economic Loss

HAZUS-MH presents the building-related economic losses in millions of dollars. Table 4-5 to Table 4-7 indicate that economic losses will result from increasing depth of inundation, and the losses will primarily happen to residential and commercial buildings.

Content losses, which refer to personal or organization-owned properties, cannot be ignored: among the buildings occupied by commercial, industrial and other (mainly institutional-oriented) land uses, the dollar values attached to content losses exceeded the values related to the building physical structures such as the foundation. Among all of the three scenarios, for commercial and industry-occupied buildings, content losses totaled over two times the expense of building-related losses. For other types of building, such as institutional-oriented buildings, content losses almost tripled the amount of the building-related losses. Residential buildings still took the largest percentage of economic-related losses. Overall, the dollar values attached to building and content losses both soar as the storm wave depth increases.

On the other hand, industrial areas contribute to few indirect losses caused by supply and reproduction after the storm surge attack. As the input Stillwater elevation gets higher, Table 4-6 and Table 4-7 demonstrate that business interruptions do not result in large amounts of economic losses. It is easy to tell that residential units will suffer losses of rental income and expenses related to relocation. Residents of commercial dwellings must endure loss of income and wages; only 2% of the industrial buildings need relocation and wage supplements during the recovery process. All in all, post-hazard recovery is a predominant reason that pre-hazard preparation strategies are instituted. Restoration of building structures is one of the foundations of post-hazard recovery. Hence, it is an essential requirement to strengthen building structures and locate the building in a secure place as much as possible. Nevertheless, a large number of buildings and related operation activities already existed. Government should not intervene ongoing constructions and business operation, so that the government can prevent overriding private property rights and public interests.

By analyzing the Hazard Event Reports, it was recognized that among all the buildings suffering physical damage and loss of economic value, buildings of residential occupancy type made up the largest proportion. Hence, it is necessary to look at potential residential land losses in the year 2040. HAZUS-MH produced scenarios representing the extents of sea-level-rise and associated storm surges. In Chapter 4, lands within different land use categories are analyzed according to HAZUS-MH-based coastal hazard scenarios. The discussion of the results is conducted through the integration of HAZUS-MH results and GIS-based analysis results, based on the given three scenarios. Specifically, the discussion explores the distribution of future residential land exposure. It also analyses the existing condition of these lands. By doing this, the discussion shows the relationship between current land use (especially residential and vacant lands) and their future designation. Additionally, a potential categorization for areas inside or adjacent to coastal hazard zones is made to elaborate on the designation of current coastal hazard zones. As mentioned, my study defined three coastal hazard scenarios by using HAZUS-MH. However, varying averages of storm water depth are applied to each of the scenarios in order to present a variety of samples in proper sizes. Scenario descriptions are listed below:

1. Stillwater scenario (Scenario 1).This scenario describes a 100-year storm surge happening in the year 2040 without accompanying sea-level-rise (this is the same setting as the Stillwater scenario defined in HAZUS-MH). In this scenario, lands were analyzed within the zones where the average wave depth ranged from 1 foot to 4 feet, and the maximum wave depth was 4 feet.

2. A Half-meter SLR scenario (Scenario 2). This scenario describes the results of a 100-year storm surge happening in the year 2040 with an accompanying half-meter sea-level rise. In this scenario, the changes between existing land use and future residential land use were analyzed within the zones where average storm surge wave depth was four feet.

3. A Full-meter SLR scenario (Scenario 3). In this scenario, a 100-year storm surge happening in the year 2040 with an accompanying full-meter sea-level-rise is described. Changes between existing land use and future residential land use were analyzed within the zones where average storm surge wave depth was four feet.

This chapter discusses the vulnerability of exposed current vacant capacity in Scenario 1. Considering there are vacant lands whose elevations are below 1 meter, these vacant lands are facing a 1-meter sea-level rise. Besides, this chapter also generally describes the limitations and availability of future land use allocation and related construction strategies.

Chapter 2 (Data and Methodology) talked about the stacked parcels which represent condominiums or other multi-story properties that were registered with the same address. For the sake of reducing the complexity from this issue, the “stacked parcels” were eliminated from the discussion.

Future Residential Lands and their Existing Condition

This step took a look at the relationship between designated future residential land uses and their existing (current) designation. The analysis from this step reflects the extent of perceived future land development designed by the county’s land use ordinances. Additionally, the analysis below also shows whether coastal hazard mitigation elements come into effect by preventing residential community development in coastal hazard-prone areas. Last but not the least, the following analysis revels the potential development capacities that can be enhanced by well-prepared land use codes and coastal management strategies, so that these potential development opportunities can be well adopted with respect to the coastal hazard management.

Future Residential Lands Exposure

According to Table 4-8 and 4-9, among all the future residential lands, the numbers and percentages occupied by low-density residential land exposure and medium-density residential land exposure remained the largest amount and are close to each other as the average wave depth rises and the scenarios changes. RES-1(which means parcels with 1 dwelling unit per gross acre) and RES-6 both took around 30% of the exposed future residential land distribution. RES-3 and RES-9 both took around 14% to 16 % in the exposed residential area.

Inside the coastal hazard areas where HAZUS-MH said that there would be a Stillwater-elevation-based storm surge but not an actual rising sea-level (Table 4-10), 7090 acres of land designated as future residential were identified as being under an average 4-feet storm wave height. Among the exposed lands, low-density residential uses make up 47% (30.83% + 16.19%) of the entire estimated areas. This proportion of the lands were designated by the county with a maximum of 1 dwelling units per acre, or 2 units on the portion of parcels where economic benefits could be derived directly ("Net Acres"). According to the future land use policy (Manatee County, 2005 A, p. 113), these residential lands are mainly located in suburban areas and are compatible for short-term or special agricultural activities, and also for neighborhood amenities such as retail and recreation. The net densities vary from 2 units per acre to 6 units per acre when the lands are needed for higher housing or public concentration. For the 16.19% "RES-3" residential lands, where gross density can be 3 units per acre, the maximum net densities can be 9 units per acre if they are inside CRA affordable housing project areas (Manatee County, 2005 A, p. 115). Medium-density lands make up another 46% (30.02% + 16.04%) to attain moderate urban districts with proper public amenities, community infrastructures and water-related uses (Manatee County, 2005 A, p. 117).

Results varied as the average depth of the storm surge rose. Basically, as the average storm surge depth was set higher, less future residential acreages were presented in the study areas. Although the total acreage exposures are different as the scenarios change, there are no large variations in the numbers of low or medium density parcels and the percentages they are representing. For instance, for the parcels designated as RES-1, as the projected average storm surge depth rises from 1 feet to 4 feet (with the maximum wave height at 4 feet) in Scenario 1, the exposed existing residential land uses was only reduced 18% (from 4101 acres to 2789 acres), while the total land area was reduced 30%, from 10,153 acres to 7,089 acres (Table 4-8 and Table 4-9).

Subtraction of other types of future land uses, such as mixed-use residential lands, contributes to the reduction of the total lands. The situation indicates that more residential lands should be released from the attack of coastal hazards according to the county policy designation. However, from Figure 4-1, we noticed that land exposures soar as a half-meter sea-level-rise with an associated storm surge changes to a one-meter sea-level rise scenario (in other words, changes from Scenario 2 to 3). At the same time, medium-density residential lands increased sharply and the line they are representing can be distinctively distinguished from the increasing line of low-density residential. The trend shows that in spite of the large amount of land exposure, the county plans to locate larger amounts of medium-or-high density lands in a landward direction.

Current Land Uses Remain Residential in the Future

By reviewing the current residential lands that are either changed in the future or remain residential, we notice how land use patterns are changed under the guidance of the county's future land use plan, and we can visually understand how coastal planning elements can be incorporated into the land use policy design.

Table 4-8, Figure 4-2and Figure 4-3 show that as the storm water depth grows and a half-meter sea-level-rise are added into consideration (a change from Scenario 1 to Scenario 2), in all of the cases, around 40.4% of the future residential will remain residential use until the year 2040. 28% - 29% of future residential lands are changed from current vacant lands, followed by current agricultural as well as conservation lands which constitute a total of 18.13% to the future residential land composition. Table 4-9 indicates that a projected sea-level-rise will definitely cause a higher amount of land exposure. The existing residential lands remaining residential in the future will decrease from 4101 acres to 2789 acres as the mean depth gets higher (4 feet). Land acreages jump from 2789 acres again to more than 4000 acres as a half-meter and then a full-meter sea level rise is added to the Stillwater elevation. Meanwhile, the other two land use categories, vacant lands and “Greenfields,” follow the same trend as the residential. There, land acreages grow with the rising storm water depth and the proportion taken by vacant and “Greenfield” lands remain stable (i.e., the “Greenfields” took around 18% and vacant lands took around 27% to 30%).

Table 4-8 also shows that generally, current lands increase or decrease incrementally as the storm water depth rises and falls. The increments portray the locations where the lands are mainly located. Results show that lands remaining residential tend to locate in the areas where storm surge depth is around 4 feet with an additional half-meter or one-meter sea-level-rise. Existing vacant lands are mainly located in areas that might be impacted if a storm surge projected in Scenario 3 (100-year storm surge brought about by a one-meter sea-level-rise) happens. But these vacant lands are not mainly located within the area where a storm surge described in Scenario 2 happens. This is because vacant land exposure increases dramatically by

21.73% (from 2347 acres to 2856 acres) in the area where Scenario 2 shifts to Scenario 3.

Besides, despite the fact that current commercial, service, and institutional lands designated as future residential lands make up smaller proportions among all of the considered acreages compared with existing residential lands, their increments of increase and decrease in terms of varying storm water depth are generally larger than the increments of changes for existing residential or vacant lands. For instance, the existing service lands maintain their rate of change above 40% for most of the time (as the average storm water depth raises from 1 foot to 4 feet, the service acreage exposure decreases 41.06% (from 418acres to 246 acres). When a half-meter sea-level-rise is added into the scenario, the service land exposures soar by 56.75% (from 210 acres to 326 acres). This reveals the fact that service lands are largely located in the area where a 100-year storm surge happens, with an average 1 to 2 foot depth, or the area where the depth reaches 4 feet as long as a half-meter or higher sea level rise happens. These areas can be interpreted as the ones with uncertainty about the possible impacts of coastal hazard, but they are definitely vulnerable once the projected hazards happen.

In conclusion, within the considered coastal hazard areas, the largest proportion constituting future residential lands is current residential lands, followed by vacant lands and “Greenfields” (agricultural and conservation lands). These lands are changed primarily to low or medium density residential land uses (RES-1 and RES-6). Therefore, considering county future land use objectives, current residential lands and vacant lands must be considered primarily for land use-based hazard mitigation strategies other than the county designated Coastal High Hazard Areas, and Greenfields not recommended for future land use allocation. Moreover, existing vacant lands are the largest categories that are flexible for future land use development. Consequently, the next section would be an in-depth categorization of vacant lands.

Vacant Lands Become Future Residential Properties

In order to broadly show the spatial distribution of the second-largest potential capacities of future residential lands, analyses in this section were conducted in terms of the scenarios used in the last section. However, in order to acquire a larger sample size of vacant lands, we do not talk about the condition when the average storm surge depth of 1 to 3 feet is applied to Scenario 1 (Stillwater Scenario). As demonstrated through Table 4-10 to Table 4-13, at Scenario 1, only part of the vacant lands have already been designated by the county's future land use plan. The topography was brought into consideration: lands where their elevation is lower than one meter were classified apart from areas with higher elevations, because a 100-year storm surge might happen in this area. The former sections might be the most dangerous area with shortest distance to the surging waves and rising sea level, so that a sustained possibility of damage can happen to these lands.

In Scenario 1, topography splits the vacant lands inside into two halves. On one hand, in the vacant area where there might be a storm surge happening above the lower-topography locations ("the area with a potential 1-meter sea-level-rise"), 36.91% (2,222 acres, Table 4-10) of the lands are currently" Vacant Residential," and the rest, 61%, have not been designated yet ("Vacant Acreage, Not Ag. 10+ Acres"). Regarding the corresponding future land designation, 29.29% of current vacant lands have been designated as future residential (especially RES-1, the lowest-density residential), and the rest of the 70% were largely designated as urban fringe area and city-owned lands. This trend shows that the future land use plan compromises the vulnerability of these areas so that few changes were made to the existing vacant uses. On the other hand, in the second half of lands where the elevation is relatively higher, 49.21% are currently vacant residential and 33.05% were designated by the county as future residential, and city or urban-fringe designations take over 50% of all the future lands. Apparently the lands were considered more livable but still vulnerable according to county's plan.

At the Stillwater elevation-based scenarios, the vacant lands within lower-topography areas are especially sensitive. Even if a projected sea-level rise does not happen in the near future, lands primarily submerged by storm surge will face repetitive shoreline erosions, property damage and the recessions of constructible area. However, if a projected 1-meter sea level rise happens, lands with a higher topography will also come in at a vulnerable place similar to that outlined in the former situation where there are storm surges happening in a low elevation. Additional construction and development opportunities will be jeopardized by the unstable natural conditions within this area. It is controversial to explore the development and redevelopment opportunities in the vacant lands exposed to a storm surge induced by a half-meter sea level rise. Uncertain environmental concerns mixed with the trend towards residential development would lead to conflicts which need to be addressed through joint application of land-use tools and coastal hazard adaptation strategies.

Vacant development opportunities in the areas that might be submerged due to a 100-year storm surge induced by sea-level-rise make the livability of mixed-use communities with large land use diversities. The government must be concerned about the proper control and release of development rights.

