DRAFT

Upper St. Johns River Basin Basin #24

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Executive Summary

Flooding is the most common and costly disaster in the United States. Over 98% of counties in the entire United States have experienced a flood and just one inch of water causing up to $25,000 in damage (FEMA 2018). Flooding can impact a community's social, cultural, environmental and economic resources, so making sound, science-based, long-term decisions to improve resiliency are critical to future prosperity and growth. To meet the longer-term goals to protect life and property, in 1990, FEMA created the National Flood Insurance Program's (NFIP) Community Rating System (CRS) program, a voluntary program for recognizing and encouraging community floodplain management activities. Nearly 3.6 million policyholders in 1,444 communities participate in the CRS program, but this is only 5% of the over 22,000 communities participating in the NFIP.

The Florida Department of Emergency Management (FDEM) contracted with FAU to develop data to enable local communities to reduce flood insurance costs through mitigation and resiliency efforts by developing watershed management plans. There are several steps to address the development of watershed plans including the development of a watershed planning template and development of support documents to establish risk associated with community risk within the watershed.

The effort discussed herein focusses on the development procedures for a screening tool to assess risk in Upper St. Johns River Basin located in South of Central Florida that combines readily available data on topography, ground and surface water elevations, tidal data for coastal communities, soils, open space and rainfall to permit an assessment of the risk of inundation of property in the basin. Such knowledge permits the development of tools to permit local agencies to develop means to address high-risk properties.

1.0 Introduction

Upper St Johns River basin is located in the south of Central Florida, the river flows to the north, and the source of the river basin headwaters large from the marshy area in the Indian river county flows toward the north and turns east direction enters into the Atlantic Ocean (see Figure 1.0). The river extends through 2000 square miles and the longest river begins its 310-mile northerly journey to the Atlantic Ocean. The most area features a merge of the marsh, sawgrass, and cypress domes and it looks more like Florida Everglades. The entire basin includes parts of eight counties. The basin extending throughout Okeechobee, Brevard, Indian River, and Osceola Counties. Central Florida is well known for its lakes, creeks, streams, and rivers. It is approximately located the headwaters of St Johns River and closure with the Atlantic Ocean at Jacksonville.

Figure 1.0: Location of Upper St Johns Basin, Florida

2.0 Summary of Watershed

2.1 General Description of Watershed

2.1.1 Climate/Ecology

The St Johns river lies within a humid subtropical zone. The warmest month in the year is August with an average maximum temperature of 31 degrees Celsius. The coldest month is January with an average temperature of 28 degrees Celsius.

2.1.2 Topography and Soils

The St Johns Basin is the longest river in Florida. It's one of the few rivers flows from south to north. The elevation changes from west to east. While the native soil and topography create an environment that is highly permeable and capable of absorbing significant percolation of the water into the soil, the change in the land use as resulted in water falling on impermeable land where the water collects in pools or runs off rapidly were development as taken place, in direct contrast to the natural condition. The result of run-off flowing over impermeable regions often results in large-scale flooding because the storm intensity (rate of rainfall) cannot be used to design facilities due to economics.

2.1.3 Boundaries/Surface Waters

The study area boundary is defined by the total maximum daily load (TMDL) of Upper St Johns Basin. All data was gathered for a few miles extended boundary to ensure complete coverage of the study area. The basin is characterized by banks, swamps and Lakes. The larger lakes in the upper basin include Lake Hell and Blazes, Sawgrass Lake, Lake Washington, Lake Winder, Lake Poinsett, Ruth Lake, Puzzle Lake, Lake Harney, Lake Jesup, and Lake Munroe.

2.1.4 Hydrogeological Considerations

The groundwater system of SJRWMD is classified into three aquifers such as Surficial, Intermediate and Floridan aquifer system. The southeastern geological society (1986) described the hydrogeologic nature of these aquifer systems.

