# GIS-BASED FUTURE LAND USE HURRICANE STORM SURGE HAZARD ANALYSIS: A CASE STUDY FOR VOLUSIA COUNTY, FLORIDA

By

YUYANG ZOU

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
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To my dearest family and friends

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TABLE OF CONTENTS

APPENDIX

LIST OF TABLES

LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| BEBR | Bureau of Economic and Business Research at University of Florida |
| CDMS | Comprehensive Data Management System |
| DEM | Digital Elevation Model |
| DOR | Department of Revenue |
| ESRI | Environmental Systems Research Institute |
| FDOR | Florida Department of Revenue |
| FEMA | Federal Emergency Management Agency |
| FGDL | Florida Geographic Data Library |
| FIS | Flood Insurance Study |
| GIS | Geographic Information System |
| SLR | Sea Level Rise |
| SS | Storm Surge |
| SWEL | Still Water Elevation |
| USACE | United States Army Corps of Engineers |
| USGS | United States Geological Survey |

Abstract of Thesis Presented to the Graduate School
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Requirements for the Degree of Master of Arts in Urban and Regional Planning

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Chair: Paul Zwick
Cochair: Dawn Jourdan
Major: Urban and Regional Planning

In recent years, the damage caused by the hazards of flooding has increased in Florida. That increase may be the result of many factors but paramount among those factors is the continued development of urban land use within flood damage areas adjacent to the Florida coastline. Planners with their role as protectors of public health and safety must work with emergency managers to develop and implement disaster plans, mitigation plans and to assist with disaster response activities.

The objective of this thesis is to explore a methodology to understand the implication of hurricane hazard analysis for future land use planning in coastal areas of Florida in an attempt to answer the following questions. First, how do we best implement quantitative hurricane hazard models for future land use decision making in coastal Florida? Next, will a quantitative hurricane hazard model (HAZUS-MH) integrated with a future land use model be helpful for planning in coastal Florida? Finally, how do we quantify the effects of sea level rise using hurricane hazard models for future land use planning?

To answer these questions, an approach using storm surge (SS) models by HAZUS-MH that incorporate the presence or absence of a 1.5 meter (approximately 4.9

feet) sea level rise was developed and three projected scenarios are created for further analysis. Volusia County, Florida is selected as a case study.

The study results show a number of parcels that would be lost in certain land use categories. Tables are generated indicating the current assessed market value for parcels inundated by the scenarios. More stress caused by sea level rise according to the result of Alternative Scenario II shows, that the coastline would be retracted by losing large amounts of land. This research is not intended to specifically represent the inundation risk due to a probabilistic 100-year SS and sea level rise for any specific building or land parcel. However, this is a good indication for what may occur. The methodology could also be used as a supplementary for forecasting economic analysis and future land use planning or county resilience planning.

# CHAPTER 1
# INTRODUCTION

## Overview

One of the components related to the study of natural hazards is the recognition of land use vulnerability. With an understanding that certain land use categories are more vulnerable to natural hazards, planners could make better development decisions based on the knowledge of the future impacts caused by those hazards.  As a result, HAZUS-MH models are widely accepted and applied by disaster management researchers, and should be employed to a greater extent by urban and regional planners. With the application of the model, the long-term impacts of SS and sea level rise on infrastructures, property parcels, and other public and private resources could be visualized. And this could help local governments to think seriously about if the development in the certain coastal areas is valuable and the appropriate property tax increasing with the worry about the liability associated with those future limitations.

## Study Area

Volusia County is located on the northeast coast of the state of Florida (Figure 1-1). The County lies on the coastline by the Atlantic Ocean. Coastal areas are particularly vulnerable to several of nature hazards, such as hurricanes, tropical storms, flooding, and sea level rise, etc. These natural hazards would threaten the safety of coastal residents and would cause damages and the loss of both public and private properties. According to Year 2010 property tax parcel data provided by Florida Department of Revenue (FDOR) and updated in Florida Geographic Data Library (FGDL) in February 2011, Volusia County covers an area of 759,743 acres, among which, 172,734 acres are residential land.

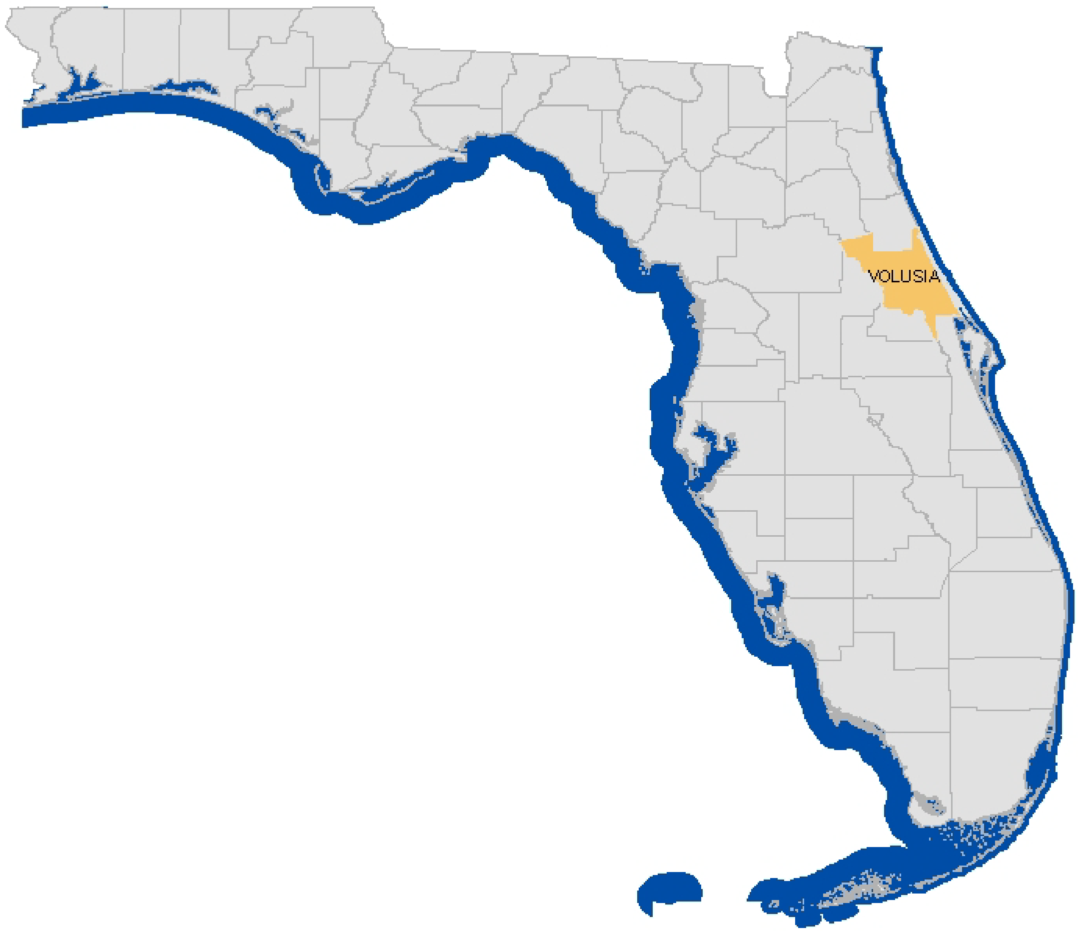


Figure 1-1. Study area location of Volusia County

According to the research of bureau of economic and business research at University of Florida (BEBR), Volusia County comprises approximately 3% of the state of Florida's population. Their medium projection of population growth in Volusia County increases every decade by 55,330 people (Table 1-1).

Table 1-1. Projections of population – Volusia vs. Florida

| **Year** | **Volusia** | **Florida** |
|---|---|---|
| | CENSUS | |
| 2000 | 443,343 | 15,982,824 |
| | PROJECTIONS(Medium) | |
| 2010 | 510,300 | 18,881,400 |
| 2020 | 565,600 | 21,417,500 |
| 2030 | 620,900 | 23,979,000 |

## Study Objectives

The purpose of this study is to examine the GIS-based hurricane hazard analysis model (HAZUS-MH), to assess if it is helpful for enhancing future land use planning in Florida coastal areas. The study includes three parts. First, a base loss will be estimated by incorporating 2000 Census data with a flood hazard model within HAZUS-MH. Second, since HAZUS-MH uses estimations based on Census 2000 data rather than actual land use property parcel data, 2010 land use parcel data will be introduced to see how different between the results generated by HAZUS–MH and the results obtained using parcel data . The last part is to incorporate the same flood hazard model with a 1.5 meter sea level rise and 2010 land use parcel data to see how much of the county is affected and to inspect the increased damage due to the sea level rise. Three projected scenarios are created as follows: (1) Base Scenario by HAZUS-MH with its default 2000 Census data, (2) Alternative Scenario I: Base scenario by HAZUS- MH and 2010 land use parcel data, (3) Alternative Scenario II: incorporates Alternative Scenario I with a 1.5 meter sea level rise.

# CHAPTER 2
# LITERATURE REVIEW

## HAZUS-MH Model

### Overview

The Hazards U.S. Multi- Hazard (HAZUS-MH) was developed by the Federal Emergency Management Agency (FEMA) with state-of-the-art geographic information systems (GIS) as its running platform in Spring 2004 (FEMA,2011). The application includes models of flood, hurricane (wind), and earthquake.

HAZUS-MH models produce loss estimates in planning for multiple hazards risk mitigation, emergency preparedness, response and recovery. The estimation methodology adopted in HAZUS-MH deals with a wide range of different types of losses.

The HAZUS-MH flood model is aimed at helping with decision-making in certain areas that are prone to flooding risk. It is a state-of-the-art analysis for identifying and quantifying risks by flood hazard and loss estimation. The analysis includes three levels. HAZUS-MH model Level 1 is based on default data provided with the software and the most updated default inventory data is based on Census 2000. To accomplish this level requires minimum technical knowledge other than knowing about basic analytical methods with GIS. The loss estimation through Level1 is due to depth of flooding. Level 2 is improved by inputting more relevant parameters which meet all the methodology used in the Level 1. Level 3, the most detailed data analysis, requires more advanced information and measurement of the flood. The methodology to finish the data acquisition might be newer and more accurate by experts and engineers who are required to put extensive effort into the process. Much more time is therefore needed to sum up and prove results compared to previous Level1 and Level 2 (FEMA, 2011).

The Major steps for Level 1 analysis in the HAZUS-MH flood model are described below.


Figure 2-1. Create study region

1. Define the study region with hazard type.

The hazards to be investigated are determined in this stage with no restriction on the amount of hazard types at a time. However, once the study region with certain hazard is built, no other hazard type can be added in. other than create another new region (Figure 2-1).

2. Input Inventory data

The HAZUS-MH flood model includes two types of flooding models, a coastal and a riverine model. Before inventory data is inputted, the type of the flood hazard is determined according to the characteristic of the study area.

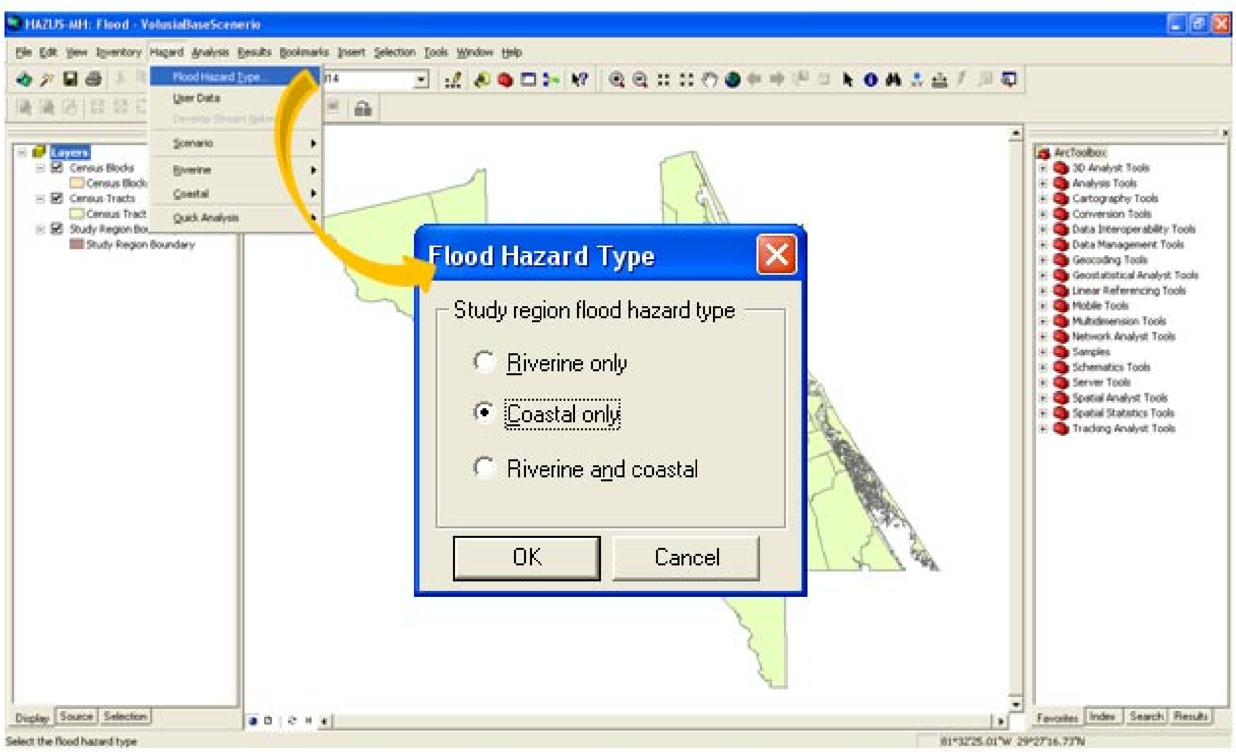


Figure 2-2. Define flood hazard type

The user data, in terms of the regional DEM data, is downloaded from the United States Geological Survey (USGS) web site.

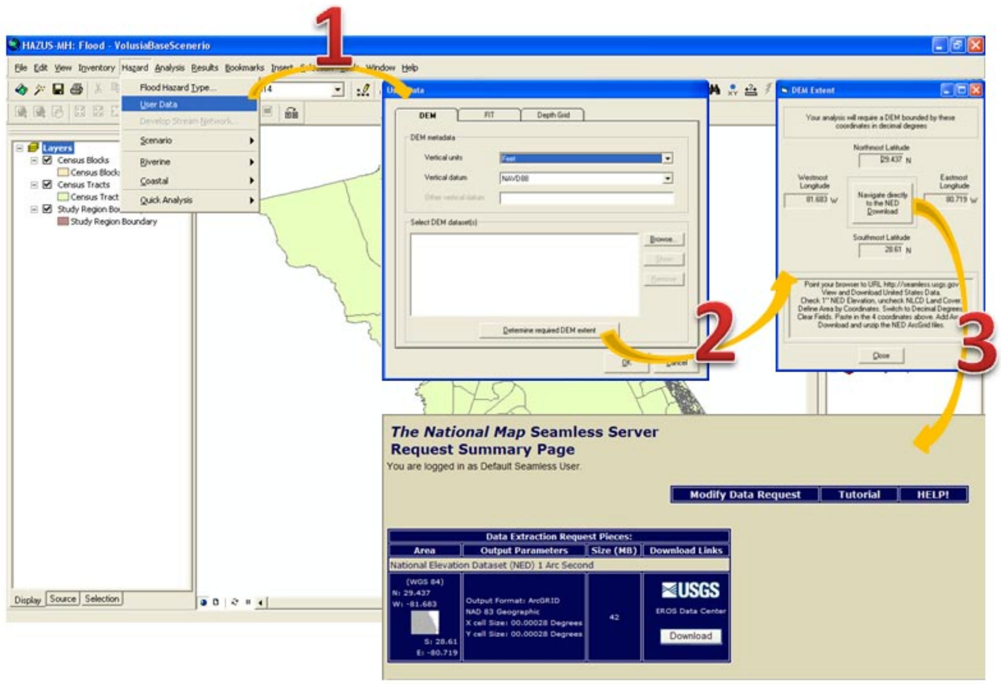


Figure 2-3. Steps in acquiring user's data

3. Damage estimations, which include direct and induced damage

4. Losses estimations, which include social and economic losses

(Source: Adapted from HAZUS-MH flood user manual)

**Coastal Flood Hazard Modeling**

Coastal flood hazards are calculated by HAZUS-MH and it requires the user to define certain information according to each specific county. The required inputs are listed below:

- Study region
- Shorelines
- Wave exposure
- Shore type
- 100-yr Flood Stillwater Elevation (SWEL)
- 100-yr wave set up which might be given in Flood Insurance Study Report (FIS).
- Coastal flood return period

For the rest of the data, the coastal model will default to the user's inputs.