Case Studies: Stacked Existing Residential Properties

"Condominium improved," is the primary land use category which has stacked parcels on exactly the same location. In this case, each parcel not only consists of multiple individual units, but also contains more than one census block. As the number of stacked registered properties on each parcel varies by different locations, with the statistics of coincident events, we would be able to check parcels individually and to know the number of units inside each individual building. HAZUS-MH possesses the information about occupancy and structural types by Census Block. Therefore, as shown in Figure4-4, 4-4 and 4-6, this part summarized to what extent the individual parcels would be affected by comparing wave depth zonal statistics with the building's first-flood elevation plus the first story height, estimation through occupancy and structural type, and analysis of parcel data attributes information.

Case 1: 887 Spanish Drive South

As shown in Figure 4-4, the Case 1 parcel is currently loaded with 212 Registered Properties and 187 building footprints. The entire parcel was expected to be affected by storm water without the consideration of sea level rise. The parcel was built before December 31, 1974 so it was considered according to the FEMA flood insurance definition as a pre-FIRM building. As a masonry building with a closed foundation (possibly slab-on-grade according to maps and pictures), the foundation structure would be around 1-feet high and would not allow water to pass through the foundation elements below the elevated building. Hence, large wall and side foundation surfaces would be exposed to the obstruction of floods. Parcel metadata identifies this group of properties as being located in Coastal High Hazard Area “Y” zone (similar to “Zone V”). As FEMA recommended constructions considered that any close foundation located within Zone V is inappropriate (FEMA, 2009. p.2-8), the structure of this residential group is susceptible to erosion (p.2-10).

According to Zonal Statistics in “Scenario 1”, the minimum wave height would reach up to 5.5 feet. Assuming that the first-floor above the walking space is 10-feet high, the flood force would be expected to attack through ground walking spaces. However, the Mean wave height of storm surge is 9.8 feet, during which the building’s first story would definitely experience moisture penetration and scouring, even without consideration of the damage through wind attack and debris destruction.

However, HAZUS-MH returned actual damage statistics, which was less than the damage expected. A total of 23 square feet in residential areas would be under a medium or higher extent of damage, only 35% of which would be substantially damaged. Undoubtedly, masonry construction represented the largest damage group, 28 square feet with medium damage, followed by wood structures (16 square feet). Concrete and steel structures were barely damaged (only 10 square feet in total). The results indicate that although the parcel is loaded with large amounts of masonry structured buildings substantially damaged at the ground level, HAZUS-MH only returns estimations based on story height instead of foundation height plus story height. Damage caused by additional wave heights above Stillwater elevation are ignored. The way that HAZUS-MH considers the damage level is generalized so that it could not precisely reflect the actual vulnerability of this area.

Nevertheless, the city will take control of the development rights over this group of properties. In the future, the lands will belong to the city. HAZUS-MH does not incorporate future land use consideration into an estimation model; the estimated results will not be in conformity under the future land use scenario: there will barely be any buildings and residential groups located in this parcel.

Case 2: 6303 Sun Eagle Lane

Figure 4-5 shows that in this case, there are 46 registered residential properties, which constituted 23 buildings identified in this parcel. A total of 99% of them will be affected by the flood. Each building is a stand-alone apartment with attached storages. The condos were built in the post-FIRM period mainly with masonry exterior and slab-on-grade foundation. The average wave height in this property is 2.3 feet, so the slab foundation will be affected.

According to General Building Stock damage statistics displayed by HAZUS-MH, only 1.22 square feet of residential areas will sustain medium damage. Considering the structural attributes, 3 square feet of the wood structure area will be substantially damaged. Around 17 square feet will sustain medium damage (around 11% to 30%). Concrete and steel components will suffer little to no damage. In total, 26 square feet of masonry areas would be mainly at medium level damage (41 – 50%), which consists of the largest damage proportion.

As a residential parcel inside “N, Y” zone of CHHA (which is similar to the area located between Zone A and Zone V), although a storm surge would let the land be exposed to storm water, there would not be substantial damage to this property. In the future, the land will remain residential. Other than residential buildings, neighborhood amenities are not allowed. The land use designation goes in consistently with HAZUS-

MH’s indication of storm surges. Hence, the designation was considered proper for coastal hazard adaptation in the future.

Case 3: 1394 Carlton Arms Drive

In Figure 4-6, this parcel consists of 15 Census Blocks with 322 registered properties located around 63 multi-family buildings. Then stacked units are included which equal 4 to 6 units for each building. The parcel was built in the post-FIRM period and is located across Zone V and Zone A.

This complex was constructed 99% under the Scenario 1 storm water surface. With a closed foundation whose height will not exceed 2 feet, the 6-foot mean wave height will definitely obstruct the base floor space. The first story will be slightly affected. The Maximum wave height, 11.5 feet, would cause moisture erosion and flood force pressure through the entire first floor.

Information returned from HAZUS-MH demonstrates that for residential buildings, 51.69 square feet will be slightly damaged, 288.76 square feet will suffer medium damage (21-50%) and 37.45 square feet will be largely destroyed. For commercial buildings, 68.53 square feet within this parcel will be moderately damaged. Considering the building structural type, the largest damaged proportion was masonry with a total of 247 square feet which were medially damaged and 23 square feet substantially damaged. The remaining 7 square feet are expected to be slightly damaged. However, the county was aware of the high risk level of this area and the controversial geo-location. Consequently, the city will take the land back for proper designation in the future. The result shows that HAZUS gave a specific and sophisticated estimation in terms of occupancy and structural types, but the program is still limited by an unspecified time period. Even though the year put into the program was “2040” The program only returned the result based on current unit density and distribution of building footprints. This indicated that we need further researches based on interpolated lands and building distributions, so that we can get more convincing and comprehensive impact estimations.

Table 4-1. Building Exposure by Occupancy Type of Study Region

Occupancy	Exposure($1000)	Percent of Total
Residential	16,075,167	77.7%
Commercial	3,022,122	14.6%
Industrial	836,819	4.0%
Agricultural	103,502	0.5%
Religion	385,799	1.9%
Government	110,083	0.5%
Education	147,212	0.7%
Total	20,680,704	100.0%

Table 4-2. Building Exposure ($1000)by Occupancy Type for the Scenario

Occupancy	Stillwater	Percent of Total	Half Meter	Percent of Total	Full Meter	Percent of Total
Residential	7,271,879	79.3%	8,084,509	78.4%	8,832,215	78.1%
Commercial	1,302,548	14.2%	1,521,345	14.7%	1,688,104	14.9%
Industrial	298,962	3.3%	341,972	3.3%	389,500	3.4%
Agricultural	57,234	0.6%	64,852	0.6%	69,682	0.6%
Religion	157,954	1.7%	186,588	1.8%	206,198	1.8%
Government	20,234	0.2%	47,653	0.5%	55,544	0.5%
Education	57,173	0.6%	68,582	0.7%	74,125	0.7%
Total	9,165,984	100.0%	10,315,501	100.0%	11,315,368	100.0%

Table 4-3. Building Damage By Occupancy Types (Counts), Summarized by Scenarios

	1 - 10			11 - 20			21-30			31-40			41-50			Substantial		
Occupancy	Still	Half	Full	Still	Half	Full	Still	Half	Full	Still	Half	Full	Still	Half	Full	Still	Half	Full
Agricultural	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Commercial	3	2	3	37	44	46	15	24	12	16	13	13	7	12	12	0	1	16
Education	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Government	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	0	0	0	1	1	1	1	1	2	0	2	2	2	4	2	3	1	6
Religion	0	0	0	15	13	15	1	0	1	0	0	0	0	0	0	0	0	0
Residential	20	3	5	817	825	860	3,042	3,141	3,200	1,761	1,552	1,549	9,265	10,374	8,865	5,640	7,321	12,631
Total	25	7	8	870	885	923	3,059	3,166	3,215	1,777	1,567	1,564	9,274	10,390	8,879	5,643	7,323	12,653

Table 4-4. Building Damage (%) By Occupancy Types, Summarized by Scenarios

	1 - 10			11 - 20			21-30			31-40			41-50			Substantial		
Occupancy	Still	Half	Full	Still	Half	Full	Still	Half	Full	Still	Half	Full	Still	Half	Full	Still	Half	Full
Agricultural	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Commercial	3.85%	2.08%	2.94%	47.44%	45.83%	45.10%	19.23%	25.00%	11.76%	20.51%	13.54%	12.75%	8.97%	12.50%	11.76%	0.00%	1.04%	15.69%
Education	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Government	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Industrial	0.00%	0.00%	0.00%	14.29%	11.11%	7.69%	14.29%	11.11%	15.38%	0.00%	22.22%	15.38%	28.57%	44.44%	15.38%	42.86%	11.11%	46.15%
Religion	0.00%	0.00%	0.00%	93.75%	100.00%	100.00%	6.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Residential	0.10%	0.01%	0.02%	3.98%	3.55%	3.17%	14.81%	13.53%	11.80%	8.57%	6.69%	5.71%	45.10%	44.68%	32.70%	27.45%	31.53%	46.59%

Table 4-5. Building-Related Economic Loss Estimates (Millions of Dollars) in Stillwater Scenario

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss	Building	1734.70	206.28	44.06	30.64	2015.69
	Content	1094.01	470.14	83.72	135.75	1783.62
	Inventory	0.00	8.22	16.66	2.66	27.55
	Subtotal	2828.71	684.65	144.44	169.06	3826.86
	Income	0.09	2.78	0	0.32	3.49
	Relocation	2.85	0.50	0	0.13	3.19
	Rental Income	0.85	0.19	0	0	1.04
	Wage	0.30	2.83	0	2.29	5.41
	Subtotal	4.09	6.29	0.01	2.74	13.13
All	Total	2832.80	690.94	144.44	171.80	3839.99

Table 4-6. Building-Related Economic Loss Estimates (Millions of Dollars) in Half-meter Scenario

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss	Building	1,913.09	264.45	54.07	37.76	2,251.36
	Content	1,197.40	551.42	105.14	146.00	1,999.97
	Inventory	0.00	10.24	21.26	3.26	34.77
	Subtotal	3,110.49	808.11	180.47	187.03	4,286.09
Business Interruption						
	Income	0.10	3.15	0.00	0.31	3.56
	Relocation	3.01	0.57	0.00	0.12	3.70
	Rental Income	0.86	0.24	0.00	0.00	1.10
	Wage	0.39	3.17	0.01	2.43	6.00
	Subtotal	4.31	7.12	0.01	2.87	14.31
All	Total	3,114.80	815.22	180.48	189.90	4,300.40

Table 4-7. Building-Related Economic Loss Estimates (Millions of Dollars) in Full Meter Scenario

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss	Building	2,280.06	319.44	71.38	54.85	2,725.73
	Content	1,396.57	680.98	140.23	178.87	2,396.65
	Inventory	0.00	13.31	28.29	4.32	45.92
	Subtotal	3,676.63	1,013.73	239.90	238.04	5,168.30
Business Interruption						
	Income	0.12	3.84	0.00	0.38	4.34
	Relocation	3.52	0.71	0.01	0.16	4.40
	Rental Income	0.99	0.31	0.00	0.00	1.30
	Wage	0.39	3.95	0.01	2.94	7.29
	Subtotal	5.01	8.81	0.02	3.48	17.32
All	Total	3,681.64	1,022.54	239.93	241.51	5,185.61

Table 4-8. Summary of Exposed Existing Land (Acreage) Designated as Future Residential By Scenarios

	Scenario 1 (Stillwater)								Scenario 2 (Half-Meter SLR)		Scenario 3(Full-Meter SLR)		
Land Use Categories	Stillwater Mean1 Max4	Percentage	Stillwater Mean2 Max4	Percentage	Stillwater Mean3 Max4	Percentage	Stillwater Mean4	Percentage	Half-Meter Mean4	Percentage	Full-Meter Mean4	Percentage	Averaged Percentage
Residential	4101.184797	40.39%	3305.7320	39.21%	3099.8891	39.50%	2789.2012	39.34%	3376.857423	40.40%	4076.237839	41.40%	40.04%
Mixed-Use	195.051954	1.92%	171.1698	2.03%	168.9261	2.15%	152.7655	2.15%	173.4346434	2.07%	178.1737147	1.81%	2.02%
Commercial	44.941703	0.44%	32.6531	0.39%	31.6450	0.40%	24.3725	0.34%	34.14374193	0.41%	31.317499	0.32%	0.38%
Service/Retail	450.91926	4.44%	278.3630	3.30%	201.2422	2.56%	140.8928	1.99%	228.0673279	2.73%	369.0760029	3.75%	3.13%
Institutional	67.722723	0.67%	59.6253	0.71%	45.2063	0.58%	32.6101	0.46%	47.01690644	0.56%	78.53421713	0.80%	0.63%
Greenfields	1882.063908	18.54%	1591.3908	18.88%	1402.2851	17.87%	1185.5918	16.72%	1531.054494	18.32%	1815.164553	18.43%	18.13%
Industrial	53.389973	0.53%	33.1474	0.39%	32.7587	0.42%	19.3724	0.27%	39.48147065	0.47%	49.88575012	0.51%	0.43%
Infill/Vacant	2764.365413	27.23%	2364.8291	28.05%	2292.0799	29.21%	2197.9529	31.00%	2346.520048	28.07%	2856.445365	29.01%	28.76%
Others/Unclassified	593.647351	5.85%	593.4618	7.04%	573.7010	7.31%	546.7555	7.71%	582.8067569	6.97%	391.4951395	3.98%	6.48%