The Surficial aquifer system consists primarily of sand, silt and sandy clay. It extends from the land surface down to the top of the confining unit of the intermediate aquifer system. The upper surface is a saturated zone called a water table. It mainly occurs under unconfined conditions. The Water table can rise and fall freely and comprises Pleistocene and Holocene Sediments. The aquifer system water quality is generally acceptable for domestic use based on the review of USGS and SJRWMD data. Its mains water sources for St. Johns, Brevard and Indian River Counties. In Coastal areas such as the barrier Islands, this aquifer system is prone to saltwater intrusion.

The Intermediate aquifer system consists of fine-grained clastic deposits of clayey sand to clay interlayered with thin water-bearing zones of sand, shell and limestone. The Hawthorn Formation, an intermediate confining unit of Miocene age, separates it from the surficial aquifer and collectively retards the exchange of water between the overlying surficial and underlying Floridan aquifer system. This unit occurs in Nassau, Duval, Clay, Orange and Indian River Counties. It occurs throughout most of SJRWMD. Based on USGS and SJRWMD data suggest water is generally of acceptable quality of domestic use in the northern part of SJRWMD such as Duval, clay and Orange Counties and meets secondary drinking water standards. However southern SJRWMD does not meet the criteria.

The world's most productive aquifers are one of the Floridan aquifer systems. It is composed of rocks, primarily limestone and dolomite underlie the entire state. Water occurs in most of the confined locations throughout SJRWMD. Recharge occurs in areas where the elevation of the water table of the surficial aquifer is higher than the elevation of the potentiometric surface of the Floridan aquifer. Discharge from Floridan aquifer occurs in areas where the elevation of the Floridan aquifer potentiometric surface is higher than the elevation of the water table.

The Florida aquifer system is sub regionally divided based on the vertical occurrence of two zones of relatively high permeability. These zones are called the Upper and Lower Floridan aquifers. A less permeable limestone and dolomitic limestone sequence referred to as the middle semiconfining unit generally separate the upper and lower Floridan aquifers. The base of the lower Floridan aquifers occurs at the top of low permeability anhydrite beds within the cedar keys formation.

USGS and SJRWMD data indicate the water quality in the Upper and Lower Floridan aquifer varies depending on the location. Water in this Upper Floridan aquifer is generally of acceptable quality of domestic use in the northern and western portions of SJRWMD. Both aquifers do not meet the secondary drinking water standards for some of the areas in SJRWMD.

2.1.5 Special Features

St. Johns River is dark, blackwater and longest river in Florida. It flows from southward to the norward direction. It is one of the flattest major rivers in North America. It drains into the Atlantic Ocean. It can influence wind speed and wind direction. As a result, most of the watershed is completely managed by people. The upper St. John's River Basinis the headwaters of the river, located primarily east of Orlando.

2.2 Socio-economic Conditions of the Watershed

2.2.1 Demographics (US Census, 2018)

As of the 2018 5-year ACS, Upper St Johns had 410,829 people (see Table 1).

Table 1: Demographics for the Upper St. John's River Basin

Name	Total	Percentage(%)
Total Population	410,829	0.00
Total: Households	149,266	36.33
Population Male	203,231	49.47
Population Female	207,598	50.53
Population White alone	329,667	80.24
Population Black or African American alone	47,221	11.49
Population American Indian and Alaska Native alone	1,559	0.38
Population Asian alone	11,697	2.85
Population Native Hawaiian and Other Pacific Islander alone	379	0.09
Population Some other race alone	7,380	1.80
Population Two or more races	12,926	3.15
Population Hispanic or Latino by Race	59,336	14.44
Not Hispanic or Latino:White alone	282,031	68.65
Average household size Total: Average Household Size of Occupied Housing Units by Tenure	459	0.11
Total: Household Type by Relatives and Nonrelatives for Population in Households	406,083	98.84
Population in family households	348,216	84.76
Population in nonfamily households	57,867	14.09
Family households	104,181	25.36
Average family size (Total Population In family households/Family households)	573	0.14
Population Under 5 years	21,698	5.28
Population 5 to 17 years	64,773	15.77
Population 18 to 21 years	17,043	4.15
Population 40 to 49 years	49,891	12.14
Population 50 to 64 years	92,454	22.50
Population 65 and up	78,660	19.15
Population 85 years and over	9,489	2.31
Median age for population	7,743	1.88
Households Total: households for poverty status in the past 12 months by household type by age of householder	149,266	36.33
Population Total: Poverty Status of Individuals in the Past 12 Months by Living Arrangement	405,869	98.79
Total Housing Units	175,428	42.70
Total Vacant housing units	26,162	6.37
Households with No public assistance income	146,460	35.65
Households with public assistance income	2,806	0.68
Single Family	138,242	33.65
Mulit Family	21,957	5.34