(Source: Adapted from HAZUS-MH flood technical manual)

**Flood Insurance Study**

This FIS report is provided by FEMA with the aim of helping local and regional planners to further promote land use and floodplain development. According to the report for Volusia County, Florida, the 1-percent Annual Chance Stillwater elevation for the Atlantic Ocean is not revised, which is 6.9 feet using the North American Vertical Datum of 1988(NAVD88) as the referenced vertical datum. At the same time, “the 1-Percent Annual Chance Stillwater Elevations for the open area along the Atlantic Ocean were not modified to include the effects of wave setup” (FEMA, 2011) which indicates that wave setup was not a necessary input for the coastal flood model by HAZUS-MH for Volusia County.

## Depth-Damage Curves and Functions

Depth is usually the primary parameter when estimating the damages due to flood.

**Depth-Frequency Curve**

Depth-frequency curve represents the relationship between the depth of flooding and the annual chance of inundation greater than the depth. The methodology adopted in HAZUS to estimate the direct economic losses is based on this curve, compiled from a variety of sources including the Federal Insurance and Mitigation Administration (FIMA) “credibility weighted” depth-damage curves, and selected curves developed by the U.S. Army Corps of Engineers (USACE), and the USACE Institute for Water Resources (USACEIWR) (FEMA, 2011).

The frequency of flood hazard varies over time measuring the risk of it occurring is difficult to predict. Also, flood hazard represents only one type of sources of natural hazards. For example, the flood hazard may be that an area is inundated about once every 100 years by the risk of storm surge or it may be that an area is subject to flood depths ranging from 0.5 to 1.5 meters. Flood frequency curves define flood hazard by showing the relationship between depth of flooding and the annual chance of inundation greater than that depth of flooding in the particular year. (FEMA, 2011) (Titus, 2001)

**Depth-Damage Functions**

The methodology of the HAZUS-MH flood model for estimating direct physical damage, such as the repair cost, replacement cost etc. to the general building stock, is relatively straightforward and easy to understand and to apply in the models. Usually, for a given Census 2000 block, each occupancy type of the construction has an appropriate damage function assigned to it. For instance, functions may vary for a one-story building without basement and a one-story building with basement. Different inundation depths leading to different extents of flooding are used to determine the associated percentage damage of the buildings and constructions. Generally, this percentage damage is multiplied by the replacement value to produce an estimate of total dollar loss. Conceptually, a 1-10% damage is considered to be a slight loss, a 11-50% damage is considered to be moderate loss, and more than 50% damage is considered as substantial loss (FEMA, 2011) (Davis, 1985).

Detailed contents damage functions are applied within different cases all over the US by the USACE. For example in New Orleans District, a number of structures without basements were reviewed to form the exact functions for this area by two categories, which are one-story and two-story buildings. A 5 feet water depth indicates a substantial loss of its maximum to a one-story building, while it could be less for a two-story building at the water level of 5 feet. In this particular function, a 14 feet water depth results in the substantial loss of its maximum to a two-story building in that area(FEMA, 2011) (Davis, 1985).

For all the functions, due to limited claims data, it is assumed that all depth-damage curves developed by the USACE represent structures with no basement for Atlantic coastal area (FEMA, 2011).

In Willett and Kiefer's research, (Willet, 1996) hypothetical damages were obtained for several levels of flooding depth, which are 0 to 1 feet, 1 to 4 feet, 4 to 8 feet, 8 to 12 feet, and above 12 feet. A series of linear models were tested and a structure damage equation was generated from the models to estimate the loss percentage of the structures. The equation could be applied to buildings with and without basements. The expression for building with basement is simplified as: % structure damage $=0.72 \cdot (1 - e^{-0.1332 \cdot depth} \cdot e^{-0.0983})$. And the expression for buildings without basement s is simplified as: % structure damage $=0.72 \cdot (1 - e^{-0.1332 \cdot depth})$.

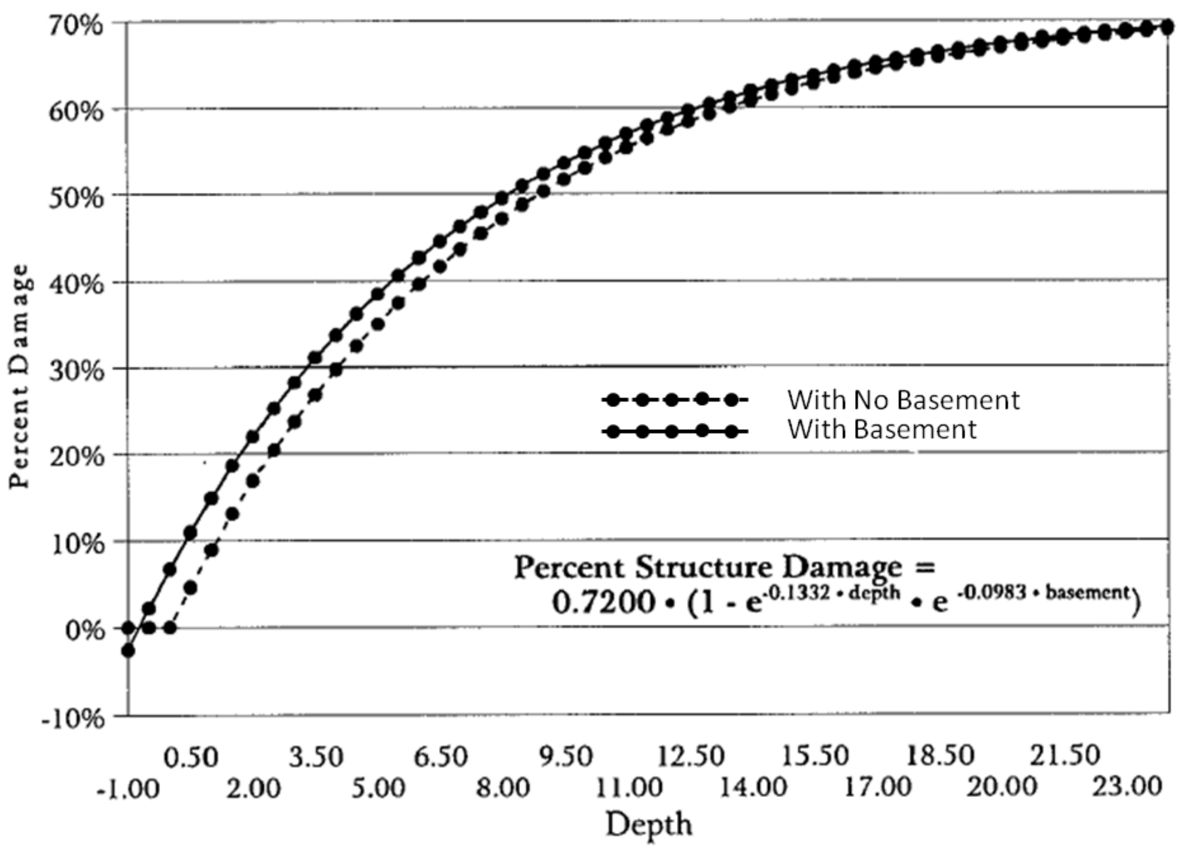


Figure 2-4. General model of structure depth-damage function.(Willett, 1996)

Figure 2-4 shows the plotted results of damage-functions of both with basement and with no basement. The damage increased fast when inundation depth was below 4 feet for both conditions. The percentages of damages were gradually level off at the inundation depth around 12 feet for both situations.

**The Definition of Vulnerability**

Climate Change 2007, the fourth assessment report from Intergovernmental Panel on Climate Change has noted that “The term ‘vulnerability’ may therefore refer to the vulnerable system itself”(IPCC, 2007) (Matisziw, 2011). To be more specific, “Disaster proneness and insufficient capability” (Pinkowaski, 2008,) are two main concerns for researchers and scholars to investigate in for the vulnerability caused by hurricane. The former is examined by the physical condition of an area according to its topography (Simpson, 1998). For instance, coastal cities are more sensitive than inland cities which are why some scholars note that most of Florida’s coastal residents are prone to disaster caused by hurricane (Pinkowski, 2008). The latter is of more concerned to geographers, ecologists, economists, humanist as well as urban planners where the post-effects of hurricanes which exceed the capability of an area to adapt itself to the situation (Puszkin, et al., 2006) (McLeod, et al., 2010).

Seven criteria used to define main vulnerabilities are(IPCC, 2007):

- magnitude of impacts,
- timing of impacts,
- persistence and reversibility of impacts,
- likelihood (estimates of uncertainty) of impacts and vulnerabilities, and confidence in those estimates,
- potential for adaptation,

- distributional aspects of impacts and vulnerabilities,
- Importance of the system(s) at risk.

## The Case Study with GIS Analysis in Florida's Coastal Area

In Murley , Chevlin and Esnard 's research, (Murley, 2004) three coastal Florida counties, Martin, St. Lucie and Indian River are selected as the study area. The researcher mapped old and new geographic delineations for the study area. Also the amount of land and number of parcels were compared, aiming to find out the difference between tax parcels and land acres and the relationship between the existing acreage of land parcels and the number of improved real estate assets on a certain parcel of land.

## Theories and Research on Sea Level Rise

Sea level rise not only could make an area of coastal land inundated and increase coastal erosion, but it could also makes events such as tsunamis, storm surges and other marine hazards more likely to occur, causing flooding and saltwater intrusion which could result in greater loss. (Oliver, 2010) (Darwin, 2001) Sea level rise issues threaten most of the U.S. coast areas. The entire Atlantic Coast is subsiding. According to Vivien's research, an area of 89.0% of the Atlantic Coast region are affected by varies of rates of sea level rise exceeding 2 mm/yr (Vivien, 1991). Nearly half of the Gulf Coast is eroding, with 40% retreating at rates greater than 2 mm/yr. The Gulf Coast west of the Florida Panhandle displays the highest rates of relative sea level rise in the U.S. Sea level trends over the period 1931-1988 had an average value of 8.1 mm/yr (Cushman, et al., 1991) (Nicholls,1999). An estimation of a global sea level rise that provided by the International Panel on Climate Change (IPCC) was between 0.6 and 2 feet (0.18 to 0.59 meters) in the next century (IPCC, 2007). The climate change should be the one of the main reasons that caused sea level rise.

The effects of the global sea level rise in the coastal areas will be spatially non-uniform. The impacts of this accelerated sea level rise (SLR) are replete with gloom which include shoreline retreat, mainland inundation, saltwater intrusion, inland population density increasing, shortage of fresh water resources and agricultural lands (McLeod, 2010). Certain areas of coastal zones will be permanently inundated to a depth equivalent to the vertical rise in sea level. Meanwhile, episodic flooding from storm surges could penetrate much further inland. Beaches and coastal structures are threatened without doubt. Increasing salinization caused by sea level rise could pollute drinking water supplies and be extremely harmful to crops and soil of agriculture land. (Cushman, et al., 1991)

# CHAPTER 3
# DATA AND METHODOLOGY

## Data

### Census 2000

Census 2000 represents the 22nd US census by the US Census Bureau conducted in April 1st, 2000 (http://en.wikipedia.org/wiki/Census_2000). A Census block is the smallest geographic unit used by the US Census Bureau to generate all housing information within a region. This suggests the data might be the most complete at the time but is an average value. HAZUS-MH has adopted Census 2000 as the basis inventory data for hazards analysis.

### Property Tax Parcel Data

The parcel data shapefile needed for analysis are retrieved from the Florida Geographic Digital Library (FGDL) which is Year 2010 tax parcel data updated in March 2010. The parcel data is used for Volusia County, Florida for the case study.

All the tax parcel data have the following horizontal coordinate system and no projections are needed. The source descriptions are listed below.

- Projected coordinate system name: Albers Conical Equal Area
- Geographic coordinate system name: GCS_North_American_1983_HARN
- Linear Units: meter

### DEM (Digital Elevation Model)

The U.S. Geological Survey (USGS) produces a digital elevation model (DEM) from terrain data. DEM represents only the height information. The grid cells of a DEM raster data are equal sized. HAZUS-MH uses the 1-degree DEM from USGS with the source descriptions listed below.

- Coordinate system name: Albers Conical Equal Area

- Datum: D_North_American_1983
- Angular Units: Degree

The HAZUS-MH model developed for this thesis is implemented in Arc View 9.3.1, the geographic information systems (GIS) software package released by the Environmental Systems Research Institute (ESRI).

## Methodology Overview

The purpose of this study was to examine the GIS-based hurricane hazard analysis model (HAZUS-MH), and to assess if it is helpful for enhancing future land use planning in Florida coastal areas.

The study included three parts. First, a base loss would be estimated by incorporating Census 2000 data with coastal flood hazard model. Second, since HAZUS-MH has its estimation on Census 2000 data rather than actual land use property parcel data, Year 2010 property land use parcel data would be introduced to examine how close the results generated by HAZUS-MH were to those obtained with parcel data . The last part was to incorporate the same storm surge (SS) model with a 1.5 meter sea level rise (SLR) and Year 2010 land use parcel data to see how much of the county was influenced and understand the increased damage due to the sea level rise.

Three projected scenarios were created as follows (1) The Base Scenario by HAZUS-MH with its default Census 2000 Data, (2) Alternative Scenario I: Base scenario by HAZUS- MH and Year 2010 Land use parcel data, (3) Alternative Scenario II: incorporate Alternative Scenario I with 1.5 meter SLR. Figure 3-1 is a diagram of the research methodology used in this study that would be discussed in detail in the following sections of this chapter.