Table 4-9. Summary of Exposed Future Residential Land Exposure (Acreage) By Scenarios

	Scenario 1 (Stillwater)								Scenario 2 (Half-Meter SLR)		Scenario 3(Full-Meter SLR)	
Future Land Use Label	Stillwater Mean1 Max4	Percentage	Stillwater Mean2 Max4	Percentage	Stillwater Mean3 Max4	Percentage	Stillwater Mean4	Percentage	Half-Meter Mean4	Percentage	Full-Meter Mean4	Percentage
MU	287.78	2.83%	208.471649	2.47%	198.180729	2.53%	99.7544	1.41%	183.640824	2.20%	237.592981	2.41%
MU-C	360.07	3.55%	194.316695	2.30%	38.393827	0.49%	38.3938	0.54%	152.265692	1.82%	375.256593	3.81%
RES-1	2,664.65	26.24%	2329.305811	27.63%	2282.588132	29.09%	2185.6937	30.83%	2303.139585	27.55%	2419.54958	24.57%
RES-16	452.98	4.46%	216.893997	2.57%	211.349237	2.69%	192.1847	2.71%	230.740967	2.76%	289.043245	2.94%
RES-3	1,637.59	16.13%	1412.547795	16.76%	1268.60949	16.17%	1147.6381	16.19%	1385.423836	16.57%	1684.720935	17.11%
RES-6	2,945.21	29.01%	2584.39808	30.66%	2442.791513	31.13%	2128.1582	30.02%	2634.738621	31.52%	3164.599481	32.14%
RES-9	1,419.33	13.98%	1196.616604	14.19%	1174.707731	14.97%	1137.2218	16.04%	1213.369864	14.52%	1335.330603	13.56%
ROR	385.67	3.80%	287.821837	3.41%	231.112754	2.94%	160.4700	2.26%	256.063424	3.06%	340.236662	3.46%
SUM	10,153.29	100.00%	8430.372468	100.00%	7847.733413	100.00%	7089.514806	100.00%	8359.382813	100.00%	9846.33008	100.00%

Table 4-10. Future residential lands exposure in Scenario 1(Stillwater, Mean Depth 4 feet, No Maximum Depth Limitation)

Future Land Use Label	Frequency	Exposed Acreage	Exposed Just Value(Million$)
MU	11	99.7544	1.4635
MU-C	2	38.3938	0.6467
RES-1	843	2185.6937	186.4767
RES-16	555	192.1847	73.4087
RES-3	1447	1147.6381	365.7650
RES-6	3603	2128.1582	572.0724
RES-9	2085	1137.2218	284.3513
ROR	323	160.4700	41.2806
Sum of Residential(All)	8869	7089.514806	1,525.4649

Table 4-11. Existing Vacant Acreages and Associated Future Land Use Designation in Scenario 1 (Stillwater Mean Depth 1 Foot, Max Depth 4 Feet) with Sea-Level-Rise Potentiality(Lower Topography)

Land Use Descriptions	Frequency	Exposed Acreage
Vac.Commercial Common Area (1555)	1	3.846081448
Vacant Acreage,Not Ag. 10+ Acres (1555),Vacant Acreage,Not Ag.10+ Acres(1555)	76	2221.95247
Vacant Commercial (1555)	29	28.24270136
Vacant Commercial w/Impv (1555)	2	0.231053557
Vacant Condominia Residential (1554)	66	3.097718193
Vacant Industrial (1555)	2	0.397413735
Vacant Institutional (1555)	16	57.97263094
Vacant Mobile Home Lot Platted (1554)	65	2.608556706
Vacant Non-Residential/Unusable (1555)	1	0.923978532
Vacant Res. Common Area (1554)(New 2014),Vacant Res.Common Area (1554)(New 2014)	103	342.3773907
Vacant Res.Common Area (1554)(New 2014),Vacant Res. Common Area (1554)(New 2014)	99	296.6794216
Vacant Residential Platted (1554)	795	466.8952177
Vacant Residential Tract/Unusable (1554)	79	196.9908573
Vacant Residential w/Site Amen. (1554),Vacant Residential w/Site Amen (1554)	111	44.63523895
Future Land Use Label	Frequency	Exposed Acreage
AG-R	18	1183.673941
CITY	717	788.2139329
CON	1	13.70236356
IH	1	33.63233219
IL	8	1.373722093
P/SP-1	1	1.538394858
RES-1	170	563.4058832
RES-16	7	6.936877158
RES-3	55	89.69159196
RES-6	136	255.6203707
RES-9	172	137.0028301
ROR	94	21.46361528
UF-3	65	570.5948758

Table 4-12. Existing Vacant Acreages and Associated Future Land Use Designation in Scenario 1 (Stillwater, Mean Depth 1 Foot, Max Depth 4 Feet) with Sea-Level-Rise Potentiality (Higher Topography)

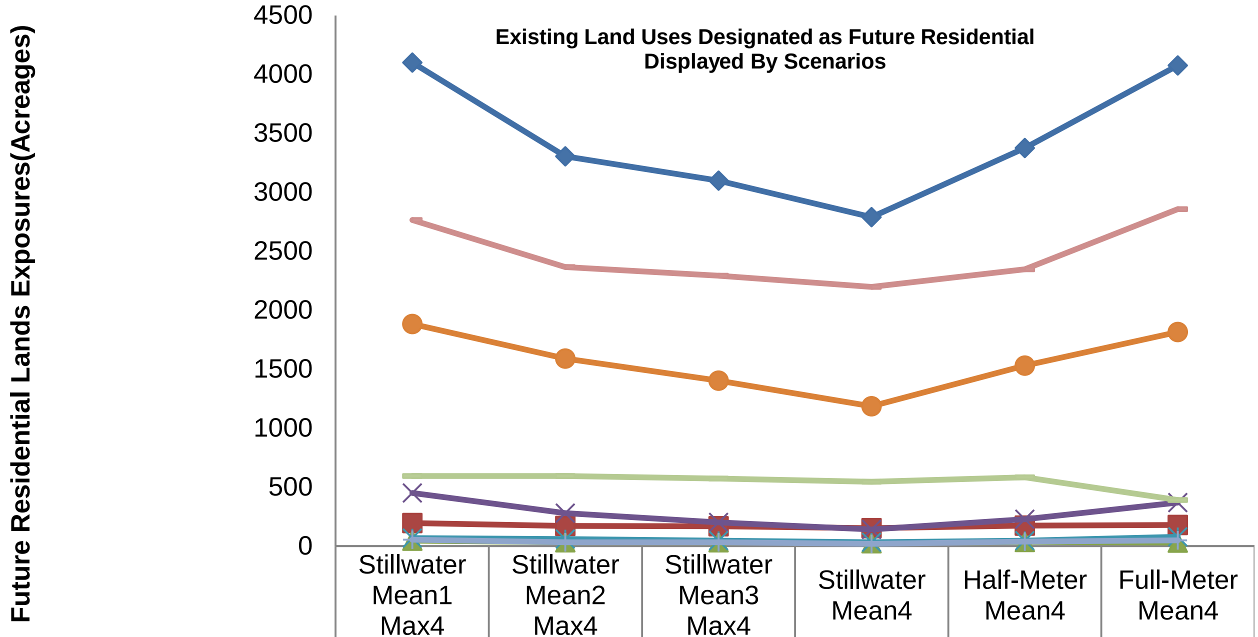
Land Use Descriptions	Frequency	Exposed Acreage
Vac.Commercial Common Area (1555)	10	37.88799091
Vacant Acreage,Not Ag. 10+ Acres (1555),Vacant Acreage,Not Ag.10+ Acres(1555)	178	1243.916538
Vacant Commercial (1555)	151	197.6641492
Vacant Commercial w/Impv (1555)	9	10.61644251
Vacant Condominia Residential (1554)	98	1.585025754
Vacant Industrial (1555)	31	301.4008053
Vacant Institutional (1555)	52	113.1348966
Vacant Mobile Home Lot Platted (1554)	159	5.518291684
Vacant Non-Residential/Unusable (1555)	9	28.21541609
Vacant Res. Common Area (1554)(New 2014),Vacant Res.Common Area (1554)(New 2014)	306	460.6833109
Vacant Res.Common Area (1554)(New 2014),Vacant Res. Common Area (1554)(New 2014)	309	677.7862532
Vacant Residential Platted (1554)	1977	675.9160079
Vacant Residential Tract/Unusable (1554)	104	13.12416179
Vacant Residential w/Site Amen. (1554),Vacant Residential w/Site Amen (1554)	199	38.24676127
Future Land Use Label	Frequency	Exposed Acreage
AG-R	4	15.28689893
CITY	789	853.116888
CON	2	27.19231485
IH	11	92.85140545
IL	26	272.6370142
MU	18	82.09857306
P/SP-1	9	79.91091791
RES-1	94	335.0259029
RES-16	61	73.4337713
RES-3	137	101.2604878
RES-6	274	382.9676157
RES-9	293	282.2717276
ROR	127	82.92906298
UF-3	302	1124.71347

Table 4-13. Existing Vacant Acreages and Associated Future Land Use Designation in Scenario 2(Half-meter, Mean Depth 1 Foot, Max Depth 4 Feet)

Land Use Descriptions	Frequency	Exposed Acreage
Vacant Commercial (1555)	53	47.34678111
Vacant Commercial w/Impv (1555)	1	0.689386089
Vacant Condominia Residential (1554)	9	2.909802924
Vacant Industrial (1555)	26	12.99374322
Vacant Institutional (1555)	14	2.894298758
Vacant Mobile Home Lot Platted (1554)	2	0.094867622
Vacant Non-Residential/Unusable (1555)	1	1.26988388
Vacant Res. Common Area (1554)(New 2014),Vacant Res.Common Area (1554)(New 2014)	67	137.8147507
Vacant Res.Common Area (1554)(New 2014),Vacant Res. Common Area (1554)(New 2014)	70	112.5393104
Vacant Residential Platted (1554)	139	79.92683112
Vacant Residential Tract/Unusable (1554)	6	16.33483532
Vacant Residential w/Site Amen. (1554),Vacant Residential w/Site Amen (1554)	9	13.15813515
Future Land Use Label	Frequency	Exposed Acreage
AG-R	2	32.87867519
CITY	104	32.56781404
IH	19	4.577130561
IL	15	8.587473907
MU	12	24.36815511
P/SP-1	2	0.714241723
RES-1	13	48.70276115
RES-16	2	0.681940887
RES-3	24	14.85831917
RES-6	78	67.72364164
RES-9	30	9.159963082
ROR	9	4.986188511
UF-3	87	178.1663213

Table 4-14. Existing Vacant Acreages and Associated Future Land Use Designation in Scenario 3(Full-meter, Mean Depth 1 Foot, Max Depth 4 Feet)

Land Use Descriptions	Frequency	Exposed Acreage
Vac.Commercial Common Area (1555)	1	0.902195122
Vacant Acreage,Not Ag. 10+ Acres (1555),Vacant Acreage,Not Ag.10+ Acres(1555)	29	229.3477194
Vacant Commercial (1555)	16	39.58581058
Vacant Commercial w/Impv (1555)	2	1.488737241
Vacant Condominia Residential (1554)	8	7.548374026
Vacant Industrial (1555)	13	22.59140908
Vacant Institutional (1555)	1	3.58842708
Vacant Non-Residential/Unusable (1555)	1	1.727306606
Vacant Res. Common Area (1554)(New 2014),Vacant Res.Common Area (1554)(New 2014)	36	121.7963577
Vacant Res.Common Area (1554)(New 2014),Vacant Res. Common Area (1554)(New 2014)	40	106.1467932
Vacant Residential Platted (1554)	65	61.96456601
Vacant Residential Tract/Unusable (1554)	3	16.44420586
Vacant Residential w/Site Amen. (1554),Vacant Residential w/Site Amen (1554)	4	17.14075534
Future Land Use Label	Frequency	Exposed Acreage
AG-R	2	32.87867519
CITY	36	78.26383237
CON	1	1.712046952
IH	10	42.36416116
IL	12	17.62074017
IU	1	2.078144196
MU	9	28.66662927
P/SP-1	1	6.581661971
RES-1	12	124.041256
RES-16	4	11.73988484
RES-3	16	16.84232758
RES-6	42	81.57193474
RES-9	22	10.8373603
ROR	5	7.369329681
UF-3	46	167.7046728



	Stillwater Mean1 Max4	Stillwater Mean2 Max4	Stillwater Mean3 Max4	Stillwater Mean4	Half-Meter Mean4	Full-Meter Mean4
Residential	4101.184797	3305.7320	3099.8891	2789.2012	3376.857423	4076.237839
Mixed-Use	195.051954	171.1698	168.9261	152.7655	173.4346434	178.1737147
Commercial	44.941703	32.6531	31.6450	24.3725	34.14374193	31.317499
Service/Retail	450.91926	278.3630	201.2422	140.8928	228.0673279	369.0760029
Institutional	67.722723	59.6253	45.2063	32.6101	47.01690644	78.53421713
Greenfields	1882.063908	1591.3908	1402.2851	1185.5918	1531.054494	1815.164553
Industrial	53.389973	33.1474	32.7587	19.3724	39.48147065	49.88575012
INFILL/VACANT	2764.365413	2364.8291	2292.0799	2197.9529	2346.520048	2856.445365
Others/Unclassified	593.647351	593.4618	573.7010	546.7555	582.8067569	391.4951395

Figure 4-1. Existing Land Uses Designated as Future Residential. Displayed By Scenarios

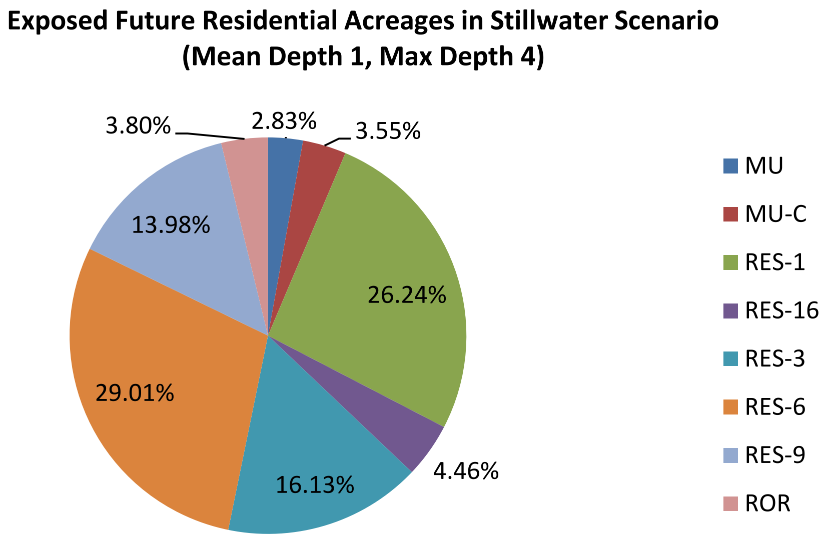


Figure 4-2. Example: Exposed Future Residential Acreages in Stillwater Scenario (Mean Depth 1 Foot and Max Depth 4 Feet)

Notice: There are 5 other Figures representing different scenarios.