2.2.2 Property

Property values are highest in the coastal region of the watershed around major cities and it consists of mostly agricultural land and upland forests with a few urban areas in cities. The urban areas have limited industrial properties. As a result, the communities are primarily residential with small concentrations of commercial activities along the US, the beach and the larger cities.

2.2.3 Economic Activity/Industry

The most beautiful area of the sunshine is the south-central Florida state. It's full of the natural environment, jobs in tourism and agriculture. Agricultural technology innovation and manufacturing industries are growing areas in this region. However, this region promotes its economic diversity in manufacturing, agriculture, tourism and small business.

The most region of this area was kept to natural agricultural preservation. In recent years, many communities have invested in solar energy to generate more electricity to power entire commercial and residential use. Additionally, growing ecotourism facilities availability of natural preservatives in South Central Florida. Some of the lands were not available for ecotourism because agriculture is a primary part of local culture and life. Hardee county which is greatly provides added value to agriculture and energy solution businesses in the local area.

The educational institution of South Florida State College has four campuses in south central Florida. It attracts both interstate and intrastate students to the region's growing workforce. Tec River’s University teaches STEM and Technology related courses. Other areas such as Gateway Logistics and Manufacturing training center to build on placement drive that encourages new manufacturing and technology companies transferring to the area.

Mixed industries such as value-added agricultural development, ecotourism and manufacturing industries. Moreover, Hardee county and its neighbors enjoy economic variety and constant growth in new industries of technology in south central Florida

3.0 Watershed Analysis

3.1 Data Sets

3.1.1 Topography

The topography is a key parameter that influences many processes involved in flood risk assessment and low-lying areas are a higher possibility of getting floods than high areas. FAU Department gathered Digital elevation model datasets with a high spatial resolution to ensure the integrity of all final flood risk maps, which will assist stakeholders in decision-making for successful watershed management. Figure 3.1 shows the results of the LiDAR DEM uses 3-meter tiles with +/- 4 inches of accuracy and combined the data with USGS one-third arc second to fill the gaps of the extent. Mosaicking of two different spatial resolutions datasets into higher elevation. The highest elevation in the basin is 250 ft above the ground level. The basin has small lakes and ponds. Project the elevation surface into NAD 1983 UTM Zone 17 N coordinate system, converting vertical units into feet.