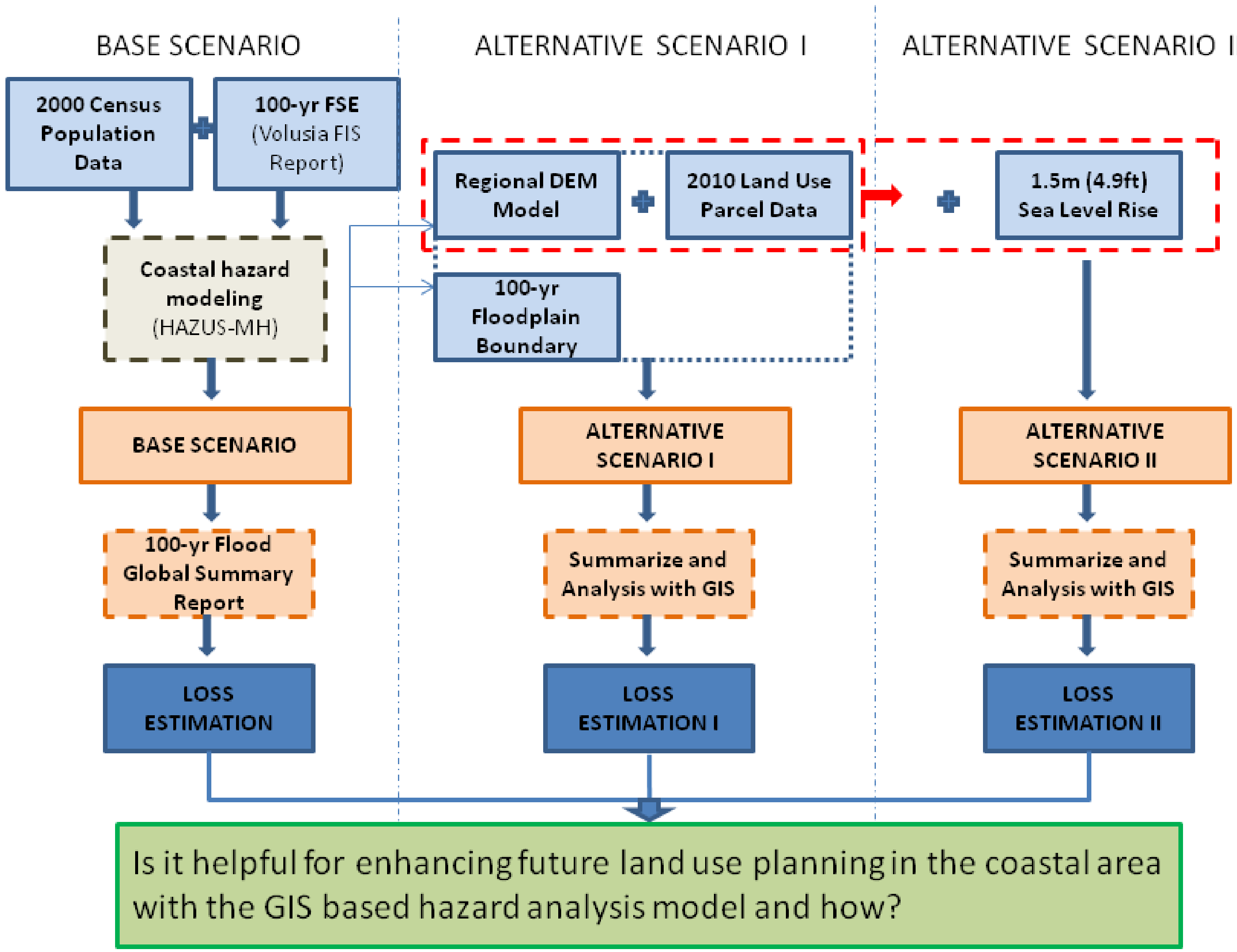


Figure 3-1. Diagram of study methodology.

## Base Scenario

The base scenario is for storm surge hazard of Volusia County. It was generated by the coastal flood model with HAZUS-MH. The objective of the base disaster scenario aimed not only to examine the accuracy of the default database in HAZUS-MH model according to the summary report created during the modeling process, but also to obtain the 100-yr floodplain boundary as well as the related Digital Elevation Model for Volusia County. This study estimated the potential losses under a presumed ideal condition that no sea level rise occurred from the 100-yrs returned storm surge.

The modeling processes to delineate floodplain by HAZUS-MH are included in the Figure 3-2 below, as an overview.

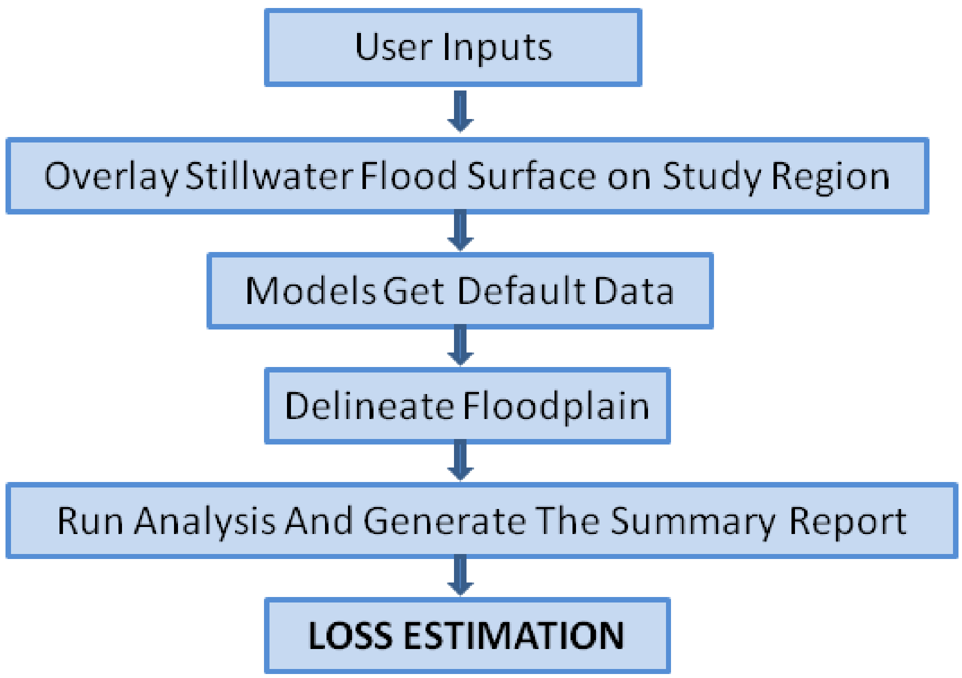


Figure 3-2. Overview of HAZUS-MH coastal flood hazard modeling process (Source Adapted from HAZUS-MH flood Technical manual)

Certain GIS steps were taken as described below.

**Create a new region.** In HAZUS-MH, a study region was created for Volusia County, Florida with a specified hazard type of flood, identified state and county names. The HAZUS-MH used its default database to generate the analysis (Figure 3-3).

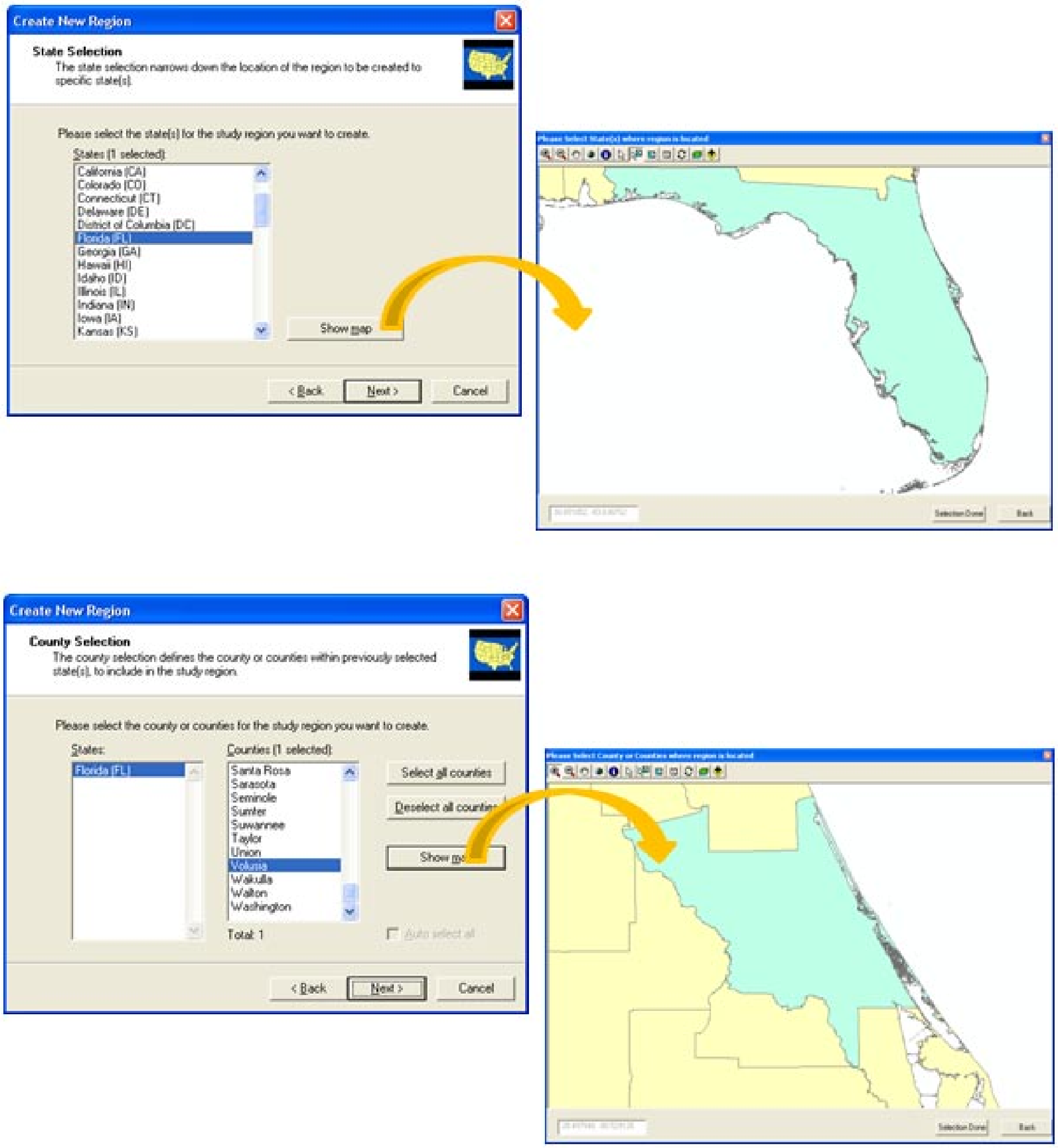


Figure 3-3. Create Volusia County study region

**Defining the flood hazard.**

- Opened the study region in HAZUS-MH, chose flood hazard type on the Hazard menu by coastal only.

- Obtained data in the study region. The regional DEM data was downloaded from USGS web site using the NAVD88 vertical datum and the DEM file should be feet for USGS NED data.

- Created new scenario. The shoreline for Volusia County was selected for analysis using a default national shoreline which was delineated by county in HAZUS-MH. The parameters were full wave exposure and sandy beach, large dunes.

- According to the FIS Report for Volusia County, the still water elevation level (SWEL) was 6.9 feet using NAVD88 as the reference vertical datum (Figure 3-4). The Scenario report was named Base Scenario, which would be seen in the summary report as appendix A.

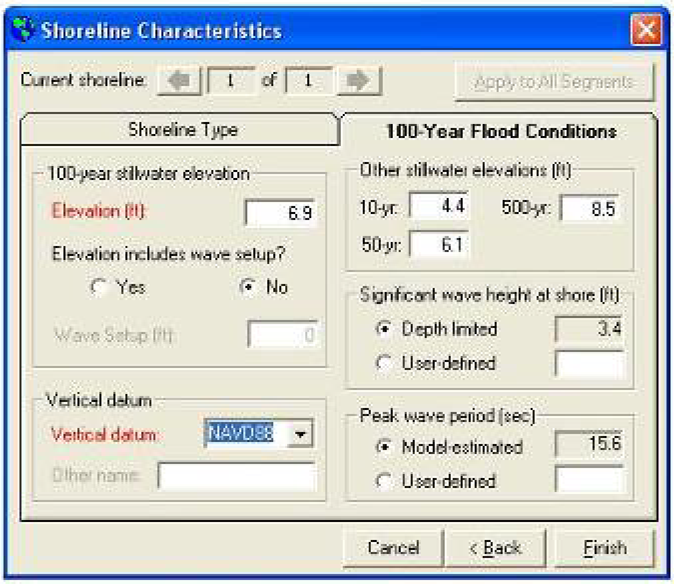


Figure 3-4. Shoreline characteristic inputs

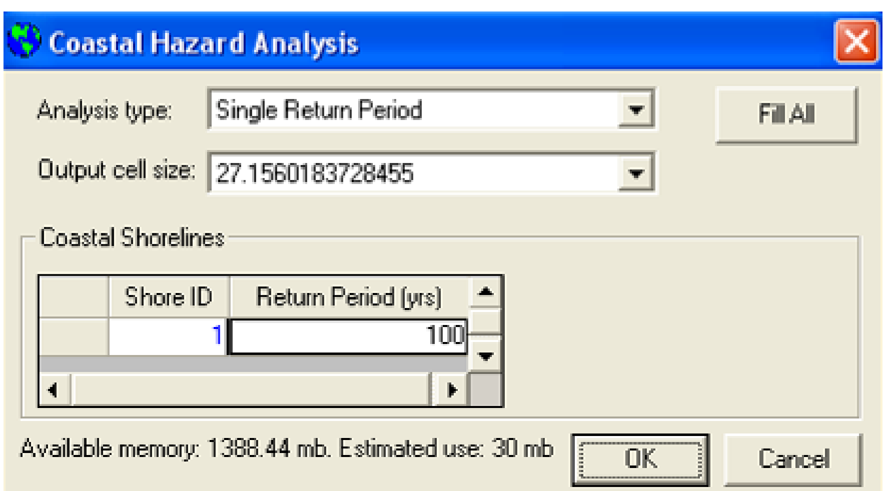


Figure 3-5. Hazard model analysis type and cell size

**Delineating floodplain.** Ran coastal hazard analysis with 100yrs single return period type with default output cell size 27.15 (Figure 3-5).

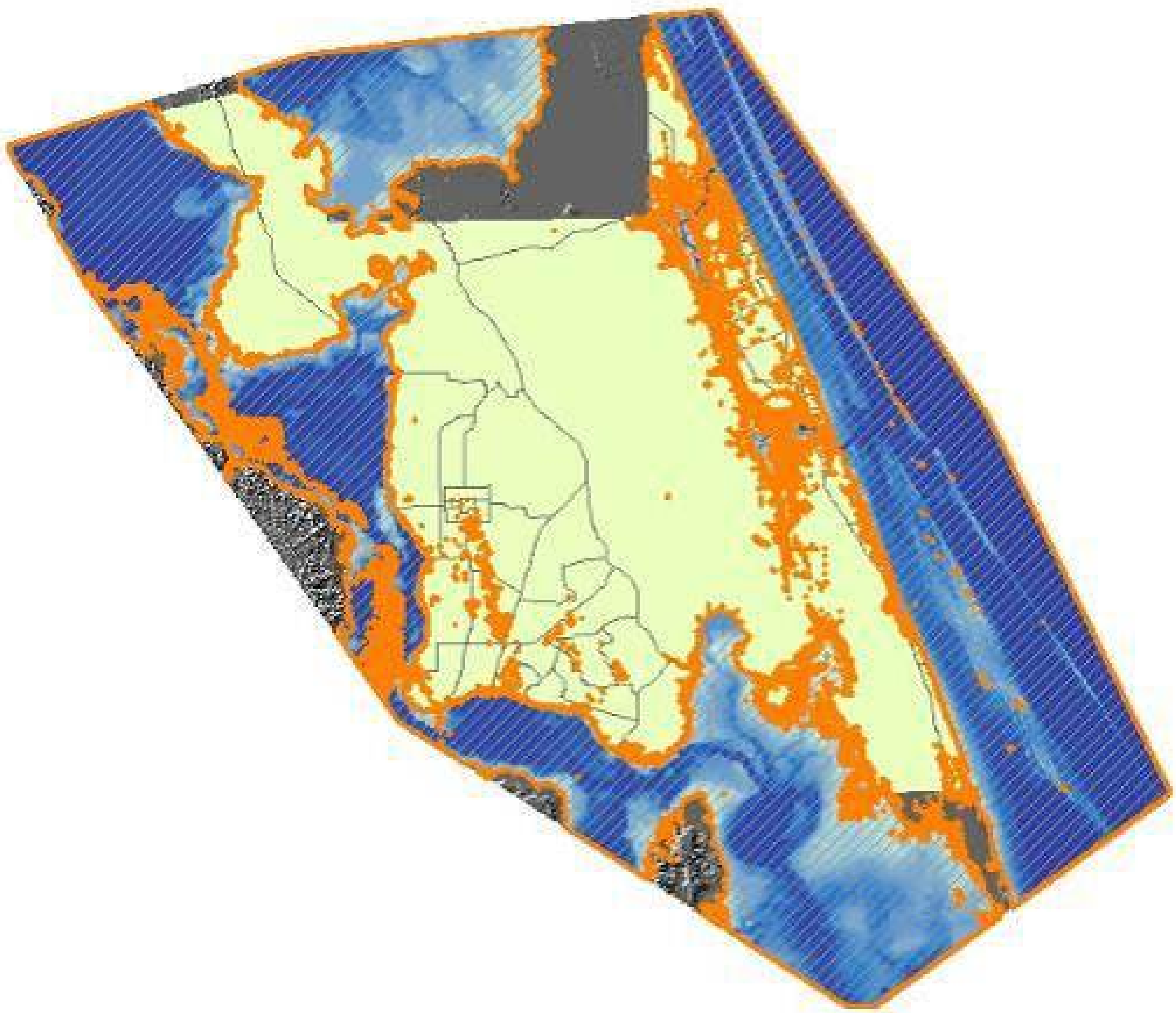

Figure 3-6. The delineated floodplain by coastal flood hazard modeling

Volusia County Floodplain: Intersected the Volusia County boundary polygon and the floodplain boundary polygon directly generated by HAZUS-MH (Figure 3-6).