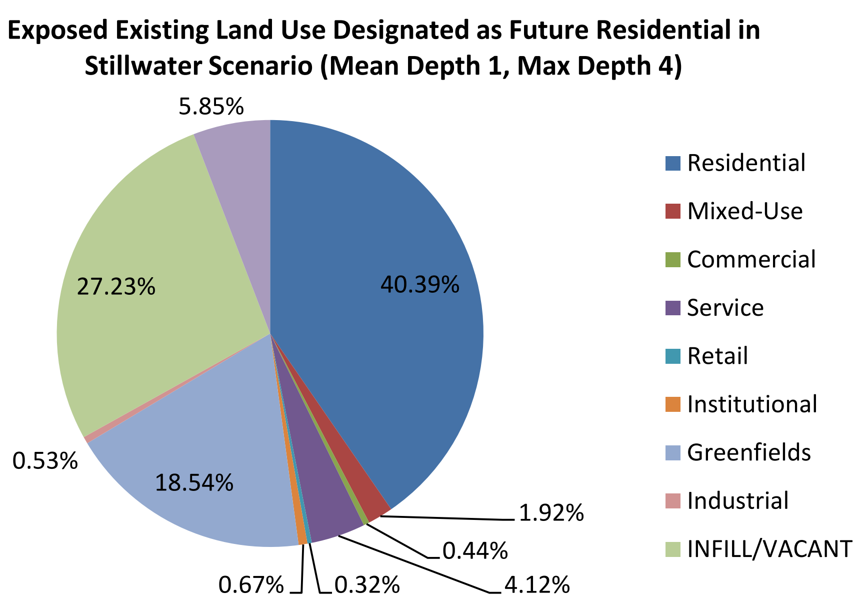


Figure 4-3. Example: Exposed Existing Land Use Designated as Future Residential in Stillwater Scenario (Mean Depth 1, Max Depth 4

Notice: There are 5 other Figures representing different scenarios.

Figure 4-4. Case 1: 887 Spanish Dr. S

Figure 4-5. Case 2: 6303 Sun Eagle Ln.

Figure 4-6. Case 3: 1394 Carlton Arms Dr.

CHAPTER 5
CONCLUSIONS: RECOMMENDATION FOR LAND DEVELOPMENT

Existing Residential Lands Remain Residential In the Future

According to the analysis in my study and official(State and County) designation about CHHAs and CPAs, the recommendation about adopting land use policy was mainly limited in the area where predicted average storm surge elevation exceeded 4 feet. Areas under discussion are consistent with areas impacted by HAZUS-MH-projected storm surges. Suggestions are made based on shoreline conservation, residential density designation, coastal hazard management elements, land use facilitation tools and a tentative integration of multiple principles listed above.

Stillwater Scenario: Exposed Areas with Average Depth Greater Than 4 Feet

Within the areas with the largest probability of beings struck by storm surges (without any sea-level-rise), there are locations where the predicted average storm surge depth is 4 feet, yielding location characteristics close to CHHA V-zone definition. Considering the changes between existing land use and future land use, large quantities of land will be received by municipalities to prevent risky development. Apart from the existing residential structures, residential density must be limited at most 3 dwelling units per gross acre (3du/ga), net density increase in community redevelopment areas (CRA) should not be allowed. In order to meet these requirements, government should gradually cease operation of neighborhood structures that represent or can generate actual values. The recommendation is that non-industrial developments such as residential amenities, quasi-public areas and water-dependent residential amenities be prohibited. If necessary, temporary evacuation access, and health and safety structures are recommended for a clustered development in the land close to communities. Reconstructions or repairs of these structures are not otherwise recommended. It is suggested that the county should stop maintaining the roadways and lighting and stop raising funding opportunities for public infrastructures.

Within the 4-foot storm surge area, regarding the designated CHHAs and vulnerable residential structures, the county should consider necessary Transfers of Development Rights (TDR) to have the vulnerable sites down-zoned or to hold the right of control over development rights. Because of the substantial financial costs that a TDR or other conservation easement tool will need, a requirement of TDR will be the most extreme case that the county should consider.

In this scenario, there are both pre-FIRM and post-FIRM buildings. The impact of storm surge was revealed both visually and statistically, making stakeholders understand the limitations of development in these areas. The county’s government, private developers, potential investors and citizens are all given chances to see the future hazard impact as a fact, and so as the private sectors of flood insurance. The county should strictly require purchasing flood insurance for housing constructions. Private insurers can perceive the storm surge-cased flood hazard impact as an insurable risk. It is feasible to charge the private property owners adequate rates that reflect the risk of losses. The higher price of flood insurance would prevent owners to purchase large amount of insurance coverage. It is possible that the owners would not purchase flood insurance, which makes their rights of development go against with the county requirement. In this way, either the properties will become unaffordable, or the market value of owners’ property would be affected.

Stillwater Scenario: Exposed Area with Average Storm Water Depth of 1 to 3 Feet and a 4-Foot Maximum Depth

If a projected sea-level-rise happens, areas exposed to storm water with average depth less than 4 feet will also not escape from the flood and wave damage. The protection of existing private properties, beaches, dunes and shoreline systems should be parallel concerns. Land within this area tends to be sensitive when both policy tools and environmental protection strategies can be easily impeded by both spatial conflicts and planning ethical dilemmas. Hence, stabilization of coastal environments and ecological processes include concerns about not to violate against Coastal Construction Control Line (Florida Department of Environmental Protection, 2014) and to avoid litigations of Bert Harris Act (Ruppert and Candiotti, 2011. p.3). Considering Bert Harris Act, the lands have already been designated as "reasonably foreseeable" for residential use, they are compatible to adjacent lands and their market values are validated. The suitability conditions are perplexed. It would be recommended that the County should initiate an analysis program about whether the property pre-regulation costs exceeded the post-regulation value. HAZUS-MH provided economic losses estimation, which can be regarded as reference, the county could consider precise subtraction of the land area where HAZUS-MH displays substantial damage (over 50% ground level damage). In these areas identified by both GIS suitability analysis and HAZUS-MH, alteration of residential structures will mainly be prohibited but maintenance of the structures will be allowed because the county needs to allow time for the property owners to cease economic-related activities in the future.

Local government needs to inspect the residential buildings located within or around a sufficient buffer zone of CCCL. According to the rules for CCCL, pile-foundation buildings, isolated wood structures (such as elevated beams) and resident structures such as roadways, lots, walkways or paved structures that are considered "under construction (FDEP, 2014. p. 9)" should be exempt from site plans and building permits, especially in the seaward direction that the structures are facing. Placement of independent structures onto the existing foundational or walking surface will not be recommended. The county should take every effort to limit the possibility of construction until large amount of areas adjacent to CCCL maintain a stable relationship between flood erosions and neighborhoods

An in-depth way to clarify the concerns about the Bert Harris Act is to identify whether the repair and maintenance fee would exceed 50% of the market value of the ground-floor structure. If so, state and county government are needed to address possible relocation of the structures or facilities. The County is encouraged to initiate a system of grants or loans to assist the owners of the residential buildings and mobile homes. They should provide information about financial costs of maintenance, the recovery process and the sales. Private owners should know how to transfer development rights through covenants, agreements and a way where the county purchases easements to control over the lands.

Basically, flood insurance will still act as one of the most important roles in controlling the development opportunities. Flood insurance are very complex programs with different amount of subsidy rates or risk premiums in terms of flood intensity, the affordability of owners and the extent of involvement of flood insurance companies. Flood insurance rate maps are clear and realistically-designed instructions about the distributions of hazards. In the scenarios with a 1-percent probability that a storm surge will happen in the coming 26 years, it is feasible to use a higher insurance and reduced subsidies to guide the trend of development out of the dangerous zones. However, apart from adjusting the trend of development by a fiscal tool, with a long-term consideration, land use policy design and construction codes should come into the first place to shape the county's future development.

Exposed Areas under a Half-Meter Sea-Level-Rise induced Storm Surge with A 4-Feet Average Depth

Outside the Scenario 1 area but inside the area where the structures are facing a half-meter of sea-level-rise and associated storm surge, with the average wave elevation reaching 4 feet, if the storm surge does not happen, there will be at least 1.64042 feet (0.5 meter) of sea-level-rise which exceeds the Base Foundation Elevation (BFE) of either slab-foundation buildings or Crawl-space buildings. If there is a 4-feet wave elevation of storm surge, the costal hazards are expected to be powerful enough to rip off the entire ground-floor structure of residential buildings within this area. Lands within this scenario but outside the Stillwater Scenario can be considered as possessing the characteristics of FEMA Zone A and the connection area between the A and V-zone. Land within this area is equipped with more residential and mixed-use community development opportunities. However, the county should minimize the possibility for community redevelopment. Considering the land use elements, future residential constructions of 1 du/ga are not recommended. Because this might cause low-density single family dwellings scatter around residential area and these dwellings are the most easily exposed objects to be threatened by surge waves.

Residential-related land development within this spatial category will include urban residential with supportive infrastructures and semi-public uses. Community service institutions, such as schools or child-care centers, will be limited to a medium or small size. Larger-sized health centers and medical research corporations should also be prohibited. It will be recommended that the county limit the formation of any large community service system but only maintain a moderate level of service supply, road infrastructure and utility system in order not to override public interests. The county needs to conduct suitability analysis to locate and sustain proper amounts of public health care, emergency and safety infrastructure. With joint consideration from the county's future land use plan and the area categorization, lands that are intended for mixed-use community development will be supported for maintaining current neighborhood retail, light industrial uses and warehouses as the part of basic community service. Construction of recreational amenities are not recommended but will be allowed for maintenance and physical reconstruction. Basically, structural improvement should be supportively allowed within this land use category. But other than that, the local government should only maintain the existing public service structure but will not assist the property owner to execute their development rights.

If the existing building structure is located in a 6 to 9 du/ga area, the county must ensure where there are extra height added onto their first horizontal structural member. The county can consider flood-resistant design such as drainable, dryable interior wall materials. Walls can be constructed with horizontal gaps between wallboard (FEMA, 2005, p.6) Pressure-treated framings can be used to strengthen the existing building structure, especially the ones that are facing windward directions or close to CCCL buffer zones.

Apart from the requirement which is consistent with the requirement for the lowest horizontal structure in the Stillwater Scenario, maintenance and reconstruction of Pile-foundation structures are allowed. For the area where residential structures are intended or for their alternation or maintenance, it is suggested that their first floor elevations be above the Designed Flood Elevation. Specifically, the county should work with design professionals to apply the Designed Flood Elevation to strengthen the precision of the height of the bottom horizontal structural member that must be raised and maintained.

It is important to allow residents sufficient time to understand that there are probabilities for a flood to exceed the 100-year flood level during a certain period of time (FEMA, 2005. p. 3). It is possible that a flood happens within a time period sooner than 50 years will exceed the predicted highest level to reach a destructive wave height above the first floor elevation . Thus, a coastal flood with a wave crest over 3 to 4 feet above the bottom of the floor beam will lead to substantial damage to the light frame structure on the ground floor surface. The land use policy implementation needs to work closely with protection standards of Florida Building Codes to ensure that the lowest horizontal structure on the bottom floor is elevated above the Base Foundation Elevation. A freeboard equal to plus 2 to 3 feet over the base floor level can be used when it is possible.

Exposed Areas under a Full-Meter Sea-Level-Rise Induced Storm Surge with a 4-Feet Average Depth

In my study area, this would be the land category with the least chance to be repetitively damaged by flood hazard, but these areas still face the risk of being largely impacted among considerable acreages in terms of the magnitude and intensity of predicted hazards. Concentrated residential and mixed-use community development will occur in these areas because of the potential watershed development opportunities that these areas would possess currently and in the future. The analysis showed that designation of future residential usage maintains stable percentages for each residential category, no matter what the predicted storm surge depth will be. The results demonstrated that there is a scattered trend of future residential distribution. This is because of the inevitable uncertainty and incomplete analysis of the designation. In these areas, the county would still proceed to maintain lots and any other access to the RES-1 single family dwellings. However, The County might have to consider adjusting the elevation of road infrastructures, if those infrastructures serve for concentrated existing residential areas. General community support of infrastructures, education, and health and safety institutions would still be maintained and be intended for quality improvement through community collected funds. But the county would not provide extra funds for community improvement for recreational and neighborhood retail services.