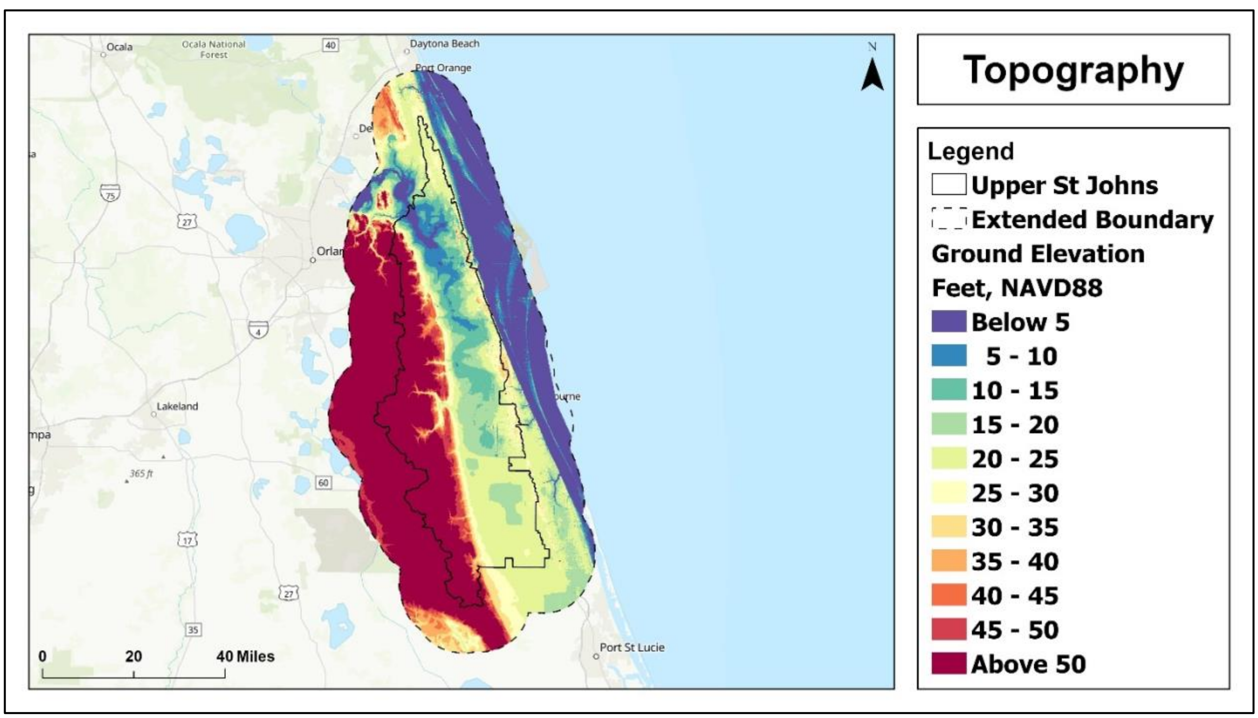

Figure 3.1: High-Resolution Digital Elevation Model

3.1.2 Groundwater

Groundwater wells are also a major contribution to flooding large portions in the Florida region as water absorbs in the soil layer increase water level in the ground. Generation of accurate elevation surface from the observed ground well-monitoring levels applying the spatial interpolation and extrapolation techniques. Water level data was extracted from the spatial database using a python script to find maximum groundwater levels dated September 9^{th} 2018 for the Upper St Johns Basin. Available site descriptive information includes well location information such as latitude and longitude, well-depth and date. Utilizing information to map the exact location of wells and convert tabular data into GIS layers and applying a highly accurate interpolation method to generate groundwater table surface. Groundwater monitoring stations mapped results shown in Figure 3.2

3.1.3 Surface Waters

Groundwater and Surface water have a direct interrelatedness between them in Florida. There is little topographic relief and groundwater is controlled by the canals, rivers and tides. Upper St Johns River Basin has a larger number of groundwater monitoring stations, the strong relationship between groundwater and surface water will be leveraged to accurately map the water table elevation. All daily maximum or mean surface water gauge level observations dated September 9^{th} 2018 for Upper St Johns Basin were gathered from monitoring stations in the US Geological Survey database. Many stations are located along canals and rivers, which assists in determining the water levels across open and connected surface water bodies. As shown in Figure 3.2, there are 32 station observations available on this date.

Trident Pier, Port Canaveral Tidal station was falling within the Upper St Johns Basin Extended boundary, is one of modern water level monitoring stations near to the coastal line is fitted with sensors that continuously records the height of the surrounding water level. It is established in October 1994. The tidal gauge observation was gathered from the station dated September 9^{th} 2018.