The flooding region was an overall calculation with all varied criteria and exceeded the boundary of Volusia County (Figure 3-7).

Result report. HAZUS - MH generated a global summary report for the estimated losses and quick assessment Report. See Appendix A and Appendix B.

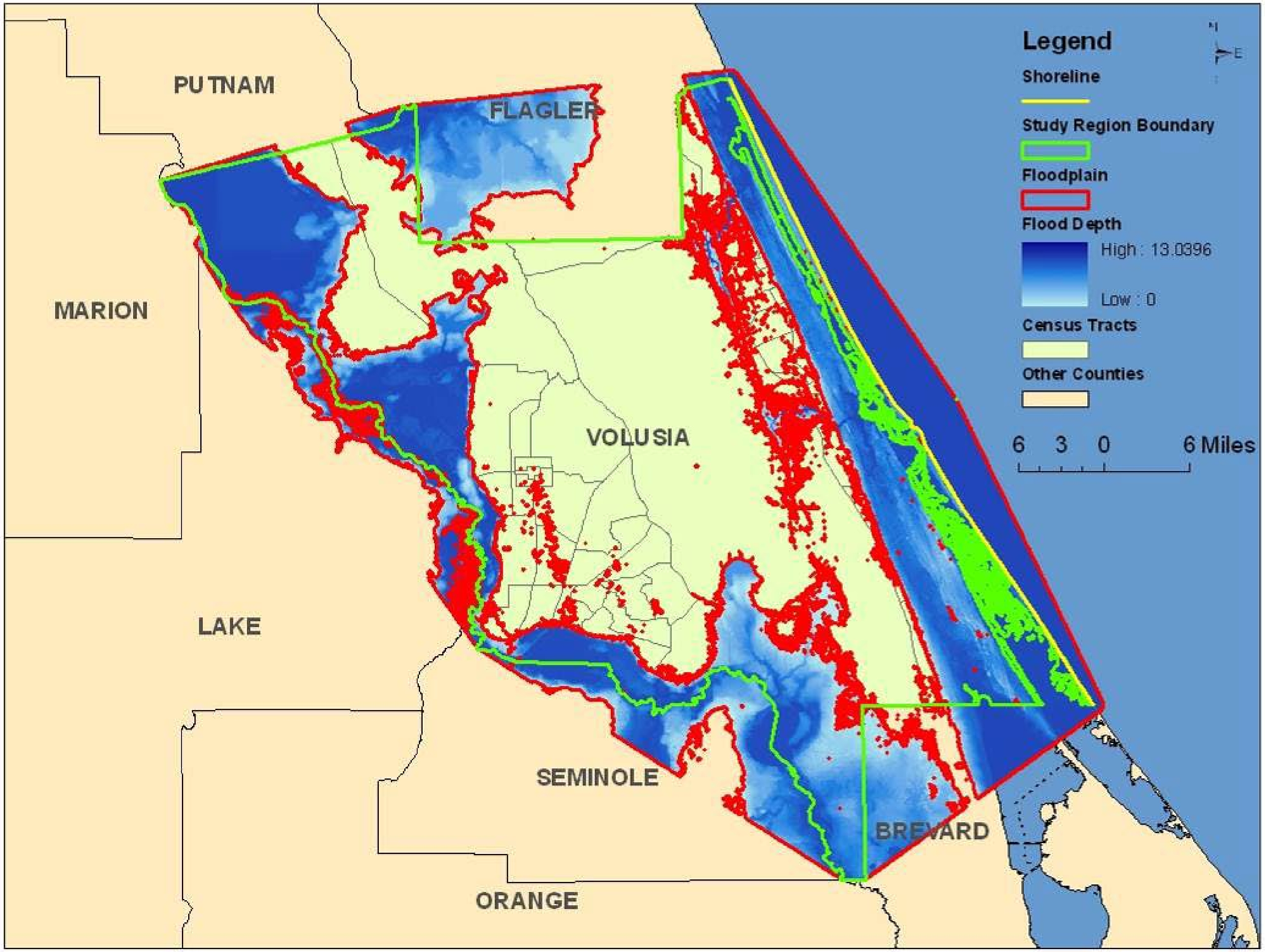


Figure 3-7. Base Scenario of 100-yr storm surge hazard, Volusia County, Florida

## Alternative Scenario I

The Alternative Scenario I, which was a storm surge only scenario, was originally from the Base Scenario incorporating Year 2010 land use tax parcel data, obtained from Florida Geographic Digital Library (FGDL). HAZUS-MH estimated the loss by Census block with data from year 2000 which was obtained by averaging the percentage of the block filled by water. The methodology adopted here was to create a storm surge (SS) polygon, which was based on the parcel polygon of Volusia County. In the polygon, a depth was given for each grid raster, followed by calculating the specific flooded area for each parcel of the county. The DEM model that HAZUS-MH provided for this stage was roughly at a cell size of 30 meters. In order to get more accurate result, the raster would need to be converted to a 5-meter cell size for further analysis.

Figure 3-8 was the flowchart for the methodology of the case study of Volusia County, Florida.

The main steps taken to quantify the loss of the SS hazard by land use were explained in the list below.

### Step One

- “Clip” Volusia 2010 parcel data by floodplain boundary from the Base Scenario
- “Add a Field” in the attribute table, for flooded area
- “Export Data” as the primary parcel data and get a second copy. One is for convert feature to raster in step two; the other is for projection in step three. The order of step 2 and step 3 can be switched.

### Step Two

Bring up a blank ArcMap map document with the DEM raster data, which was an inundation depth based on 100-yr single return period flooding chance for Volusia County. It could be directly used for Alternative Scenario I. Whenever doing the raster analysis, “Environment Setting” is very important. Here, the 5-cell-size DEM raster is applied for both “Extent” in the “General Setting” and the “Cell Size” in the “Raster Analysis”.

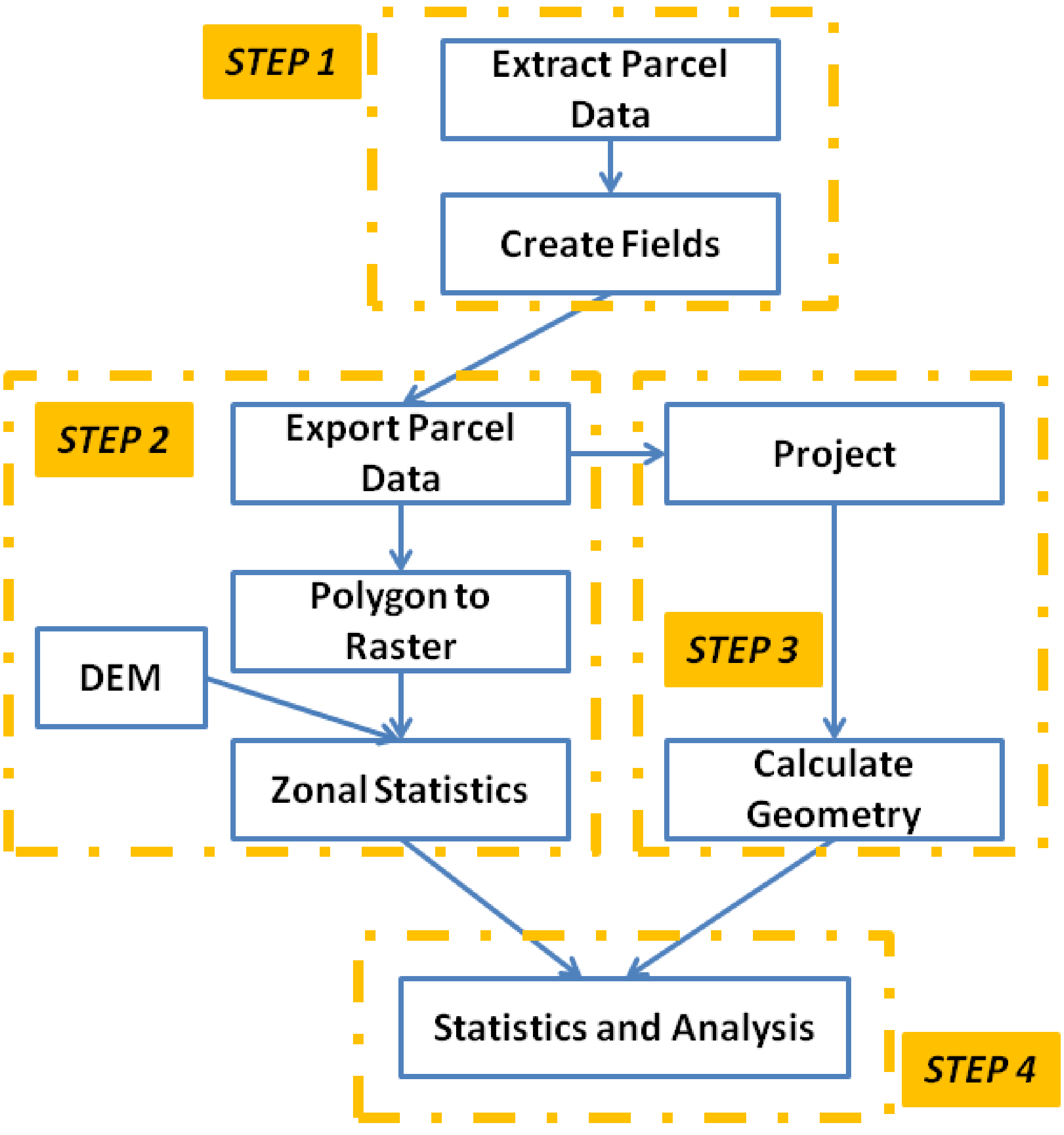


Figure 3-8. Flowcharts for steps of GIS methodology

- Spatial Analysis for Regional DEM raster data with Spatial Analysis Tools- “Times”, to change the cell size from roughly 30 to 5
- “Single Output Map Algebra” with the equation, INT ( rpd100_c_5 * 12 ), to get the DEM model by inch.

- Extract data from the primary parcel data for water body and data with no value, and use the rest for further analysis.

- Convert the newer parcel data with “Polygon to Raster”

- Add a field for user defined ID, which in field calculator expression is “FID + 1” with the type of long integer.

- “Zonal Statistics By Table” for the raster attribute data

**Step Three**

- Project the primary parcel data copy from step one.
- Calculate geometry for the field of flooded area in the attribute table by US acres
- Join the output zonal stats data with parcel data by value and user defined ID.

**Step Four**

Summarize tables, statistic analysis and further analysis. Detailed analysis and description is shown in the Chapter 4.

## Alternative Scenario II

The Alternative Scenario II is a storm surge simulated with 1.5m sea level rise scenario. Sea level rise is one of the natural hazards that will cause tremendous loss of land along the coastline. The phenomenon of global sea level rise is caused by many factors, such as global warming, upper ocean thermal expansion, etc. Although the research results by different researchers and scientists may vary, sea level rise is an unquestionable fact over the past century. Since the late 19th century, sea level has risen more than 10 centimeters (IPCC, 2007). Sea level rise will have severe impacts.

The previous two scenarios are ideally projected without the variable of sea level rise. In the third scenario, 1.5-meter (approximately 4.9 feet) sea level rise is taken into consideration.

One effective way to achieve the goal of bringing the SS analysis on top of the projected sea level is to subtract a certain height or depth from the DEM model produced by HAZUS-MH, which was used in the former two scenarios. The methodology to maintain the loss estimation is the same as the one used in Alternative Scenario I.

# CHAPTER 4
# FINDINGS AND RESULTS

## Base Scenario

As shown in table of building exposure by occupancy in Appendix A, the global summary report produced by HAZUS-MH indicated that: there are about 2 million buildings affected by the hazard with a loss of value in 2006 dollars of 34 thousand million. The majority of the damaged buildings were residential ones accounting for 76.3% of the total loss, while commercial building damage was one fifth of that for the residential ones.

A comparison building loss by different land use types in Appendix A, shows that the content of the building losses were weighted differently by land use type. For residential uses the building losses were weighted more than the loss for content. Conversely for all other uses the building losses were weighted lower than the content loss.

## Alternative Scenarios

Both the alternative scenarios were applied with Year 2010 tax parcel data. The latest inventory data for HAZUS-MH is for Year 2000.Cencus data. Census 2010 data has been recently released. Once it has been updated for HAZUS-MH, the process for Base Scenario could be run again and may produce more proximal results.

The parcel data is categorized by the description accomplished with a certain land use code according to the code from the Florida Department of Revenue. For instance, land use codes from number 000 to 009 are residential, 010 to 039 are commercial, 040 to 049 are industrial, 50 to 69 are agricultural, 070 to 079 are institutional, and 080 to 089 are governmental (FDOR, 2011).

**Define Building Loss**

According to the depth-damage function by Kiefer and Willett, (Willett, 1996) the equation could be written in two expressions. The first one is without basement. The second one is with a basement.

% structure damage = $0.72 \cdot (1 - e^{-0.1332 \cdot depth})$

% structure damage = $0.72 \cdot (1 - e^{-0.1332 \cdot depth} \cdot e^{-0.0983})$

Table 4-1. Parameters for depth-damage equitation for estimating building losses

| Depth of Inundated (ft) | Structure damage (%) | |
|---|---|---|
| | Without basement | With basement |
| [0, 1] | 4.6 | 11 |
| [1, 4] | 20 | 25 |
| [4, 8] | 39 | 42 |
| [8, 12] | 53 | 55 |
| [12, 20] | 63 | 64 |

In both of the alternative scenarios, structures assumed without basement had lower loss estimation. The assumptions were made according to the main structure situations in Florida coastal areas where there were seldom basement for building constructions.

**Comparison: Alternative Scenario I - Base Scenario**

As shown in Table 4-2, a total of 72403.9 acres of land was analyzed in Alternative Scenario I. A proportion of 10% Volusia was under water by different depths. A total loss of direct building damage for residential uses was around $2.76 billion dollars. The loss estimation was a little lower than the result by HAZUS-MH with Census 2000 data, which was $3.28 billion dollars (Figure 4-2). However, the commercial use building loss by Year 2010 parcel data was about $3.1 billion dollars which accounted for half of the building loss of $5.95 billion dollars by HAZUS. Similarly, a loss of $98 million dollars for industry occurred in Alternative Scenario I compared with a loss of $171 million dollars, for industry structure damage loss from HAZUS-MH default data inventory. A total loss for Alternative Scenario I of $2.76 billion dollars occurred compared to the total loss of $3.99 billion dollars from the Base Scenario (Figure 4-2). The lower loss in the Alternative Scenario I may due to the changes during the10 years' time frame or an error when taking different depth- damage function into the calculation.