This land category faces a variety of issues and opportunities; in response, local government should present diverse land use planning tools to address the potential upcoming issues. Involvement of flood insurance programs will be mandated and executed in residential development projects to facilitate the construction of community-related evacuation services, roadway elevations and to strengthen utility systems and public building infrastructures. It would also be possible for local government to negotiate for easements for certain areas for a dedication or exactions for evacuation uses by specific designation of subdivision. The county should prepare redevelopment plans for areas that are suffering repetitive damage and should specify purchasing for elevating habitable structures on the ground level for the redevelopment area. Foundation reconstructions are allowed by raising the Base Foundation Elevation, adding freeboard and interior/exterior water-proof structures.

All in all, the areas within the 100-year sea-level-rise induced storm surge area are loaded with both development and redevelopment opportunities, and the vulnerabilities of substantial building structural damage. Government needs to stabilize the control and release of the development rights through a multitude of land-use decisions, site speculations and negotiation with private property owners.

In the “half-meter” and the “full-meter” scenario, the probability that the projected sea level rises happen with associated storm surges is very low (only at 0.01%). It will be difficult to convince the stakeholders solely with the modeled results about flood impacts. Flood insurance rate map can be introduced, especially to citizens and private insurers. The insurance rate varies because of the hazard intensities in different areas. The average zonal statistics of storm water depth can also assist the government to interpret the variation of insurance and subsidy rates. However, the county should still rely on the land use plan and the integration of land use tools to establish the rational connections between public interests and policy or strategy implementation processes. Because the plans and policies can be better monitored and assessed by the communities and other stakeholders to determine their effectiveness. And the approaches of stakeholder participation are the most radical and crucial factor to set the foundations for long-term hazard mitigation approaches.

Vacant Lands for Future Capacity

Vacant lands are the second-largest future group for residential development, which means they are the primary future capacity for density development and relocation. However, being designated as vacant lands indicated that uncertainty is the largest characteristics of this land use group. The uncertainty might result from insufficient adjacent spatial references, uncertain ecological processes, and scattered spatial locations away from urban and suburban area. Therefore, the government must categorize vacant lands through coastal hazards spatial categories summarized through hazard analysis, so that the they can tell which piece of land is truly equipped with development potential and whose rights of development needs to be held under strict regulation.

Compared with the development strategies for existing residential lands, the government will mainly focus new strategies on limiting the scale of unnecessary residential sprawl and maintain stable community operations under the circumstance of coastal hazard adaptation. Vacant land residential development will focus on new building construction and the formation of residential communities and associated service systems and amenities. The governments need to proactively apply building codes in terms of the joint consideration of land use categories, special flood hazard areas (such as CHHA, CEA, CPA) in order to form a residential community resistant to potential hazards, and to improve the infrastructure and service system to ensure the capacity for recovery.

Adaptation of Exposed Vacant Areas with Potential SLR Occurrence

This is different from the areas equipped with a storm surge caused by a 1-meter sea-level-rise. Although a 1-meter sea level rise may not happen around the predicted time period, the low topography would led to severe storm water inundation according to the scenario in my study.

As the analysis showed, around 80% of the existing vacant properties (29.29% out of 36.91% of all the vacant parcels) had already been designated as residential uses in the future. Residential development on vacant properties should basically follow the future land use plan: to locate buildings 1 du/ga in suitable vacant areas, and to promote medium density residential development (RES-6 and RES-9). Lands are not recommended for urban infill redevelopment projects to prevent the possibility that affordable housing ends up being located in ecologically sensitive areas. The County would cease to initiate grants and loans for unnecessary public infrastructure improvement, but only provide basic public safety, public health and education systems, water-dependent uses or community-level recreational uses. The county might also have to consider purchasing-and-selling back strategies to ensure the evacuation process for specific zones, if it is necessary to locate new evacuation access and special infrastructures areas would be required. The county can also take full advantage of the exemption area of CCCL buffer zones to locate vital infrastructures.

Specifically, for the new building construction area, crawl space foundations would be recommended outside Zone V. If the foundations are slab-on grade, additional freeboard elevation (for instance, 1 to 3 feet according to a decision made after site-specific inspection) is encouraged. Strong and stable connections between the foundation and elevated structural members would contribute to the longevity of buildings. Rigid and water-resistant interior and exterior structures (especially for wooden framing systems, if proposed) would help maintain the value of buildings and protect buildings from substantial or repetitive losses through storm water destruction. Additionally, for concrete construction materials, governments have to ensure that the property owner and the developer understand that proper water cement ratio of concrete mix will affect the extent of moisture resistance and stiffness of the building structures. In other words, any new construction must be confirmed as pressure-preservative against the wind and water.

Vacant properties within this category are about to be confronted with the highest level of hazard risk. The government must update strategies for supplying and satisfying the elementary levels of support for single family communities. Current public interests should be protected. But the further consideration of improving living quality is not highly recommended.

A similar strategy used for existing residential lands in the same spatial category can be adopted for this vacant area. The county must specify the connection between the land exposure and flood insurance rates to stakeholders, especially the publics.

Adaptation of Exposed Vacant Areas without Potential SLR Occurrence

A total of 3666 acres, which was the largest amount of land area, were categorized in this spatial location. Compared with the scenario above, this scenario will require more flexible adoption of land use tools consistent with coastal hazard adaptations. Vacant lands within this area are still under the highest level of storm surge threat.

Local governments are able to initiate concentrated or continuous forms of residential area development, because land distribution in this category is more compatible with consistent development in building form, the structures of associated amenities, neighborhood-related services and other activities that support a residential environment. For example, lands located around the southeastern side of Manatee River are close to large amounts of agricultural lands. Short-term or special agricultural uses considered as potential uses in the future (Manatee County, 2005 A, p.117) can be temporarily permitted along with residential development. Although the county allows clustered development in residential areas of 9 du/ga, it would be foreseeable that development should only be small-scale and designed for residential daily activities. Large mixed-use development projects, and integrated mobility system development will not be supported. Urban infill redevelopment projects are still not allowed in these areas.

Despite the fact that the areas will be developed as residential land use, the county should focus on maintaining a steady community-system and to elongate the building lifespans. This will prevent unnecessary modification, restoration and developments.

As high-risk areas, local private insurance sectors might not be able to provide full flood insurance coverage. It might be possible that the federal government's flood insurance program can assist to provide a portion of subsidy or risk premiums. However, the overall insurance coverage for areas inside this scenario should be high, so that land value and property values can be raised to a level to phase out the developments that cannot meet the requirement of construction. Raised insurance can also possibly prevent local owners from purchasing the development in this area, which can avoid a pool of residential growth. However, both the insurance and the land planning strategies should came into work at the same time to reach a long-term achievement: the release of residential concentration in these areas.

Adaptation of Vacant Exposure inside a Half-Meter SLR Induced Storm Surge

Vacant lands in this land category must co-exist with residential, commercial, mixed-use and other types of land development in the future. Hence, the lands have to be well-prepared to accept density development in terms of public interests. On one hand, land development in conformity with the future land use plan will be validated but not encouraged. On the other hand, vacant properties might serve for other land use purposes, such as being used as receiving zones, or planned unit development (PUD) which will accept partial or total density development rights temporarily or permanently. However, it is inappropriate for this area to support further residential development other than the current designation. Even the Incentive Zone, which spares spaces for placement of special infrastructure, will not be highly recommended. As 60% of the existing residential vacant lands have already been designated for future residential usage, the rest of the lands can take up to 9du/ga residential development, and the county should enhance the infrastructure system and continue maintenance for the medium-density development.

Adaptation of Vacant Exposure inside a Full-Meter SLR Induced Storm Surge

The 630 acres of scattered vacant lands are loaded with larger development opportunities as they are adjacent to the lands that are out of special flood hazard areas. Residential development will be encouraged in this area in terms of compatibility to the land development in the adjacent areas. However, clustered development or PUDs can be allowed in order to set impedance for a sprawling urban development pattern.

Summary

My study explored how a projected 100-year storm surge would affect the lands, given three scenarios of sea-level-rise. It then sought answers about how to apply current land use policies, coastal planning principles, and coastal hazard adaptation strategies in an integrated way to achieve the goals about maintaining land developments and to concurrently implement the coastal hazard adaptation process. To answer the first question, the study used HAZUS-MH to summarize storm-surge induced property damages under three scenarios.

1. Stillwater Scenario. This scenario stands for the situation where a 100-year storm surge happens at Stillwater elevation.
2. A Half-Meter Scenario. In this scenario, a 100-year storm surge happens at Stillwater elevation, plus a half-meter of sea-level-rise.
3. A Full-Meter Scenario. In this scenario, a 100-year storm surge happens at Stillwater elevation, plus a full-meter of sea-level-rise.

The summary included estimation about dollar values of buildings exposed to the flood damage (Building Dollar Value Exposure), the number of buildings facing different levels of damage (General Building Stock Damage), and building-related economic losses in dollar values. HAZUS-MH performed the analysis based on occupancy type (land use type, such as residential and commercial) and building type (structural type, such as wood and concrete). Apart from the summary report, HAZUS-MH also generated storm surge depth grids at three different scenarios. The depth grids were then processed by ArcGIS so that each parcel had zonal statistics information about storm wave depth.

Future residential lands and their existing conditions were summarized according to different depth levels of projected 100-year storm water. With the HAZUS-MH Hazard Event Reports and storm water depth grids, ArcGIS was introduced into the process to estimate the future residential land exposure and vacant capacities. For the sake of capturing a proper sample size, the analysis summarized information generally following the scenarios built in HAZUS-MH, but it selected a specific range of average and maximum storm surge depth to control the sample sizes. More importantly, analysis performed in the light of varied average depth helped answer how land exposures vary through the changing depth, which showed the scale of the storm surge impact, and spatial differentiation of the distribution of future residential lands and vacant capacities.

During the analysis, a particular GIS processing strategy was developed for the property data which were then prepared as stacked parcel polygons in case they need to be analyzed under projected coastal hazard impact. Three cases about stacked properties were studied to determine how they are going to be affected by a projected storm surge happening at Stillwater scenario. These case studies considered the land use type, building material and foundation type. It is a normal issue that the county and property appraisers summarized multiple individual units into only one parcel according to their owners. These issues usually happened to parcels designated as "Condominium Improved." The case studies dealt with specific issues that might happen when incorporating property data into coastal hazard impact estimation. Hence, this step helped solve a normal problem that the planning department has to face during their upcoming coastal planning stages.

According to HAZUS-MH Hazard Event Reports, the largest area of land exposed under projected storm surges consists of residential buildings. From the perspective of land use, the following analysis done by ArcGIS shows that current residential lands constitute the largest proportion of future residential lands. And these lands were designated primarily for low or medium-density residential land uses. Both HAZUS-MH Hazard Event Reports and GIS-based Analysis indicate that vacant lands are the second-largest group for future residential development. Vacant capacities were also categorized in terms of the depth of storm water.

Based on the analysis, my study gave resolutions about future development for two land categories: existing residential lands remaining residential in the future, and vacant future capacities. Resolutions were broken down into details following the previous categorizations based on storm water depth and the elevation of sea-level-rise. Basically, recommendations were made about application of land use codes, building construction strategies and land use tools. It was suggested that areas within Stillwater scenarios should only follow the future land use designation but not pursue further land development or redevelopment opportunities. The government must provide basic residential service and infrastructures in order to avoid overriding public interest, but they can gradually withdraw the service and infrastructure in order to remove unnecessary development opportunities. Land use tools for site-specific development should be cautiously restricted to prevent residential density growth in potential flood areas.

In the areas landward but still in potential sea-level-rise areas, the government must focus on properly applying building codes to meet the requirements of FEMA construction strategies. It is important to ensure the foundation types, building structures and materials are able to protect the residential community from substantial damage. These areas can be allowed for application of land use tools for site-specific development and density adjustment in order to capture development opportunities. However, these developments must not jeopardize the relationship between stable environmental processes and human activities. In these flood-prone areas, land regulatory tools should take predominant places when collaborating with flood insurance programs. Flood insurance program places mandatory purchase requirements for owners who intend to develop their properties. Within the protection of flood insurance program, residential development were strictly required to meet the standards about base foundation elevation and first floor heights, and the standards about structure material. The Federal government has been considering eliminating the premium subsidy or charging full rates for repetitive loss properties or second homes (United States General Accounting Office, 2003, p.2). And the insurance programs are assets-based, which means that the program can also address an amount of financial equity issues. This is a process that can phase out improper development in the areas with certain probabilities of suffering catastrophic damages. However, the way that the land use policy design to react the placement of flood insurance and reduction of subsidies are not simply remap the flood insurance rates and bring more properties that should be eliminated from development in to the program's consideration.

"Land-use planning is the means of gathering and analyzing information about the suitability of development of land exposed to natural hazards, so that the limitations of hazard-prone area are understood by citizens, potential investors, and government officials." (Burby, et al., 2000, p. 99). As the foundation of coastal hazard mitigation strategy in the view of urban planning, land use plan or land regulatory tools factor special flood hazard circumstances and to control the intensity of development. Land use ordinances can also manage the spatial distribution of developments by allocation of future development.