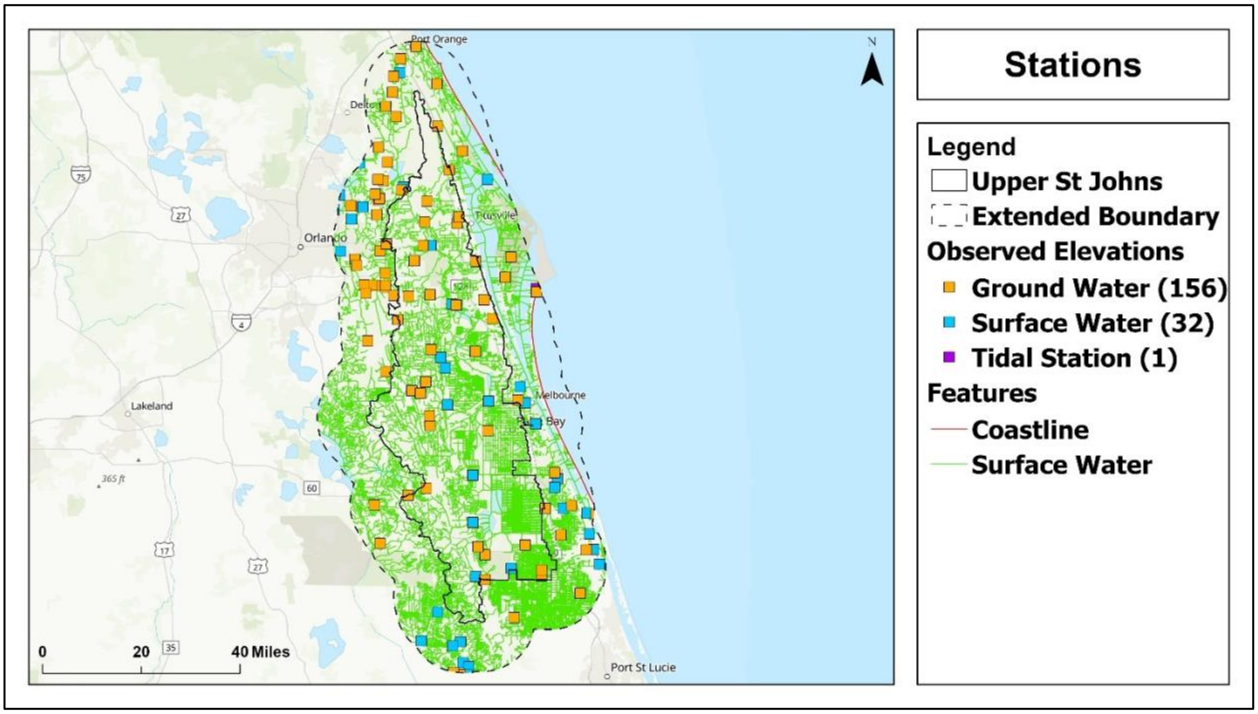

Figure 3.2: Groundwater, Surface Water and Tidal Station Locations

3.1.4 Open Space

Open Space and land frequently inundated throughout the year will be unable to store additional water during a rainfall event. For mapping of soil storage capacity across the basin that will influence the vulnerability of flooding, those areas should be set to zero storage capacity as these areas cannot store additional water. These areas, shown in Figure 3.3, were delineated from statewide land use land cover datasets and were used in the calculation of soil storage capacity. Additionally, these areas will be overlaid onto the final risk map as flooding is likely to occur near open surface water bodies and areas such as wetlands, swamps and marshes.