Table 4-2. Total building damage due to 100-yr SS by year 2010 parcel, Volusia, Florida (thousand dollars)

| Major use | Sum_Blgs | Inundated area | Dollar loss | Percent |
|---|---|---|---|---|
| Agriculture | 186 | 4733.4 | $8,595 | 0.24% |
| Commercial | 5771 | 5199.2 | $309,982 | 8.65% |
| Entertainment | 824 | 2128.7 | $61,471 | 1.72% |
| Government | 1681 | 14266.1 | $194,549 | 5.43% |
| Industry | 1839 | 1696.9 | $98,305 | 2.74% |
| Institutional | 1052 | 1558.4 | $128,200 | 3.58% |
| Miscellaneous | 357 | 1315.0 | $15,705 | 0.44% |
| Not zoned agriculture | 99 | 2566.5 | $1,949 | 0.05% |
| Residential | 98348 | 38939.8 | $2,763,893 | 77.15% |
| Total | 110157 | 72403.9 | $3,582,654 | 100.00% |

As a result, a lower than average estimation of loss was obtained in the analysis for the 100-yr storm surge with Year 2010 parcel data for Volusia County, except for the loss estimation for residential building loss. Based on the same consideration, the result from Alternative Scenario II, which took sea level rise risk into consideration, could also be a lower estimation as well.

**Comparison: Alternative Scenario I - Alternative Scenario II**

With 1.5m sea level rise (Table 4-3), an additional area of 229,551 acres would be under water and additional $1.52 billion dollars of real property. Under a conservative estimation, a 1.5m sea level rise could cause 30% more of Volusia County to be under water. Of the inundated land, 4% would be residential uses and 24% would be agricultural uses. The additional 4% loss of residential land would account for more than

15% of all residential area in Volusia County, creating a short-term housing crisis and a need for permanent housing relocation in the long-term.

Table 4-3. Total Building damage due to 100-yr SS and 1.5m SLR by 2010 Parcel, Volusia, Florida (thousand dollars)

| Major use | Sum_Blgs | Inundated area | Dollar loss | Percent |
|---|---|---|---|---|
| Agriculture | 435 | 184619.5 | $27,679 | 0.50% |
| Commercial | 6667 | 6748.1 | $442,565 | 7.988% |
| Entertainment | 881 | 3013.8 | $82,808 | 1.49% |
| Government | 2126 | 23839.3 | $333,271 | 6.02% |
| Industry | 2012 | 2271.8 | $134,161 | 2.42% |
| Institutional | 1351 | 2647.2 | $192,635 | 3.48% |
| Miscellaneous | 388 | 2745.4 | $22,163 | 0.40% |
| Not zoned agriculture | 230 | 9294.4 | $6,958 | 0.13% |
| Residential | 125306 | 66775.4 | $4,298,139 | 77.58% |
| Total | 139396 | 301954.9 | $5,097,915 | 100.00% |

A set of data points for main land use types were selected from Table 4-8 to Table 4-11 at the end of this chapter. The summarizations of the data are represented in Table 4-4 to Table4-7. An analysis for the relationship between the losses of building value, the land use type and inundation depth was developed.

Figure 4-1 shows the inundated area of Volusia County would be by land use type if the 0.01 chance of flooding had happened. Figure 4-2 shows the inundated area of Volusia County would be by land use type if both the coastal flood hazard and the sea level rise threat were considered. With the consideration of a 1.5m SLR, much more residential and agriculture land would be under water. With the SLR, the county would lose most of its land, and the coastline would significantly move inland.

Comparing the inundation maps in Figure 4-3 and Figure 4-4, there is only an area of central land would remain above the water including a certain area of existing water bodies, such as rivers, lakes, and wetlands. The more direct loss from sea level rise could be visualized through the comparison.

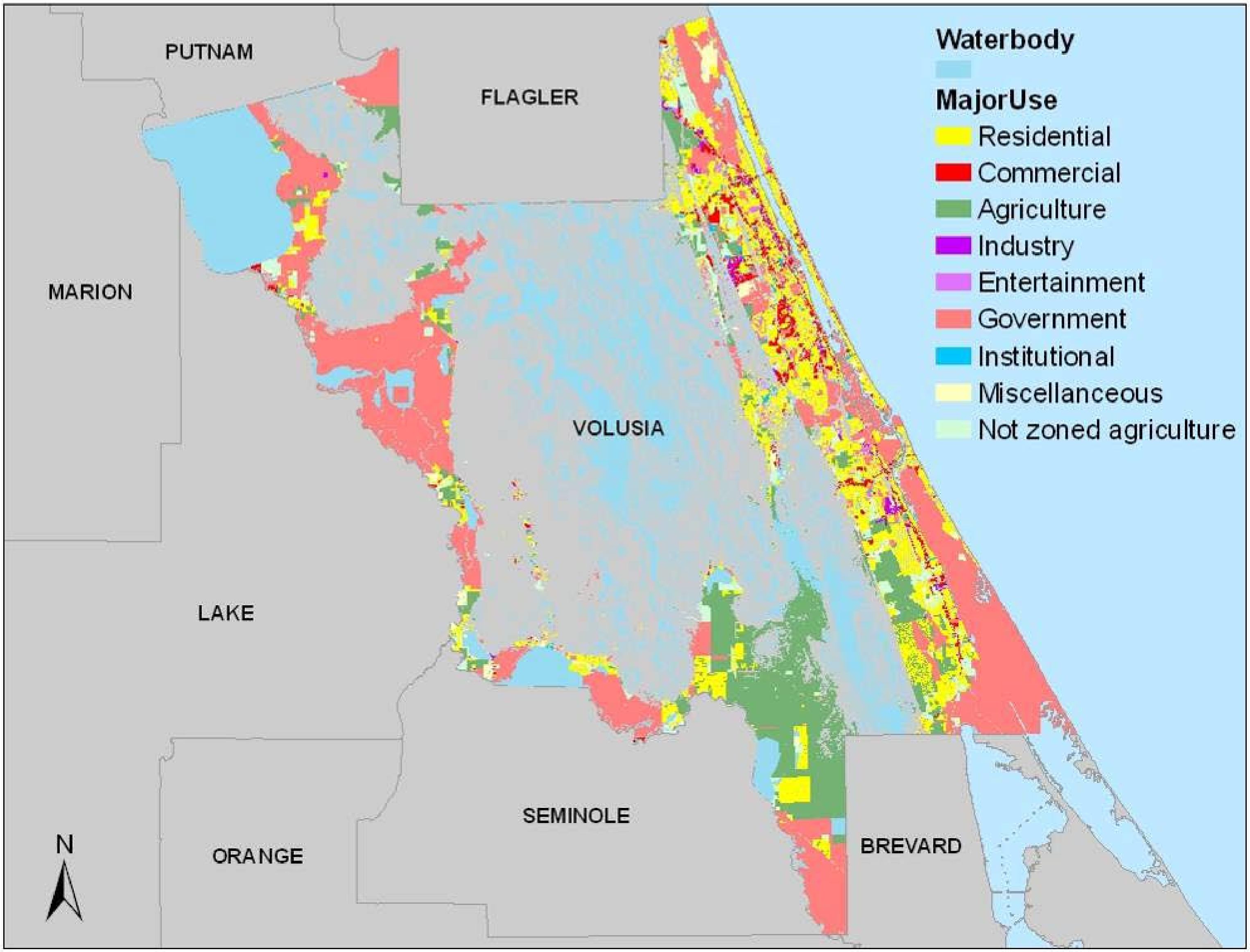


Figure 4-1. Land use map for Alternative Scenario I of SS hazard, Volusia, Florida

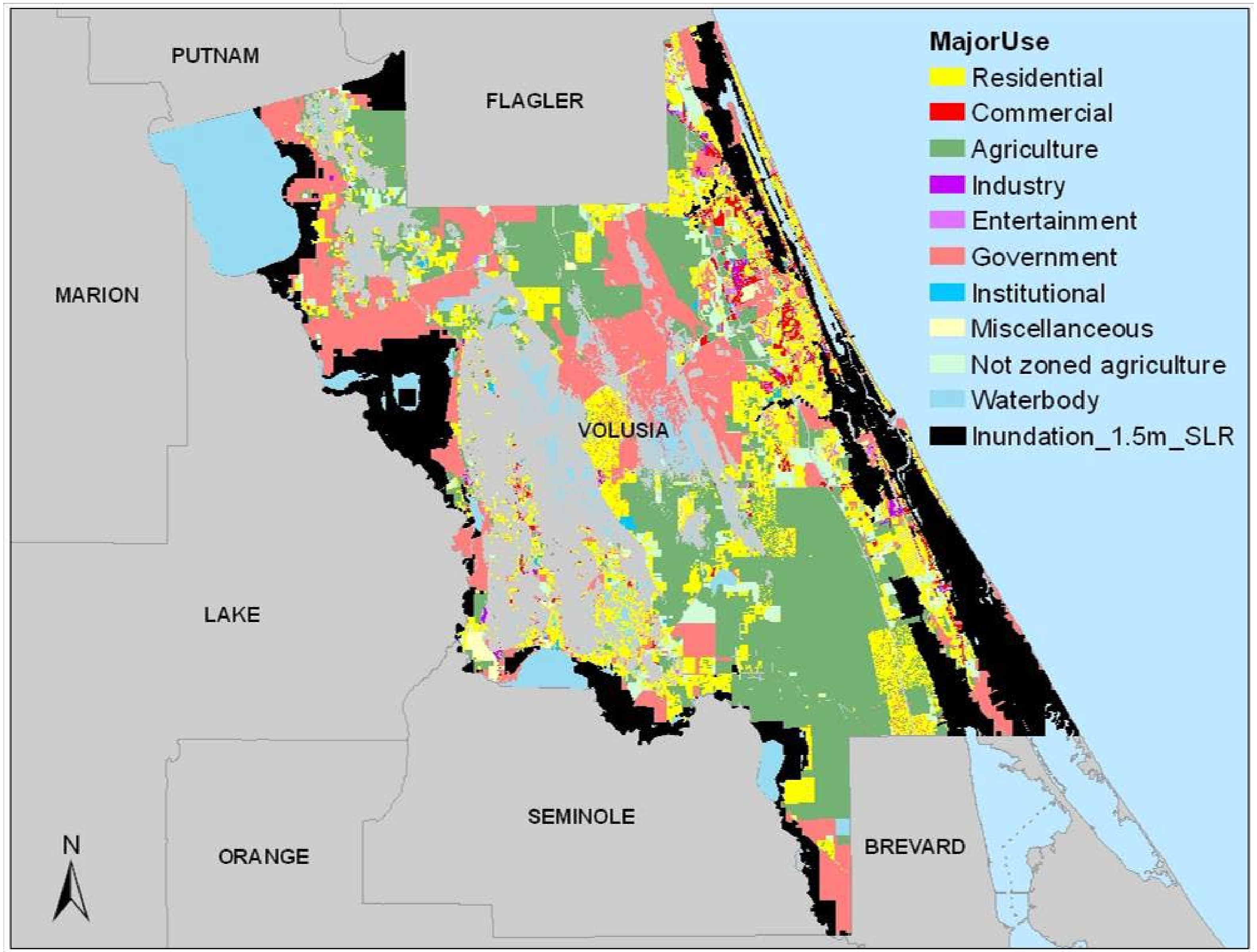


Figure 4-2. Land Use Map for Alternative Scenario II of SS and a 1.5M SLR hazard, Volusia, Florida

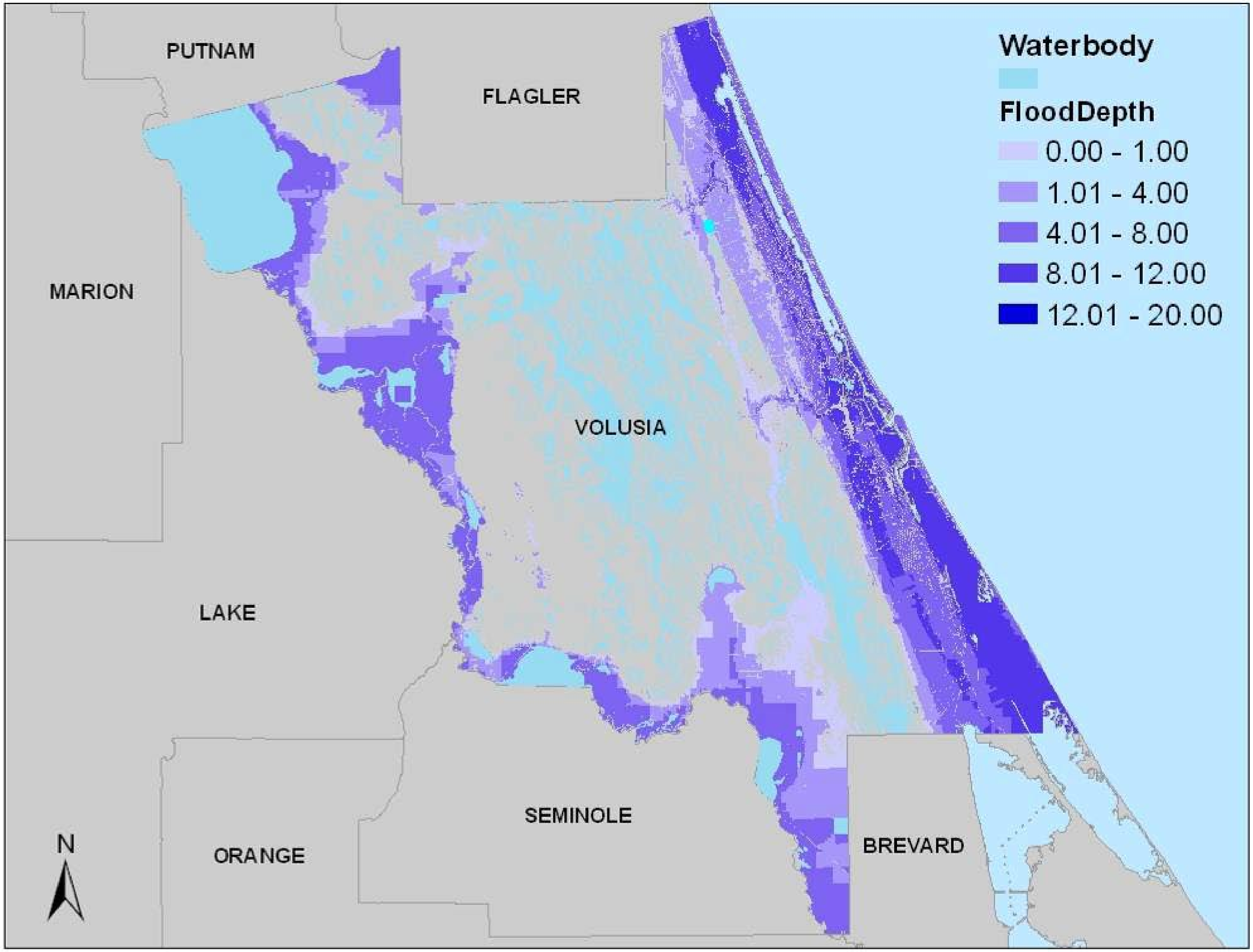


Figure 4-3. Inundation depth map for Alternative Scenario I of SS hazard, Volusia, Florida