In the view of land-use planning, my study provided one of the technical approaches to inform the stakeholders about the intensity and location of coastal hazard and the residential properties' vulnerability in terms of the projected hazards. My research process also offered a resolution to identify the imprecisely recorded information in parcel data. The technical approaches in my study involved accurate storm water depth into a parcel-level scale, and this is useful in a practical level that the county can capture sophisticated measurement for the intensity of the projected hazards. The strategy is hopefully bringing the government officials more information and to build their commitment in hazard area management. Residential development and remaining future development capacities that are both exposed to coastal hazard-prone locations. "The key to build real commitment to change the way of hazard area management lies with local planning programs"(Burby and Beatly, 2007, p.10). As FEMA has been focusing on adopting proper flood insurance rates, it means that it is local governments' responsibility to prepare to cope with coastal management issues. With the help of the increasing advanced researches and growing sophisticated statistics, the role of the local government officials and land use planning or land use controls in hazard adaptation process should be strengthened.

Local government should also help improve the involvement of flood insurance private sectors, so that the federal-issued programs can be specifically localized to adapt the real circumstances in certain areas. The Congress put effort in charging the policyholders rates that reflect the actual coastal hazard risk, the private sector will be given more chances to identify the proper rates that a property owner should be charged, and the owners without adequate affordability can get more assistance. My study mainly focused on the local level land use planning. However, the models and the categorization of future capacities for development will show the place that private insurers are willing to cover. The area that the private sectors are not able to be involved, such as high-vulnerability area, can also be shown for local government and higher-level municipalities in case of further steps of protections.

Creating a coherent environment for the implementation coastal planning-based land use strategy is crucial for regional development. The public's awareness of coastal hazard, the developers and investors' understanding about resilient and flood-resistant constructions standards, the insurance companies' understanding about the hazard's severity in the view of economic values are all contributing to a consistent hazard-resilient policy –design environment. The most important principle is that the government official should be fully aware of the facts about the coastal hazards, and the essence of implementation of land use planning and coastal mitigation strategies. Only by consensus and participations of stakeholders will make a long-term plan adoptable and sustainable.

APPENDIX
TABLES, FIGURES AND MAPS

Table A-1. Future residential lands exposure in Scenario 1(Stillwater, Mean Depth 1 foot, Max Depth 4 feet)

Future Land Use Label	Frequency	Exposed Acreage	Exposed Just Value(Million$)
MU	37	287.78	55.75502829
MU-C	5	360.07	7.784422444
RES-1	974	2,664.65	213.7605616
RES-16	644	452.98	108.0426291
RES-3	1747	1,637.59	431.1673901
RES-6	4756	2,945.21	740.3676176
RES-9	2274	1,419.33	326.2320418
ROR	434	385.67	84.19214092

Table A-2. Future residential lands exposure in Scenario 1(Stillwater, Mean Depth 2 foot, Max Depth 4 feet)

Future Land Use Label	Frequency	Exposed Acreage	Exposed Just Value(Million$)
MU	28	208.471649	2.7219
MU-C	4	194.316695	6.3139
RES-1	949	2329.305811	206.8903
RES-16	602	216.893997	82.3480
RES-3	1699	1412.547795	415.2016
RES-6	4455	2584.39808	700.4033
RES-9	2141	1196.616604	288.6395
ROR	394	287.821837	60.6010

Table A-3. Future residential lands exposure in Scenario 1(Stillwater, Mean Depth 3 foot, Max Depth 4 feet)

Future Land Use Label	Frequency	Exposed Acreage	Exposed Just Value(Million$)
MU	21	198.180729	2.5565
MU-C	2	38.393827	0.6467
RES-1	913	2282.588132	202.0181
RES-16	597	211.349237	81.7456
RES-3	1596	1268.60949	390.7848
RES-6	4222	2442.791513	667.7435
RES-9	2125	`	287.4236
ROR	378	231.112754	55.6151

Table A-4. Future residential lands exposure in Scenario 2(Half-meter, Mean Depth 4 feet, No Maximum Depth Limitation)

Future Land Use Label	Frequency	Exposed Acreage	Exposed Just Value(Million$)
MU	18	183.640824	2.1701
MU-C	3	152.265692	6.1240
RES-1	929	2303.139585	209.9172
RES-16	762	230.740967	89.8947
RES-3	1742	1385.423836	443.6139
RES-6	4765	2634.738621	744.7273
RES-9	2285	1213.369864	296.0230
ROR	401	256.063424	64.8814

Table A-5. Future residential lands exposure in Scenario 3(Full-meter, Mean Depth 4 feet, No Maximum Depth Limitation)

Future Land Use Label	Frequency	Exposed Acreage	Exposed Just Value(Million$)
MU	35	237.592981	6.3638
MU-C	5	375.256593	11.5209
RES-1	959	2419.54958	220.3575
RES-16	1203	289.043245	112.3485
RES-3	2154	1684.720935	541.2502
RES-6	6055	3164.599481	875.8849
RES-9	2533	1335.330603	316.3919
ROR	446	340.236662	77.6801

Table A-6. Example: Exposed Existing Lands Designated as Future Residential in Scenario 1(Stillwater, Mean Depth 4 feet, No Maximum Depth Limitation)

Land Use Descriptions	Frequency	Land Use Category	Exposed Acreage	Exposed Values ($1000)
NULL	5	Others/Unclassified	1.5792	0
Acreage Improved for Condo (1555)	1	Others/Unclassified	30.6992	0
Athletic Centers (1555)(New 2014)	1	Service	4.2950	1018.944
Church (1555)	15	Others/Unclassified	28.2943	5619.048322
Clubs,Lodges,Union Halls (1555)	8	Service	69.1266	1589.494276
Commercial Boat Slip (1554)	2	Service	1.4174	260.372
Commercial Related Amenities(New 2014)	3	Commercial	7.1180	115.5496375
Community Shopping Centers (1555)	1	Retail	0.6668	385.56
Condominium Header	3	Others/Unclassified	5.29201	20.68199552
Convenience Store (1555)(New 2014)	3	Retail	0.9076	366.389
Convenience Store w/Gas(1555)(New 2014)	4	Retail	3.0696	1335.682529
Coop Owned Lot (1554)	104	Commercial	5.4145	1975.631
County (1555)	7	Others/Unclassified	22.8562	204.9236745
Cropland,Class II (1555)	2	Greenfields	2.3715	348.395
Double Wide MH/Condominia(1554)(New 14)	1	Residential	0.0972	59.708
Double Wide MH/Coop (1554)(New 2014)	91	Residential	7.4594	7675.670074
Double Wide Mobile Home (1554)(New 2014),Double Wide Mob.Home (1554)(New 2014)	159	Residential	23.0004	10039.25349
Duplex (1554)	10	Residential	9.5145	1387.751
Fast Food/Drive In Restaurants (1555)	3	Service	1.7085	781.0280867
Financial Institutions (1555)	2	Commercial	2.3863	589.033
Garage/Auto Body/Paint Shop(1555)(2014)	5	Industrial	4.8514	912.1814187
Golf Courses,Driving Ranges (1555)	5	Service	11.7257	4.679978045
Govt Owned Forest,Parks,Rec Area (1555)	1	Greenfields	3.4689	102.7142002
Govt Owned Public County School (1555)	2	Institutional	9.5959	2423.489483
Govt Owned Vac Forest,Prks,RecArea(1555)	5	Greenfields	61.6292	446.2287768

Table A-6. Continued

Land Use Descriptions	Frequency	Land Use Category	Exposed Acreage	Exposed Values ($1000)
Govt Owned Vac Public Cnty School(1555)	3	Institutional	2.3636	82.96955963
Govt Owned Vacant County (1555)	25	Others/Unclassified	64.9654	720.7635537
Govt Owned Vacant Municipal (1555)	2	Others/Unclassified	0.4118	5.778
Govt Owned Vacant State (1555)	16	Others/Unclassified	160.0103	2063.84634
Grazing,Class I (1555)	16	Greenfields	493.1612	14639.31273
Grazing,Class I Improvements (1555)	9	Greenfields	91.1190	3120.118764
Half Duplex (1554)	39	Residential	5.6027	4118.625
House Plus Duplex (1554)	2	Residential	2.6858	796.626
Imp.Res.Common Area (1554)(New 2014)	23	Mixed-Use	146.1861	6.887375724
Light Industrial (1555)	2	Industrial	1.4879	423.647
Limited Service Hotel (1555)(New 2014)	2	Service	1.6444	941.2067593
Lumberyards,Sawmills (1555)	1	Industrial	1.4391	298.202
Marinas/Piers (1555)(New 2014)	7	Others/Unclassified	33.3874	4401.920878
Mixed Use Comm./Res.(1555)(New 2014)	1	Mixed-Use	3.4163	97.76321928
Mixed Use Commercial (1555)	1	Mixed-Use	3.1631	139.339
Mobile Home Parks (1555)	3	Residential	78.0953	1086.776274
Mortuaries,Cemeteries (1555)	1	Service	28.9815	446.2967732
Motel (1555)(New 2014),Motels (1555)(New 2014)	4	Service	3.7082	1439.687644
Multi-Family (3 to 9 Units) (1554)	5	Residential	2.2096	463.7138572
Municipal (1555)	3	Others/Unclassified	2.3833	913.525
Night Clubs,Lounges,Bars (1555)	3	Service	1.3181	520.484
Office Buildings-One Story(1555)	9	Commercial	8.8300	2341.372263
Open Storage,Supply/Junkyards (1555)	1	Industrial	1.2463	45.431
Orchard,Groves,Citrus (1555)	4	Greenfields	2.0418	125.947

Table A-6. Continued

Land Use Descriptions	Frequency	Land Use Category	Exposed Acreage	Exposed Values ($1000)
Orchard,Groves,Citrus Imprv (1555)	4	Greenfields	21.9421	1700.723162
Ornamentals,Misc (1555)	22	Greenfields	121.2177	3936.287823
Ornamentals,Misc Improvements (1555)	23	Greenfields	450.1575	15011.62399
Orphanages,Other Services (1555)	1	Institutional	0.7279	143.537
Parking Lots,Commercial (1555)	1	Commercial	0.6237	114.078
Poultry,Bees,Fish Improve (1555)	1	Greenfields	2.3953	328.358
Produce and Fishhouses Whole (1555)	1	Greenfields	1.1857	329.995
Rec.Vehicle/MH Sales(1555)(2014)	1	Service	1.8198	198.982
Repair Service Shops (1555)	2	Industrial	3.0759	760.8270701
Res. Related Amenities(1554)(New 2014),Res. Related Amenities (1554)(New 2014)	10	Residential	23.7571	1567.124289
Res.Amenities on 10+ Ac.(1554)(New 2014),Res. Amenities on 10+ ac.(1554)(New2014)	2	Residential	40.1585	628.0070238
Restaurants,Cafeterias (1555)	8	Service	7.5246	2802.323499
Rights-of-Way (1555)	12	Institutional	19.9227	6.538035367
Rivers,Lakes,Submerged Lands (1555)	58	Others/Unclassified	194.6849	95.0057297
Service Stations (1555)	1	Service	1.2625	387.049
Single Fam. Res./10+ Ac.(1554)(New 2014)	1	Residential	10.4050	189.431
Single Family Homes/Condominia (1554)	13	Residential	2.5341	2488.308057
Single Family Residential (1554)	5193	Residential	2404.0711	1230196.411
Single Wide MH/Condominia(1554)(New 14)	1	Residential	0.0804	49.899
Single Wide MH/Coop (1554)(New 2014)	980	Residential	57.8282	41579.31351
Single Wide Mob.Home (1554)(New 2014),Single Wide Mobile Home(1554)(New 2014)	311	Residential	26.8686	14248.8232
State (1555)	1	Others/Unclassified	2.1916	387.61
Stores,One Unit (1555)	4	Retail	1.7167	658.554

Table A-6. Continued

Land Use Descriptions	Frequency	Land Use Category	Exposed Acreage	Exposed Values ($1000)
Triple Wide MH/Coop (1554)(New 2014)	21	Residential	1.9284	3013.182
Triple Wide+ Mob.Home (1554)(New 2014),Triple Wide+ Mobile Home(1554)(New 2013)	32	Residential	5.1635	3199.036025
Two or More Houses (1554)	58	Residential	87.7415	21389.38429
Utilities (1555)	2	Industrial	0.9149	246.2
Vac.Commercial Common Area (1555)	4	Vacant/Infill	18.2417	0.018
Vacant Acreage,Not Ag. 10+ Acres (1555),Vacant Acreage,Not Ag.10+ Acres(1555)	77	Vacant/Infill	996.0425	10329.58606
Vacant Commercial (1555)	46	Vacant/Infill	86.6450	4584.081036
Vacant Commercial w/Impv (1555)	1	Vacant/Infill	0.6636	230.692
Vacant Condominia Residential (1554)	97	Vacant/Infill	4.2000	10224.24816
Vacant Industrial (1555)	2	Vacant/Infill	3.0923	35.19
Vacant Institutional (1555)	15	Vacant/Infill	53.3585	2417.29539
Vacant Mobile Home Lot Platted (1554)	75	Vacant/Infill	3.9033	1350.01
Vacant Non-Residential/Unusable (1555)	3	Vacant/Infill	1.0550	5.592592153
Vacant Res. Common Area (1554)(New 2014),Vacant Res.Common Area (1554)(New 2014)	94	Vacant/Infill	164.6378	0.264459703
Vacant Res.Common Area (1554)(New 2014),Vacant Res. Common Area (1554)(New 2014)	94	Vacant/Infill	214.3820	26.13955395
Vacant Residential Platted (1554)	847	Vacant/Infill	512.6871	61983.23087
Vacant Residential Tract/Unusable (1554)	22	Vacant/Infill	47.0049	202.0404794
Vacant Residential w/Site Amen. (1554),Vacant Residential w/Site Amen (1554)	99	Vacant/Infill	26.9411	7685.210978
Warehousing-Ministorage (1555)	2	Industrial	4.3405	3214.235
Warehousing,Distribution (1555)	3	Industrial	2.0163	617.782