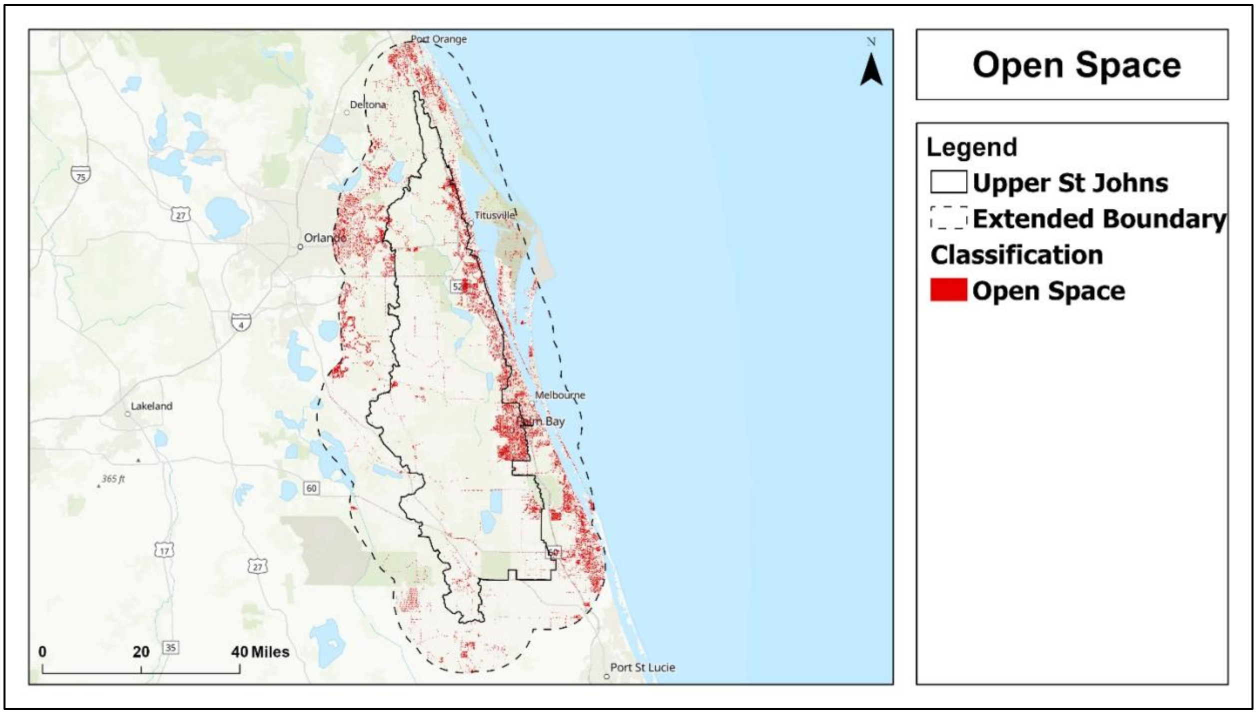

Figure 3.3: Open Space Surface

Another includes for Soil Storage calculation is the land area, where the water does not permit infiltrate into the ground. The area is called an Impervious surface, the rainfall will not infiltrate the soil causes surface runoff and increased flooding. those are the area permits to infiltrate the soil to store unsaturated zone. Impervious surface is also considered for the generation of storage surface. The National Land Cover Database was used to classify land as a pervious or impervious surface. Figure 3.4 shows Impervious surface and pervious surface (a mask with 0 as impervious and 1 as non-impervious) also assumed to have zero soil water capacity.