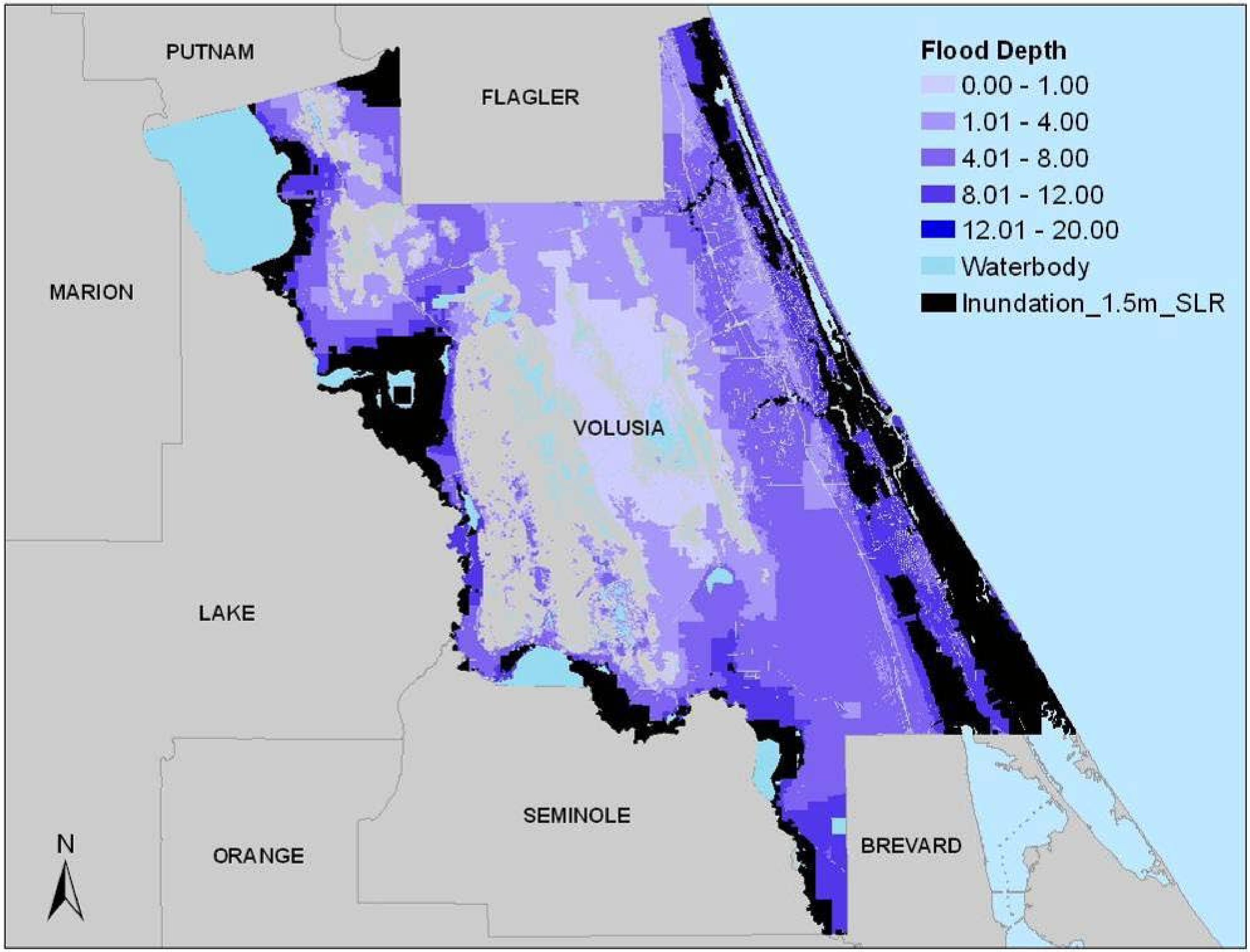


Figure 4-4. Inundation depth map for Alternative Scenario II of 100-yr SS and a 1.5m SLR hazard, Volusia, Florida

Figure 4-5 and Figure 4-6 show the pie charts for total percentage losses with and without sea level rise. The percentage loss of each land use type changed very little after taking sea level rise into consideration. This indicated that a 1.5m sea level rise proportionally induced additional loss for each land use type, while the difference would only be the total loss from the hazards. It was apparent that more damage was induced with sea level rise.

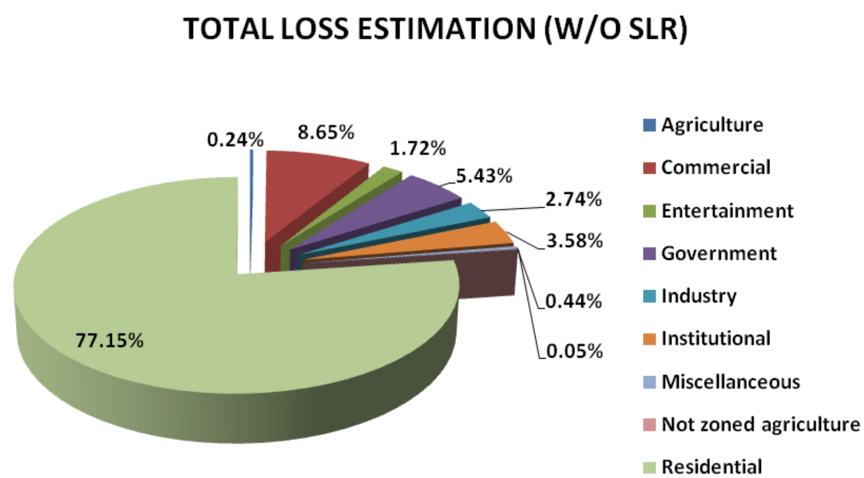


Figure 4-5. Pie Charts for total percentage losses of building damage by 100-yr SS, Volusia, Florida

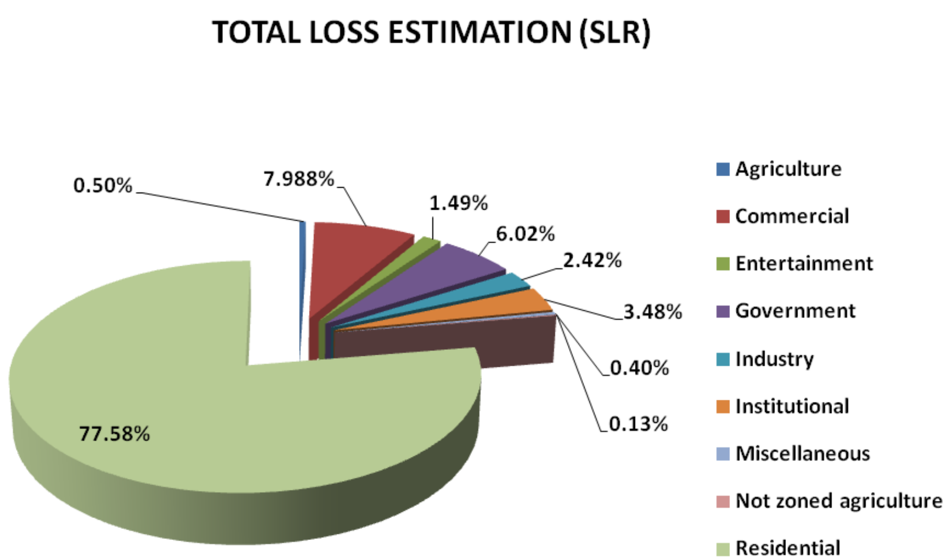


Figure 4-6. Pie Charts for total percentage losses of building damage by 100-yr SS and 1.5m SLR, Volusia, Florida

**Alternative scenario I: 100-yr storm surge**

Table 4-4. Original table by depth, loss and land use type for 100-yr storm surge (thousand dollars)

| Depth | Residential | Commercial | Industry | Agriculture | Government | Entertainment |
|---|---|---|---|---|---|---|
| 0.5 | $62,210 | $5,746 | $1,237 | $886 | $12,231 | $1,364 |
| 2.5 | $421,731 | $58,699 | $22,834 | $6,625 | $69,057 | $5,291 |
| 6 | $2,134,298 | $248,646 | $67,800 | $7,705 | $156,700 | $57,986 |
| 10 | $2,763,893 | $309,982 | $98,305 | $8,595 | $194,549 | $61,471 |

The loss value as a function of inundation depth was presented in Figure 4-7. The loss of residential building exceeded that of the other building types at different inundation depth. The second biggest loss came from commercial buildings, which only accounted for one tenth of that of the residential buildings.

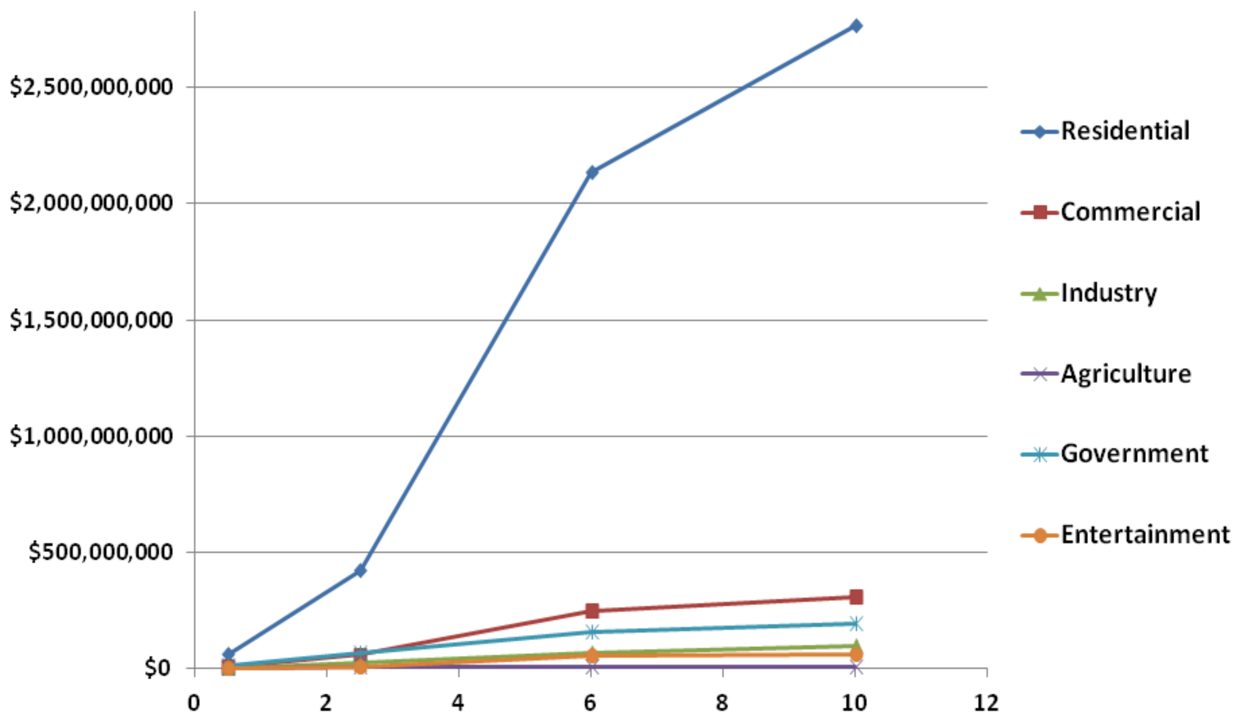


Figure 4-7. Building Loss by different land use type in the function of inundation depth for 100yr storm surge

In order to better illustrate the dependence of loss value on inundation depth for different type of buildings, the loss at different inundation depths was normalized to the maximum loss value of each particular category. The normalized losses are plotted in

Figure 4-8. The steeper increase of loss as a function of inundation depth indicates that more particular types of building were more susceptible to flood hazard.

Table 4-5. Normalized table by depth, loss and land use type for 100-yr storm surge

| Depth | Residential | Commercial | Industry | Agriculture | Government | Entertainment |
|---|---|---|---|---|---|---|
| 0.5 | 2.3% | 1.9% | 1.3% | 10.3% | 6.3% | 2.2% |
| 2.5 | 15.3% | 18.9% | 23.2% | 77.1% | 35.5% | 8.6% |
| 6 | 77.2% | 80.2% | 69.0% | 89.6% | 80.5% | 94.3% |
| 10 | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

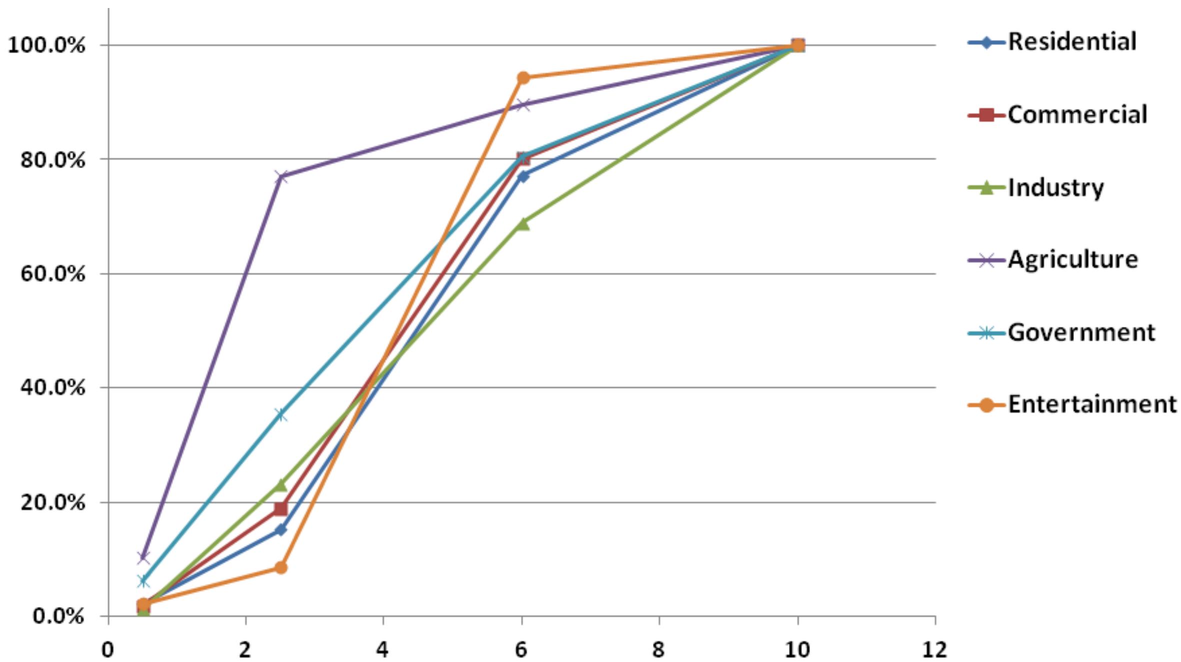


Figure 4-8. Building Loss Normalized by different land use type in the function of inundation depth for 100yr storm surge

In Figure 4-8, the residential buildings showed a steady increase in losses with an increase in inundation depth, indicating that these buildings constantly received the same level of damage at various depths. This scenario is similar for buildings on commercial, industrial and governmental areas. The loss for entertainment areas shows substantial increase as the depth goes beyond 2 feet. This suggested most of buildings in entertainment areas might locate to higher ground compared to other buildings. Only when the depth level reaches as high as 2 feet, does the influence on entertainment areas become apparent. The loss for agricultural area exhibits differently. More than 80% of the loss occurred when the depth level increased from 0 to 3ft, indicating that most of the agricultural areas were distributed at lower ground levels.

**Alternative scenario II: 100-yr storm surge and a 1.5m sea level rise**

The same process was done for the Alternative Scenario II.