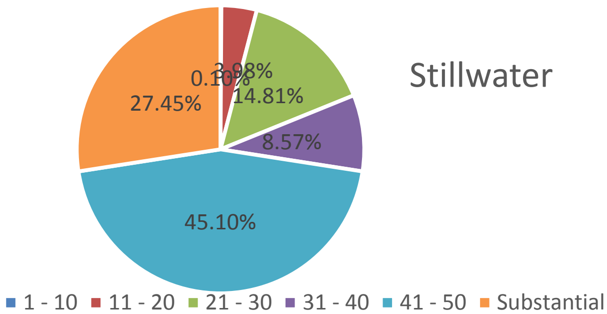


Figure A-1. Expected residential building damage (Level of Damage) in Stillwater scenario

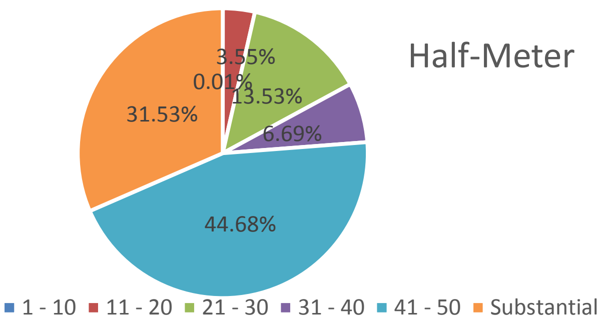


Figure A-2. Expected residential building damage (Level of Damage) in Half-meter scenario

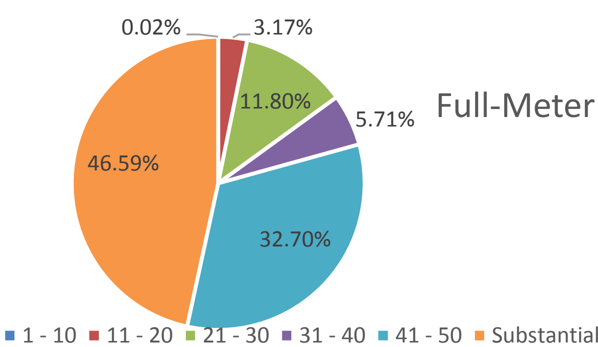
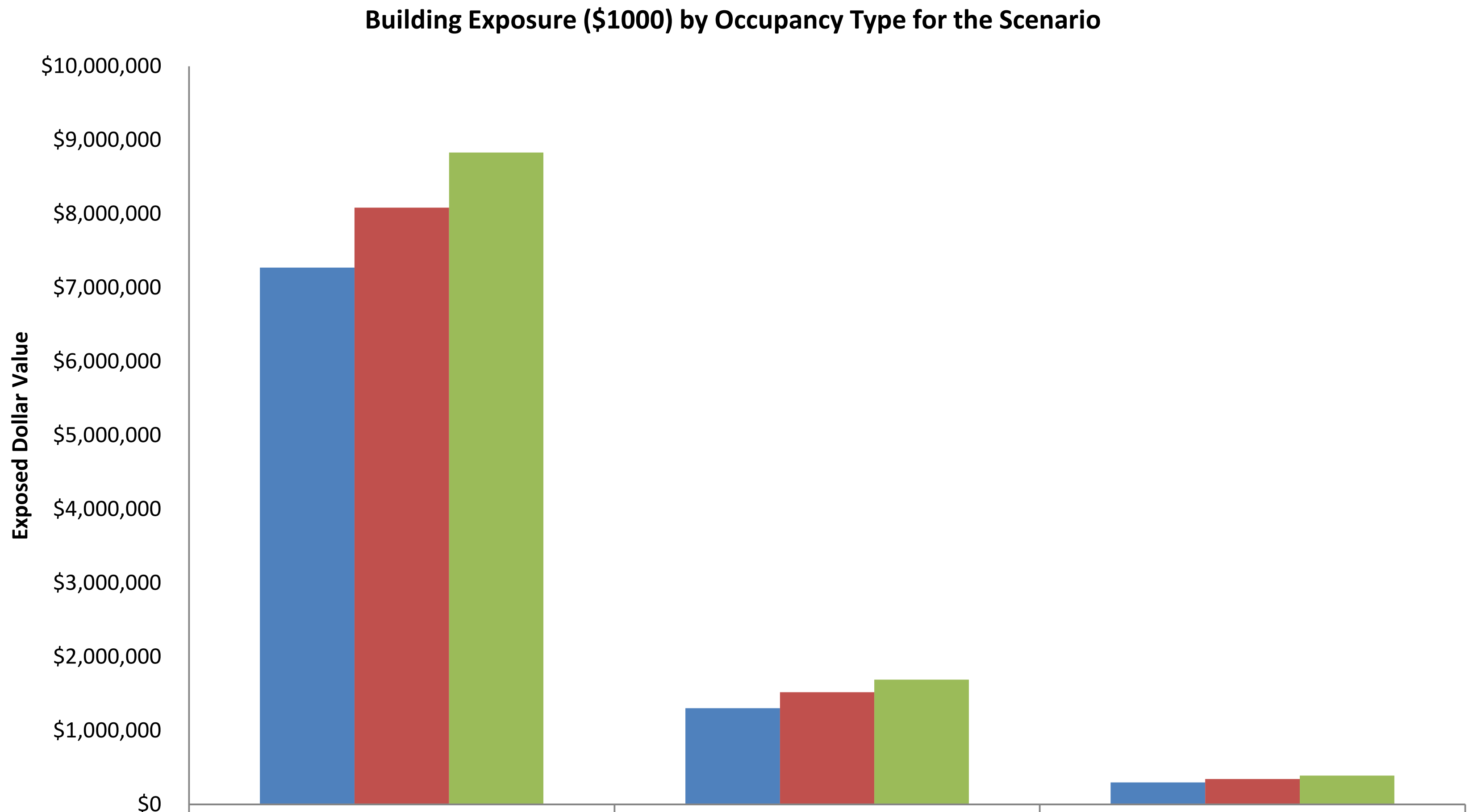
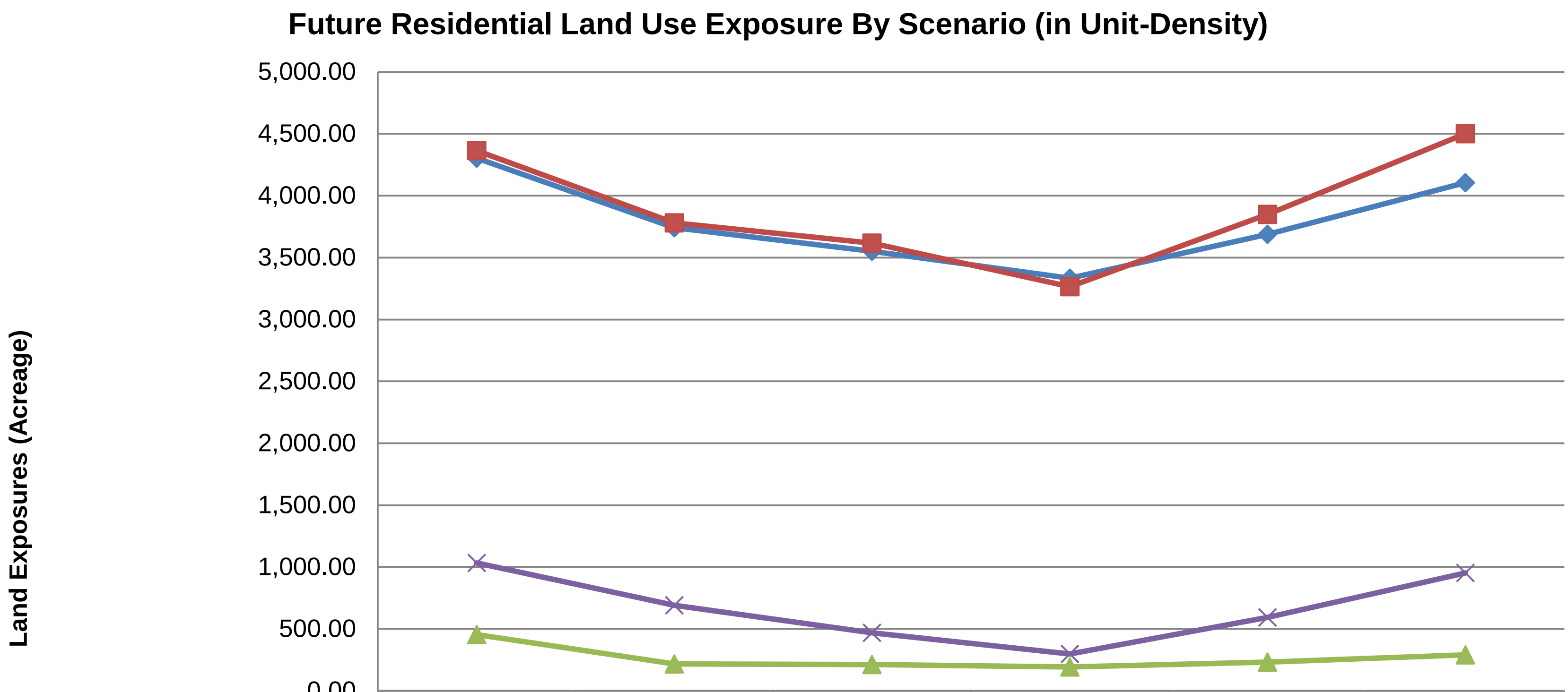


Figure A-3. Expected residential building damage (Level of Damage) in Full-meter scenario



	Residential	Commercial	Industrial
Stillwater	7,271,879	1,302,548	298,962
Half-Meter	8,084,509	1,521,345	341,972
Full-Meter	8,832,215	1,688,104	389,500

Figure A-4. Building Exposure ($1000) by Occupancy Type by Scenarios



	Stillwater Mean1 Max4	Stillwater Mean2 Max4	Stillwater Mean3 Max4	Stillwater Mean4	4(Mean) with a Half-meter SLR	4(Mean with a Full-meter SLR
RES-Low Density (1&3)	4,302.24	3,741.85	3,551.20	3,333.33	3,688.56	4,104.27
RES-Medium Density(6&9)	4,364.54	3,781.01	3,617.50	3,265.38	3,848.11	4,499.93
RES-(High Density(16)	452.98	216.89	211.35	192.18	230.74	289.04
Mixed Use	1,033.53	690.61	467.69	298.62	591.97	953.09