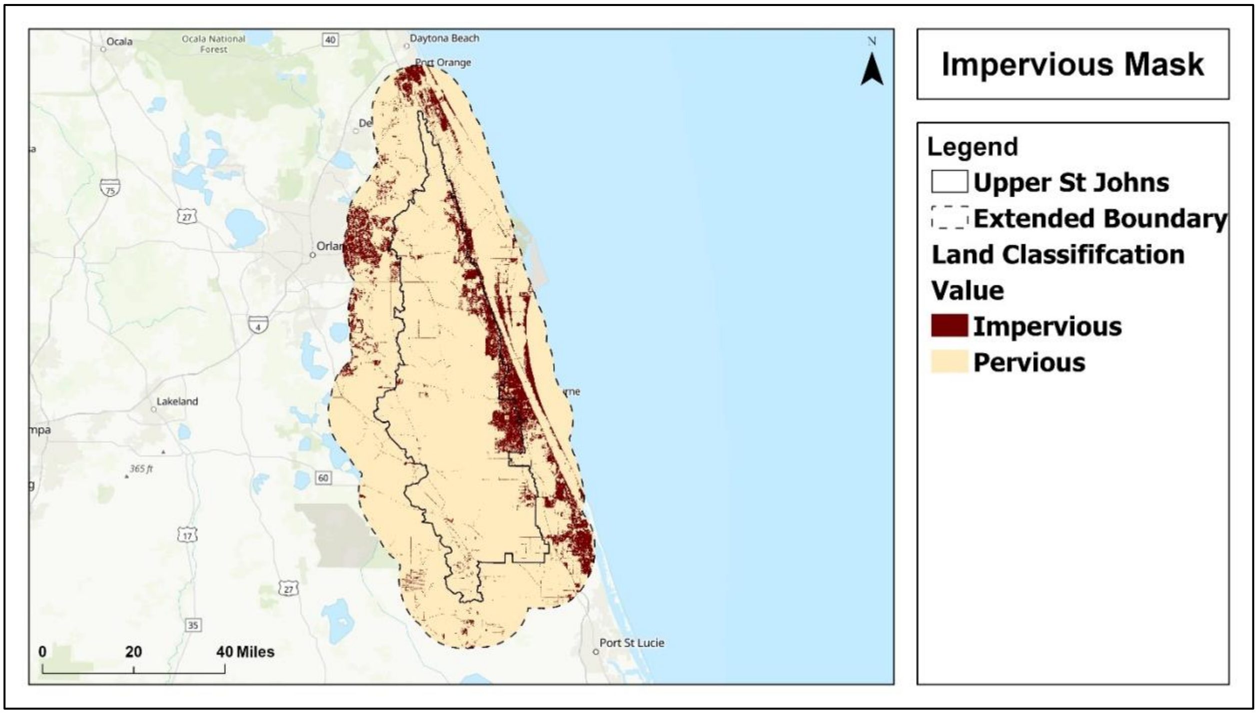

Figure 3.4: Impervious and Pervious Surface

3.1.5 Soil Capacity

Every land Surface can store excess water in the soil layer, for quantifying the unsaturated zone depth for water storage based on the type of soils present in that location. Some soil can store more water than compared to other soil, so it is better to find the relationship between soil characteristics and their water storage. The water holding capacity of the soil was calculated through the adequate processing of data from USDA's Gridded SSURGO Database. Figure 3.5 shows the water holding capacity ratio of the basin will be used to calculate the total amount of water that can be stored in the soil. Poorer ground storage will greatly influence the flooding in the watershed.