Table 4-6. Normalized table by depth, loss and land use type for 100-yr storm surge and a 1.5m sea level rise (thousand dollars)

| Depth | Residential | Commercial | Industry | Agriculture | Government | Entertainment |
|---|---|---|---|---|---|---|
| 0.5 | $29,293 | $3,325 | $665 | $834 | $4,770 | $117 |
| 2.5 | $515,312 | $71,698 | $16,516 | $6,077 | $89,953 | $6,070 |
| 6 | $1,812,096 | $161,239 | $49,365 | $22,518 | $186,715 | $54,989 |
| 10 | $4,298,119 | $442,468 | $134,161 | $27,679 | $333,271 | $82,808 |

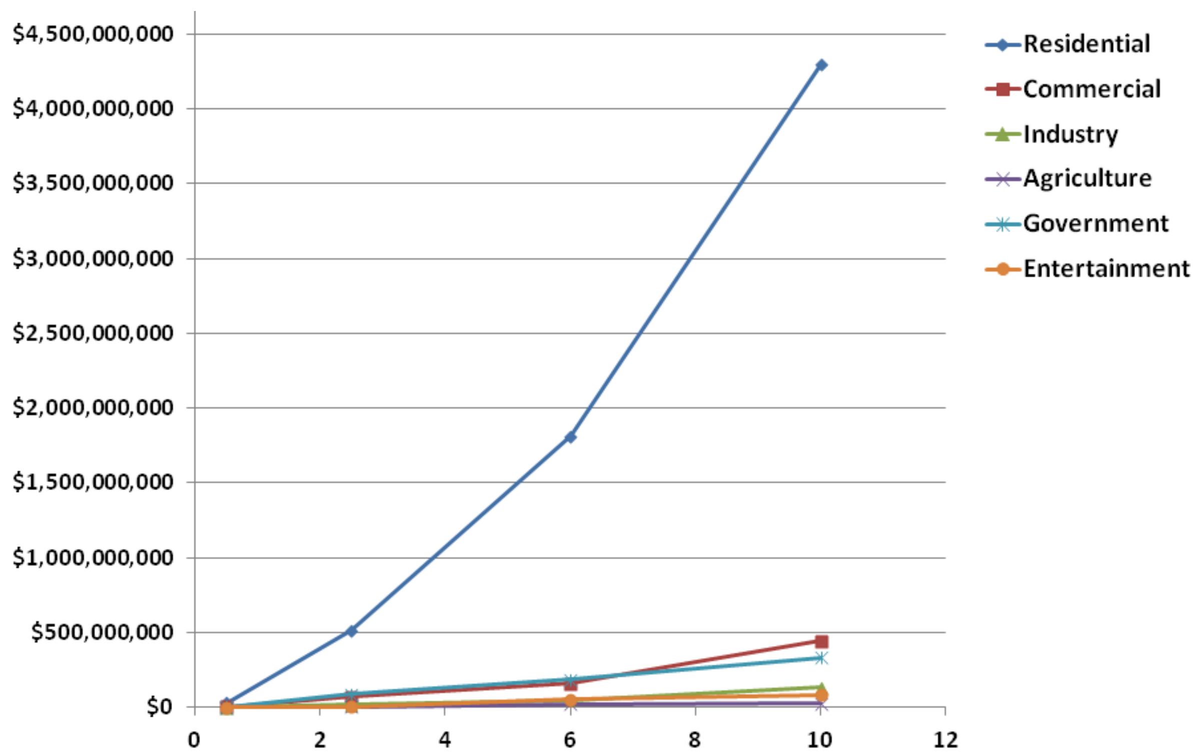


Figure 4-9. Building Loss by different land use type in the function of inundation depth for 100yr Storm Surge and a 1.5m sea level rise

Figure 4-9 shows the loss of different buildings with the consideration of a storm surge plus a 1.5m sea level rise. More loss occurs when 1.5m sea level rise is considered. The loss from residential buildings is almost twice that of the scenario without sea level rise. Different levels of increased loss are observed in other type of buildings.

Table 4-7. Normalized table by depth, loss and land use type for 100-yr storm surge and 1.5m sea level rise

| Depth | Residential | Commercial | Industry | Agriculture | Government | Entertainment |
|---|---|---|---|---|---|---|
| 0.5 | 0.7% | 0.8% | 0.5% | 3.0% | 1.4% | 0.1% |
| 2.5 | 12.0% | 16.2% | 12.3% | 22.0% | 27.0% | 7.3% |
| 6 | 42.2% | 36.4% | 36.8% | 81.4% | 56.0% | 66.4% |
| 10 | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

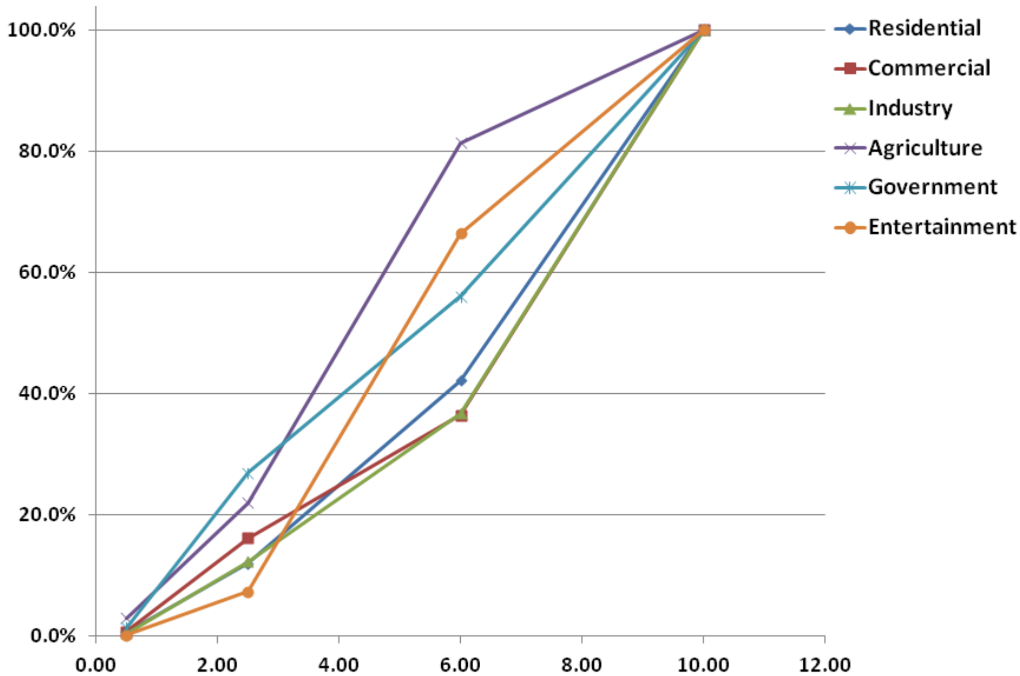


Figure 4-10. Building Loss Normalized by different land use type in the function of inundation depth for 100yr storm surge and a 1.5m sea level rise

As shown in Figure 4-10, the dependence of loss on inundation depth shows less variation for different types of buildings compared to those of the scenario without sea level rise. All types of building show a relatively linear increase of loss with depth level. Deviation from such linearity is only observed in agricultural and entertainment buildings. This may attributed to the non-uniform distribution of the particular buildings along the altitude. All these indicate the loss pattern will change with the sea level rise and additional care should be taken.

Table 4-8. Controlled building damage between WS/WO SLR by 2010 parcel, inundation between 0 - 1ft (thousand dollars)

| | Inundated between 0 to 1 feet | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | W/o sea level rise | | | | 1.5 m (4.9 feet) sea level rise | | | |
| Major use | Sum_Blgs | Inundated area | Dollar loss | Percent | Sum_Blgs | Inundated area | Dollar loss | Percent |
| Agriculture | 79 | 1424.9 | $886 | 0.99% | 109 | 17680.7 | $834 | 1.96% |
| Commercial | 489 | 446.8 | $5,746 | 6.40% | 414 | 130.3 | $3,325 | 7.81% |
| Entertainment | 62 | 308.1 | $1,364 | 1.52% | 27 | 55.6 | $117 | 0.28% |
| Government | 237 | 620.9 | $12,231 | 13.62% | 276 | 965.9 | $4,770 | 11.21% |
| Industry | 86 | 91.5 | $1,237 | 1.38% | 89 | 44.5 | $665 | 1.56% |
| Institutional | 224 | 241.0 | $4,764 | 5.30% | 220 | 367.8 | $2,863 | 6.73% |
| Miscellaneous | 50 | 114.1 | $1,031 | 1.15% | 8 | 8.7 | $466 | 1.09% |
| Not zoned agriculture | 40 | 226.6 | $354 | 0.39% | 49 | 571.0 | $228 | 0.54% |
| Residential | 11511 | 4411.1 | $62,210 | 69.26% | 8707 | 4856.9 | $29,293 | 68.82% |
| Total | 12778 | 7885.0 | $89,828 | 100.00% | 9899 | 24681.3 | $42,564 | 100.00% |

Table 4-9. Controlled building damage between WS/WO SLR by 2010 parcel, inundation between1 - 4ft (thousand dollars)

| | Inundated between 1 to 4 feet | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | W/o sea level rise | | | | 1.5 m (4.9 feet) sea level rise | | | |
| Major use | Sum_Blgs | Inundated area | Dollar loss | Percent | Sum_Blgs | Inundated area | Dollar loss | Percent |
| Agriculture | 78 | 3054.5 | $5,739 | 1.09% | 137 | 51889.7 | $5,243 | 0.74% |
| Commercial | 586 | 1243.9 | $52,952 | 10.09% | 1072 | 1431.5 | $68,373 | 9.67% |
| Entertainment | 111 | 948.1 | $3,926 | 0.75% | 100 | 1059.2 | $5,953 | 0.84% |
| Government | 392 | 4606.6 | $56,826 | 10.83% | 468 | 4201.6 | $85,183 | 12.05% |
| Industry | 333 | 563.7 | $21,596 | 4.12% | 221 | 687.0 | $15,851 | 2.24% |
| Institutional | 169 | 416.6 | $14,222 | 2.71% | 261 | 799.8 | $25,925 | 3.67% |
| Miscellaneous | 230 | 968.0 | $8,951 | 1.71% | 230 | 652.0 | $11,966, | 1.69% |
| Not zoned agriculture | 30 | 1201.3 | $965 | 0.18% | 88 | 3638.0 | $2,530 | 0.36% |
| Residential | 16972 | 10602.1 | $359,520 | 68.52% | 26083 | 17243.6 | $486,018 | 68.74% |
| Total | 18901 | 23604.7 | $524,701 | 100.00% | 28660 | 81602.4 | $707,047 | 100.00% |

Table 4-10. Controlled building damage between WS/WO SLR by 2010 parcel, inundation between 4- 8ft (thousand dollars)

| | Inundated between 4 to 8 feet | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | W/o sea level rise | | | | 1.5 m (4.9 feet) sea level rise | | | |
| Major use | Sum_blg | Inundated area | Dollar loss | Percent | Sum_blg | Inundated area | Dollar loss | Percent |
| Agriculture | 19 | 193.8 | $1,079 | 0.05% | 151 | 90533.9 | $16,441 | 1.01% |
| Commercial | 3528 | 2614.3 | $189,946 | 8.75% | 1032 | 1738.5 | $89,540 | 5.50% |
| Entertainment | 561 | 608.2 | $52,695 | 2.43% | 285 | 1091.5 | $48,918 | 3.00% |
| Government | 738 | 7584.4 | $87,642 | 4.04% | 405 | 5598.6 | $96,761 | 5.94% |
| Industry | 912 | 703.8 | $44,966 | 2.07% | 398 | 559.2 | $32,848 | 2.02% |
| Institutional | 478 | 632.8 | $79,849 | 3.68% | 271 | 680.3 | $39,842 | 2.45% |
| Miscellaneous | 46 | 139.9 | $2,499 | 0.12% | 88 | 1750.5 | $4,052 | 0.25% |
| Not zoned agriculture | 25 | 942.5 | $449 | 0.02% | 60 | 3758.6 | $3,258 | 0.20% |
| Residential | 56448 | 17970.6 | $1,712,567 | 78.86% | 31114 | 21302.9 | $1,296,784 | 79.63% |
| Total | 62755 | 31390.3 | $2,171,697 | 100.00% | 33804 | 127013.9 | $1,628,448 | 100.00% |

Table 4-11. Controlled building damage between WS/WO SLR by 2010 parcel, inundation between 8 -12ft (thousand dollars)

| | Inundated between 8 to 12 feet | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | W/o sea level rise | | | | 1.5 m (4.9 feet) sea level rise | | | |
| Major use | Sum_Blgs | Inundated area | Dollar loss | Percent | Sum_Blg | Inundated area | Dollar loss | Percent |
| Agriculture | 10 | 60.2 | $890 | 0.11% | 38 | 24515.2 | $5,160 | 0.16% |
| Commercial | 1168 | 894.2 | $61,336 | 7.70% | 4145 | 3443.5 | $281,228 | 8.89% |
| Entertainment | 90 | 264.3 | $3,484 | 0.44% | 469 | 807.6 | $27,818 | 0.88% |
| Government | 314 | 1454.2 | $37,848 | 4.75% | 977 | 13073.2 | $146,556 | 4.63% |
| Industry | 508 | 337.9 | $30,504 | 3.83% | 1304 | 981.1 | $84,795 | 2.68% |
| Institutional | 181 | 268.0 | $29,363 | 3.69% | 599 | 799.3 | $124,003 | 3.92% |
| Miscellaneous | 31 | 93.0 | $3,223 | 0.40% | 62 | 334.2 | $5,678 | 0.18% |
| Not zoned agriculture | 4 | 196.2 | $180 | 0.02% | 33 | 1326.8 | $941 | 0.03% |
| Residential | 13417 | 5956.0 | $629,594 | 79.05% | 59401 | 23369.6 | $2,486,022 | 78.62% |
| Total | 15723 | 9523.8 | $796,427 | 100.00% | 67028 | 68650.4 | $3,162,207 | 100.00% |

Table 4-12. Controlled building damage between WS/WO SLR by 2010 parcel, inundation above 12ft

| | Inundated above 12 feet | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | W/o sea level rise | | | | 1.5 m (4.9 feet) sea level rise | | | |
| Major use | Sum_Blgs | Inundated area | Dollar loss | Percent | Sum_Blgs | Inundated area | Dollar loss | Percent |
| Agriculture | - | - | - | - | - | - | - | - |
| Commercial | - | - | - | - | 4 | 4.4 | $97,151 | - |
| Entertainment | - | - | - | - | - | - | - | - |
| Government | - | - | - | - | - | - | - | - |
| Industry | - | - | - | - | - | - | - | - |
| Institutional | - | - | - | - | - | - | - | - |
| Miscellaneous | - | - | - | - | - | - | - | - |
| Not zoned agriculture | - | - | - | - | - | - | - | - |
| Residential | - | - | - | - | 1 | 2.5 | $19,851 | - |
| Total | - | - | - | - | - | - | - | - |

. CHAPTER 5
DISCUSSION

## Discussion of Findings and Methods

To calculate the losses due to flood is a complicated and comprehensive work. Many factors could add up to the sum of the loss. Both direct loss and indirect loss should be considered. Direct loss includes the physical damages of the building, the direct economic loss, the crop loss, shelter for people. Indirect loss includes the upcoming wildfire, removal of debris, people’s relocation or the area’s redevelopment (Zhang, et al., 2011).

There are particular damage functions for different categories suffered from flooding. For example, the loss of building content is usually calculated by correlating the characteristics of the buildings by weight to a certain percentage of the building value. For the Volusia case study, further in-depth research should be carried out to define those certain parameters.(Davis, 1992) Other than that, a more accurate conclusion could be drawn. However, debates come up in some specific field. The damage function for agricultural land needs to be discussed because some research shows that after certain intense floods might even bring benefits to the agriculture land, as the soil becomes more fertile after the flood.

However, efficient evaluation of the criteria is of critical importance in the process of comparing the results of projected scenarios. A good evaluation should be comprehensive enough to clarify the results of the associated objectives as well as be measurable for a more convincible quantitative analysis. At last, it should be representative, which means it could fully cover certain aspects of the situation and would not be confusing to cause double-counting either for further analysis , for conclusion drawing-out, or for decision- making.(Rashed & Weeks, 2003)

Other than depth, some other primary factors such as velocity of water during the flooding period and how long it takes for water to recede the after the flooding period are also contributing to flood losses. (Bullock, et al. 2008) Some other type of hazards associated with flooding could also contribute to flood losses, suggesting, more damage functions needs to be figured out through future research.

On the other hand, the data used in this research is the best available data in reach. Nevertheless, the method in data inventory could be improved. HAZUS- MH level 2 provide a platform which is Comprehensive Data Management System (CDMS) tool. By exploring this, more updated date from the newest census or curves on site could be processed in the software, such as the population, numbers and types of the buildings, and other related parameters.