Figure A-5. Future Residential Land Use Exposure By Scenario

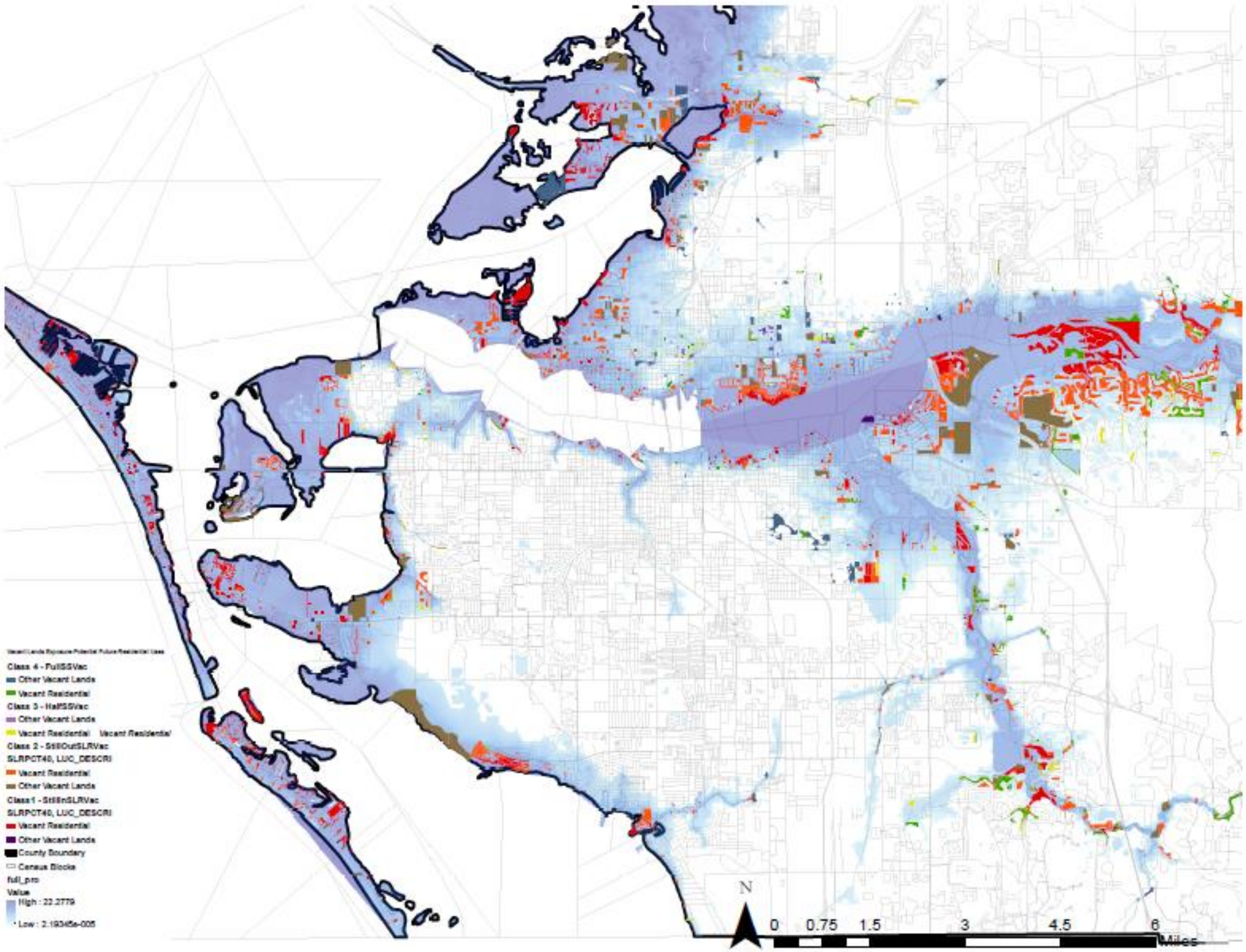


Figure A-6. Vacant Lands Categorizations by Scenarios

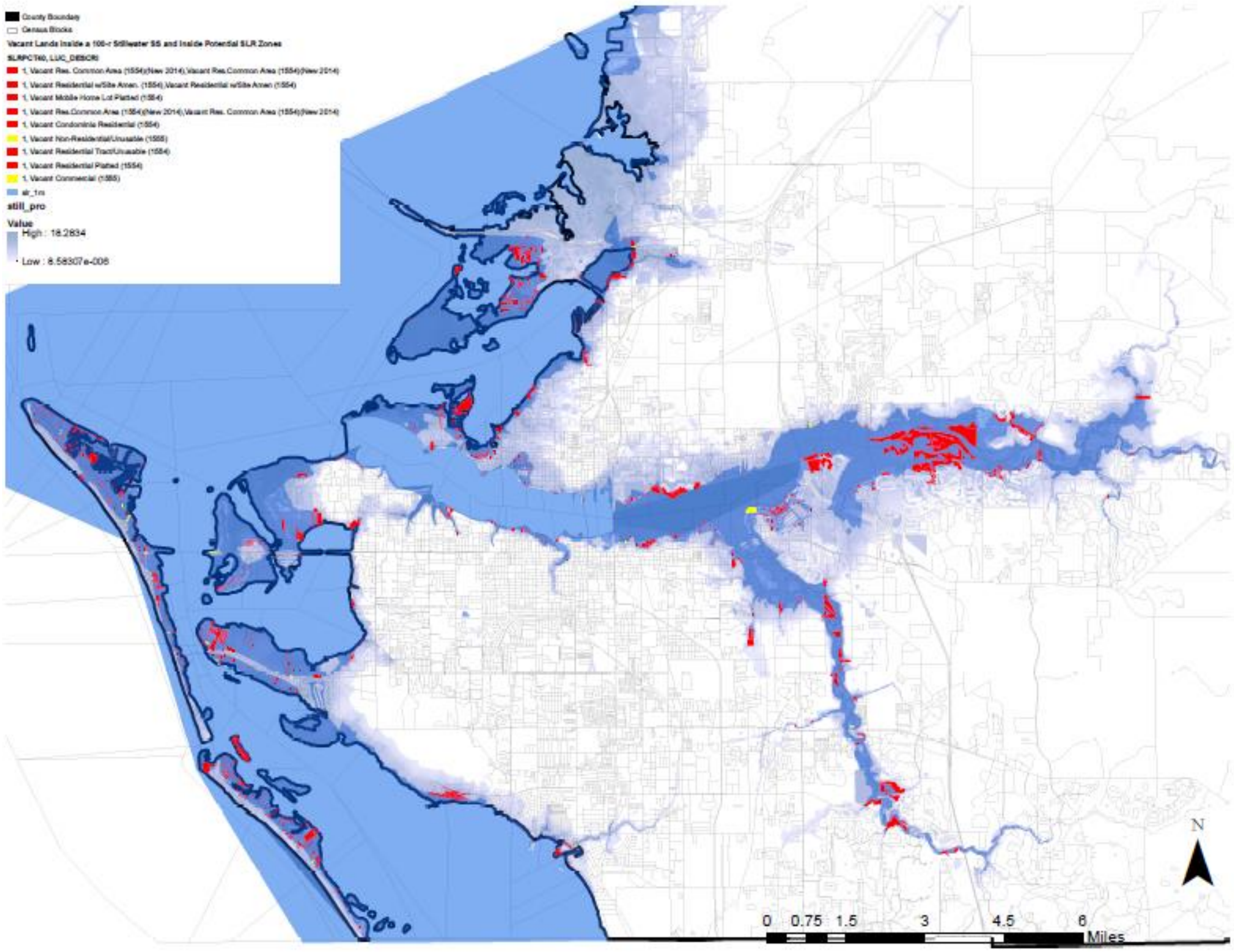


Figure A-7. Vacant Lands exposed to 100-yr Stillwater-based SS and a potential 1-meter SLR

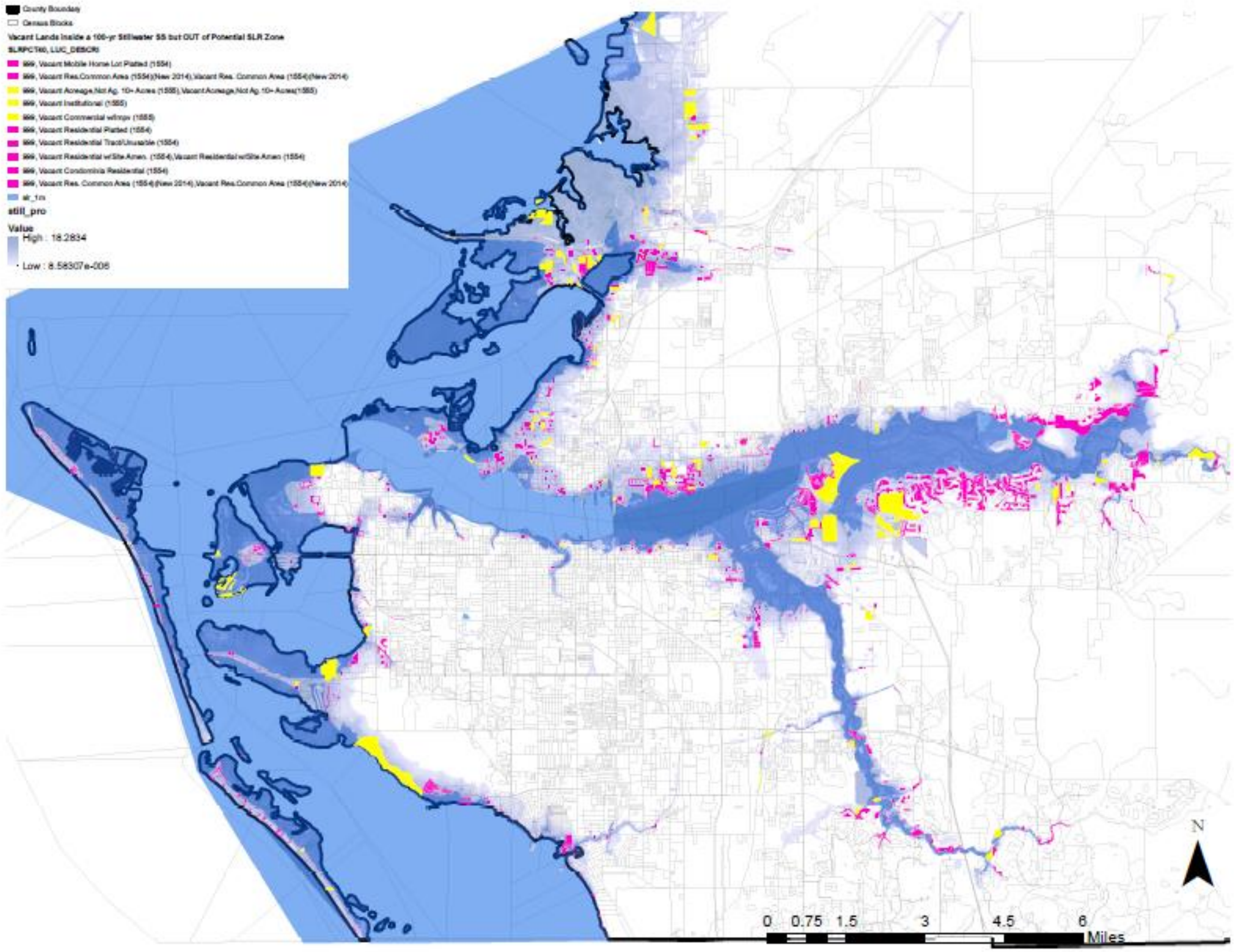


Figure A-8. Vacant Lands exposed to 100-yr Stillwater-based SS without a potential 1-meter SLR

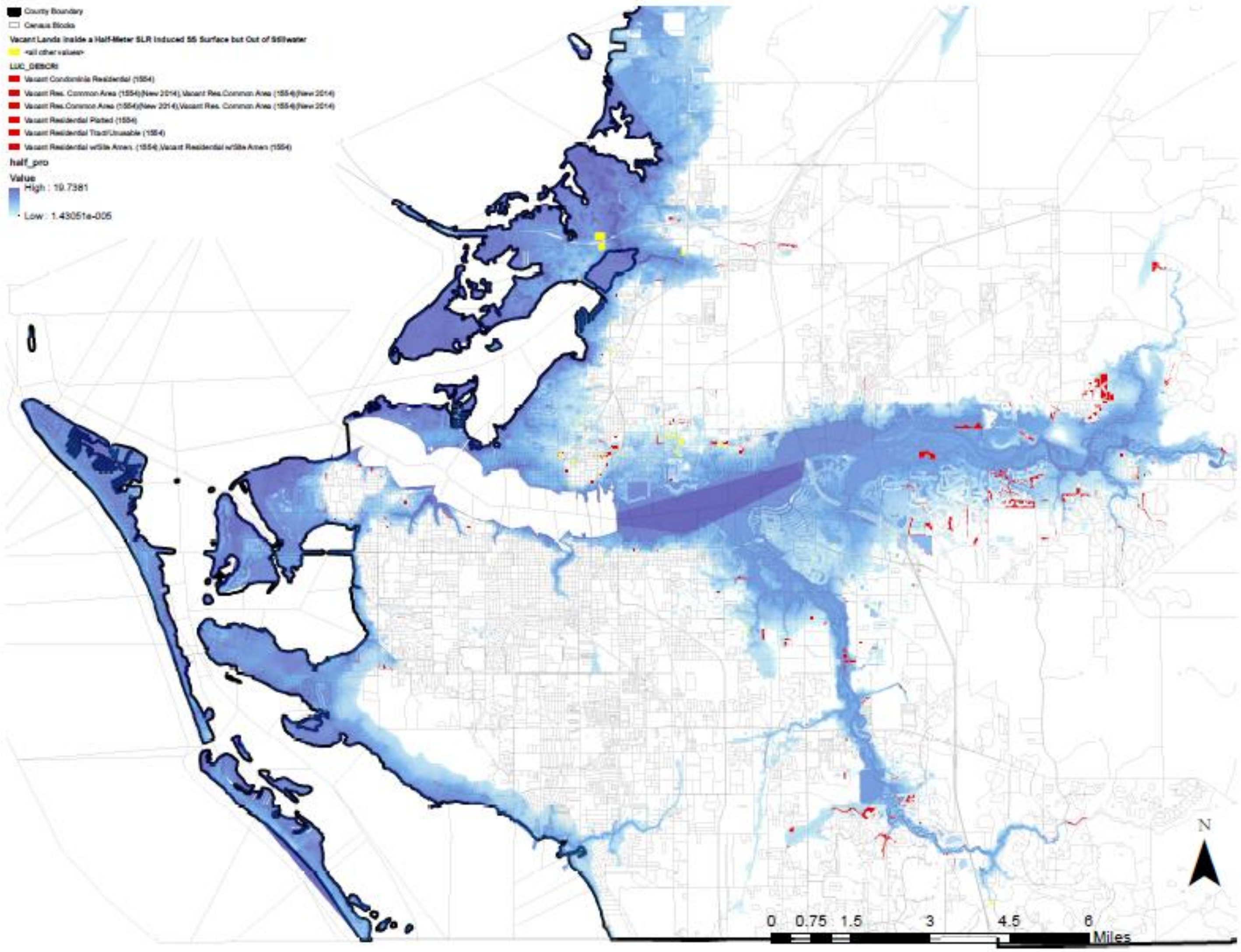


Figure A-9. Vacant Lands exposed to a half-meter SLR induced SS

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BIOGRAPHICAL SKETCH

Jingru Zhang is currently pursuing a Master of Arts degree in Urban and Regional Planning in University of Florida (UF) in Gainesville, Florida. She has a Bachelor of Science in Resource and Environment, City Planning and Management from the Huaqiao University in Quanzhou, China. Jingru's master's studies have focused on the use of geographic information systems (GIS) in spatial analysis of land development in adapting potential impacts brought by coastal hazards. Jingru's past experience included urban design and most recently, she has worked with Regional Transit System in Gainesville, Florida on GIS-based transit research projects. Jingru was also enrolled in the "URP Curitiba". It is an UF's Study Abroad Program focusing on transit mobility and urban design issues in Brazil. Jingru's future interests include working in the field of land development, coastal planning and integrated applicationS of GIS techniques.