## Future Research Opportunities

R. Klein and R. Nicholls proposed three level of assessment to the vulnerability of coastal area by the limited available data. Planning assessment (PA) is considered to be the in-depth criticism with the suitability analysis. The other two levels in order are screening assessment (SA) to get a facade view to the vulnerability and then vulnerability assessment (VA) to have a comprehensive consideration to effects from various aspect might lead to vulnerability.(Nicholls, 1999) In that case, further study on suitability and sustainability analysis in planning scope and appropriate implementation might be formed base on this. Since this type of research could visualize the future possible hazards, with more specific and accurate input, the relative scenarios might be created and analyzed to help planners work with emergency managers to develop and implement disaster plans and mitigation plans and to assist with disaster response activities. On the other hand, planning strategies development may also take the visualized results into consideration to make mitigation plans and evacuation plans for short-term use, and land use adaptation plans, and population reallocation plans for long-term use.

# CHAPTER 6
# CONCLUSION

In this study, the “Base Scenario” is ideally static with variables including population growth, land use change, socio-economic status, and changes in the natural environment are not taken into account. This scenario, however, is necessary to compare future possibilities. The “Alternative Scenario I” uses Year 2010 tax parcel data and a Volusia County DEM raster to estimate building loss by land use types with Kiefer and Willett’s depth-damage function. The estimation was with an acceptable error and lower than the loss in the Base Scenario. The “Alternative Scenario II” is based on “Alternative Scenario I” by incorporating a modified Volusia County DEM raster, which was subtracted by 1.5m (4.9 feet). This approach intends to simulate a situation with a 1.5m sea level rise. The loss was dramatically increased by this which indicated that sea level rise can hardly be ignored for an efficient land use planning.

Therefore, it is important to create an appropriate model and fully evaluate the results in order to determine whether the data is reasonable and ready to be used for decision-making. The decision-maker should also carefully interpret the results and provide their own inputs when it is necessary. (Darwin & Tol, 2001) In addition, it would be helpful to have comparisons between the real events that take place and historical, documented losses, as well as the existing potential losses to examine the validity of the model.

Considering the factors that can impact the study region, the results can be re-run and documented to support mitigation strategies.(Davis, 1985) At this stage one can identify the assets that are subject to the greatest potential damage (FEMA 2004).

Not only the direct economic losses, but also the indirect loss of the agriculture land products output, industrial products output and damage of the infrastructure are expected to cause more severe economic losses due to flooding by sea level rise and storm surge. (McLeod, et al., 2010) This also greatly increases the possibility of bankruptcy of various entities involved due to limited coverage of FEMA's mitigation plan and insurance companies. Moreover, the extra expense on post-disaster resilience will increase the financial burden of local and federal governments, which will lead to potential budget-cuts in education, health care and other social benefits. The government should not only keep the above fact in mind but also that it is important to remind individuals of these risks so that they are willing to spend more on flood insurance. Many people do not pay attention to the threat of such infrequent risk to their properties. If people could understand that the risks exist, they will be more cooperative and supportive toward the implementation of revised future land use and/or evacuation plans in certain areas. However, the extra expense of these plans has to be afforded by someone, which needs to be further discussed.

Human-caused environmental deterioration caused by flooding has been well documented. (Cushman, et al., 1991) On the contrary, wetlands, swamps, mangroves are ecologically positive with water drainage capacity and they are important in terms of flood prevention. Since these risks of nature disasters are inevitable, we should prepare to face the challenges by keeping up the related systems in pace with that of climate change. The HAZUS-MH model should be employed to a greater extent by urban and regional planners. With the application of the model, the long-term impacts of storm surge and sea level rise on infrastructure, property parcels, and other public and private resources may be visualized.

This research eschews the typical science or engineering schemes to help or prevent inevitable hazards and to offer visualized scenarios to help related organizations to make more serious decisions to reduce the hazards damage. According to the results of the hypothesis of the research, more rational and appropriate coastal county planning implementation should be seriously considered in the future with regard to aspects such as conditional developments caused by climate change, in terms of sea level rise. This is likely to be a reasonable approach to allocating limited resources. From a societal perspective, all qualifying proposals are worth pursuing. This type of analysis should help politicians to begin to seriously think about whether development within coastal areas is appropriate and what might be the liability associated with those decisions for Florida.

APPENDIX A
VOLUSIA 100-YR COASTAL FLOOD EVENT SUMMARY REPORT

# HAZUS-MH: Flood Event Report

**Region Name:** VolusiaBaseScenerio

**Flood Scenario:** BaseScenario

**Print Date:** Monday, October

***Disclaimer:***

*Totals only reflect data for those census tracts/blocks included in the user's study region.*

*The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social*

# Table of Contents

## General Description of the Region

HAZUS is a regional multi-hazard loss estimation model that was developed by the Federal Emergency Management Agency (FEMA) and the National Institute of Building Sciences (NIBS). The primary purpose of HAZUS is to provide a methodology and software application to develop multi-hazard losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from multi-hazards and to prepare for emergency response and recovery.

The flood loss estimates provided in this report were based on a region that included 1 county(ies) from the following state(s):

- Florida

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 1,102 square miles and contains 10,768 census blocks. The region contains over 185 thousand households and has a total population of 443,343 people (2000 Census Bureau data). The distribution of population by State and County for the study region is provided in Appendix B.

There are an estimated 212,019 buildings in the region with a total building replacement value (excluding contents) of 34,059 million dollars (2006 dollars). Approximately 90.67% of the buildings (and 76.32% of the building value) are associated with residential housing.

## Building Inventory

### General Building Stock

HAZUS estimates that there are 212,019 buildings in the region which have an aggregate total replacement value of 34,059 million (2006 dollars). Table 1 and Table 2 present the relative distribution of the value with respect to the general occupancies by Study Region and Scenario respectively. Appendix B provides a general distribution of the building value by State and County.

**Table 1**
**Building Exposure by Occupancy Type for the Study Region**

| Occupancy | Exposure ($1000) | Percent of Total |
|---|---|---|
| Residential | 25,994,873 | 76.3% |
| Commercial | 5,595,147 | 16.4% |
| Industrial | 1,217,315 | 3.6% |
| Agricultural | 149,305 | 0.4% |
| Religion | 720,076 | 2.1% |
| Government | 179,670 | 0.5% |
| Education | 202,612 | 0.6% |
| **Total** | **34,058,998** | **100.00%** |

**Table 2**
**Building Exposure by Occupancy Type for the Scenario**

| Occupancy | Exposure ($1000) | Percent of Total |
|---|---|---|
| Residential | 16,933,986 | 75.5% |
| Commercial | 3,896,257 | 17.4% |
| Industrial | 867,532 | 3.9% |
| Agricultural | 78,654 | 0.4% |
| Religion | 453,992 | 2.0% |
| Government | 88,746 | 0.4% |
| Education | 117,673 | 0.5% |
| **Total** | **22,436,840** | **100.00%** |

### Essential Facility Inventory

For essential facilities, there are 6 hospitals in the region with a total bed capacity of 1,180 beds. There are 137 schools, 14 fire stations, 21 police stations and no emergency operation centers.

## Flood Scenario Parameters

HAZUS used the following set of information to define the flood parameters for the flood loss estimate provided in this report.

| | |
|---|---|
| **Study Region Name:** | VolusiaBaseScenerio |
| **Scenario Name:** | BaseScenario |
| **Return Period Analyzed:** | 100 |
| **Analysis Options Analyzed:** | No What-Ifs |

## Building Damage

### General Building Stock Damage

HAZUS estimates that about 59,438 buildings will be at least moderately damaged. This is over 49% of the total number of buildings in the scenario. There are an estimated 9,222 buildings that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS Flood technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 summarizes the expected damage by general building type.

**Table 3: Expected Building Damage by Occupancy**

| | 1-10 | | 11-20 | | 21-30 | | 31-40 | | 41-50 | | Substantially | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Occupancy** | **Count** | **(%)** | **Count** | **(%)** | **Count** | **(%)** | **Count** | **(%)** | **Count** | **(%)** | **Count** | **(%)** |
| Agriculture | 0 | 0.00 | 23 | 85.19 | 4 | 14.81 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| Commercial | 40 | 5.66 | 581 | 82.18 | 59 | 8.35 | 26 | 3.68 | 1 | 0.14 | 0 | 0.00 |
| Education | 6 | 100.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| Government | 0 | 0.00 | 18 | 100.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| Industrial | 4 | 3.01 | 23 | 17.29 | 42 | 31.58 | 44 | 33.08 | 19 | 14.29 | 1 | 0.75 |
| Religion | 1 | 2.22 | 44 | 97.78 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| Residential | 33 | 0.06 | 5,604 | 9.57 | 31,084 | 53.06 | 7,089 | 12.10 | 5,555 | 9.48 | 9,221 | 15.74 |
| **Total** | **84** | | **6,293** | | **31,189** | | **7,159** | | **5,575** | | **9,222** | |

**Table 4: Expected Building Damage by Building Type**

| **Building Type** | 1-10 | | 11-20 | | 21-30 | | 31-40 | | 41-50 | | Substantially | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Count** | **(%)** | **Count** | **(%)** | **Count** | **(%)** | **Count** | **(%)** | **Count** | **(%)** | **Count** | **(%)** |
| Concrete | 2 | 0.14 | 142 | 10.00 | 996 | 70.14 | 127 | 8.94 | 153 | 10.77 | 0 | 0.00 |
| ManufHousing | 0 | 0.00 | 69 | 0.73 | 140 | 1.47 | 0 | 0.00 | 124 | 1.31 | 9,166 | 96.49 |
| Masonry | 32 | 0.09 | 4,141 | 11.91 | 21,651 | 62.28 | 4,998 | 14.38 | 3,901 | 11.22 | 42 | 0.12 |
| Steel | 20 | 4.22 | 341 | 71.94 | 48 | 10.13 | 45 | 9.49 | 19 | 4.01 | 1 | 0.21 |
| Wood | 16 | 0.12 | 1,524 | 11.38 | 8,452 | 63.12 | 1,975 | 14.75 | 1,410 | 10.53 | 13 | 0.10 |

## Essential Facility Damage

Before the flood analyzed in this scenario, the region had 1,180 hospital beds available for use. On the day of the scenario flood event, the model estimates that 1,180 hospital beds are available in the region.

Before the flood analyzed in this scenario, the region had 1,180 hospital beds available for use. On the day of the scenario flood event, the model estimates that 740 hospital beds are available in the region.

**Table 5: Expected Damage to Essential Facilities**

| | | # Facilities | | |
|---|---|---|---|---|
| **Classification** | Total | At Least Moderate | At Least Substantial | Loss of Use |
| Fire Stations | 14 | 9 | 0 | 9 |
| Hospitals | 6 | 3 | 0 | 3 |
| Police Stations | 21 | 11 | 0 | 11 |
| Schools | 137 | 50 | 0 | 48 |

If this report displays all zeros or is blank, two possibilities can explain this.

(1) None of your facilities were flooded. This can be checked by mapping the inventory data on the depth grid.

(2) The analysis was not run. This can be tested by checking the run box on the Analysis Menu and seeing if a message box asks you to replace the existing results.

## Induced Flood Damage

### Debris Generation

HAZUS estimates the amount of debris that will be generated by the flood. The model breaks debris into three general categories: 1) Finishes (dry wall, insulation, etc.), 2) Structural (wood, brick, etc.) and 3) Foundations (concrete slab, concrete block, rebar, etc.). This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 416,351 tons of debris will be generated. Of the total amount, Finishes comprises 80% of the total, Structure comprises 7% of the total. If the debris tonnage is converted into an estimated number of truckloads, it will require 16,654 truckloads (@25 tons/truck) to remove the debris generated by the flood.

## Social Impact

### Shelter Requirements

HAZUS estimates the number of households that are expected to be displaced from their homes due to the flood and the associated potential evacuation. HAZUS also estimates those displaced people that will require accommodations in temporary public shelters. The model estimates 71,849 households will be displaced due to the flood. Displacement includes households evacuated from within or very near to the inundated area. Of these, 204,609 people (out of a total population of 443,343) will seek temporary shelter in public shelters.

## Economic Loss

The total economic loss estimated for the flood is 16,650.00 million dollars, which represents 35.90 % of the total replacement value of the scenario buildings.

### Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the flood. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the flood.

The total building-related losses were 8,265.56 million dollars. 1% of the estimated losses were related to the business interruption of the region. The residential occupancies made up 64.81% of the total loss. Table 6 below provides a summary of the losses associated with the building damage.

**Table 6: Building-Related Economic Loss Estimates**

(Millions of dollars)

| Category | Area | Residential | Commercial | Industrial | Others | Total |
|---|---|---|---|---|---|---|
| Building Loss | | | | | | |
| | Building | 3,275.33 | 538.08 | 171.48 | 9.43 | 3,994.32 |
| | Content | 2,107.81 | 1,628.00 | 369.43 | 37.63 | 4,142.87 |
| | Inventory | 0.00 | 42.36 | 80.03 | 5.98 | 128.37 |
| | **Subtotal** | **5,383.14** | **2,208.44** | **620.94** | **53.04** | **8,265.56** |
| Business Interruption | | | | | | |
| | Income | 0.98 | 9.71 | 0.01 | 0.69 | 11.39 |
| | Relocation | 6.41 | 1.93 | 0.02 | 0.03 | 8.40 |
| | Rental Income | 2.70 | 1.15 | 0.00 | 0.01 | 3.86 |
| | Wage | 2.55 | 9.92 | 0.03 | 23.30 | 35.80 |
| | **Subtotal** | **12.65** | **22.70** | **0.07** | **24.02** | **59.44** |
| ALL | **Total** | **5,395.78** | **2,231.15** | **621.01** | **77.06** | **8,325.00** |

## Appendix A: County Listing for the Region

Florida

- Volusia

## Appendix B: Regional Population and Building Value Data

| | Population | Building Value (thousands of dollars) | | |
|---|---|---|---|---|
| | | Residential | Non-Residential | Total |
| **Florida** | | | | |
| Volusia | 443,343 | 25,994,873 | 8,064,125 | 34,058,998 |
| **Total** | **443,343** | **25,994,873** | **8,064,125** | **34,058,998** |
| **Total Study Region** | **443,343** | **25,994,873** | **8,064,125** | **34,058,998** |

APPENDIX B
VOLUSIA 100-YR COASTAL FLOOD EVENT QUICK ASSESSMENT REPORT

## Quick Assessment Report

*October 17, 2011*

**Study Region :** VolusiaBaseScenerio
**Scenario :** BaseScenario7ft
**Return Period:** 100
**Analysis Option:** 0

### Regional Statistics

| | |
|---|---|
| **Area (Square Miles)** | 1,102 |
| **Number of Census Blocks** | 10,768 |
| **Number of Buildings** | |
| Residential | 192,240 |
| Total | 212,019 |
| **Number of People in the Region (x 1000)** | 443 |
| **Building Exposure ($ Millions)** | |
| Residential | 25,995 |
| Total | 34,059 |

### Scenario Results

**Shelter Requirements**

| | |
|---|---|
| Displaced Population (# Households) | 71,849 |
| Short Term Shelter (# People) | 204,609 |

**Economic Loss**

| | |
|---|---|
| Residential Property (Capital Stock) Losses ($ Millions) | 5,383 |
| Total Property (Capital Stock) Losses ($ Millions) | 8,266 |
| Business Interruptions (Income) Losses ($ Millions) | 59 |

***Disclaimer:***

*Totals only reflect data for those census tracts/blocks included in the user's study region.*

*The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific flood. These results can be improved by using enhanced inventory data and flood hazard information.*

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# BIOGRAPHICAL SKETCH

Yuyang Zou was born in 1984 in Hubei, China. She has a degree of Bachelor of Architecture from Huazhong University of Science and Technology. She is pursuing her degree of Master of Arts in Urban and Regional Planning at University of Florida. She has worked as a research assistant for Dr. Paul Zwick since 2009. Her master's studies are focused on GIS-based analysis for nature hazards and land use suitability models. She has also been a research assistant at in the Shimberg center for Housing Studies since May 2011. Her research at the Shimberg Center involves the development of the Affordability Housing Suitability Model. She will continue the research her after graduation.