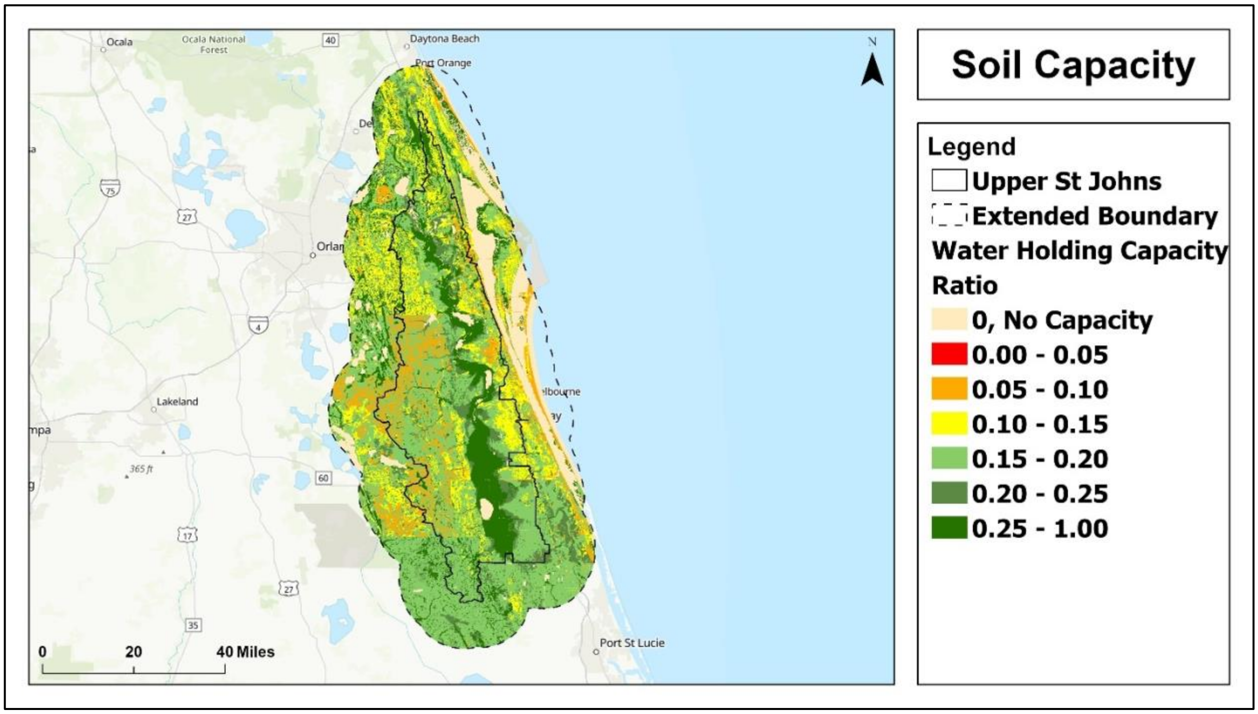

Figure 3.5: Soil Water Holding Capacity

3.2 Modeling Protocol

Flood Modeling requires various inputs to simulate the model based on the surface in Upper St Johns Basin including Groundwater table, soil storage capacity and Elevation surface. The above-discussed data were used to calculate input parameters need to run a flood simulation model called CASCADE 2001 is a multi-basin hydrologic/hydraulic routing model developed by the South Florida Water Management District (SFWMD). The model developed solutions based on the basin. A basin is defined as an area where all the water that falls via rainfall stays in an area and travels to an outlet.

Characteristics of the model are unique to each watershed basin, including the topography, groundwater, surface water, tides, soil type, land cover and rainfall. FAU's modeling protocol for the Upper St Johns basin, all the necessary input parameters to run CASCADE 2001 were calculated from existing datasets. Several surfaces were derived from the data and those are primary contributing inputs for the flood model. The areas of the basin and the longest time it takes the runoff to travel to the most distant point to reach the point of discharge must be estimated.

Rainfall is also needed. The waterway flow paths from ArcHydro as shown for Upper St. Johns River Basin.

For generating water table elevation surface throughout the basin requires spatial interpolation methods and semivariogram model. Based on the water table surface greatly contributes to flooding in the region. Observations of Groundwater well-monitoring station locations from DBHYDRO database and well distributed over an area, Surface water station gauge elevation is extracted USGS surface water for the Nation. Searched for the daily data within Florida state and downloaded spatial and Non-spatial data separately and joined together using ArcGIS Tools. The station distributed throughout the lakes, canals and river lines. Additionally, NOAA’s Trident Pier, Port Canaveral tidal station was used to determine the elevation of tides along the coastline. All stations actively observing water levels are shown in Figure 3.2.

The first step involves data collection of the Upper St Johns Basin. Based on the dataset distribution have to apply interpolation techniques to receive higher accuracy results. Utilizing the wells dataset to generate water table elevation surface applying Empirical Bayesian Kriging (EBK) in ArcGIS ESRI GIS Mapping Software. EBK is a geostatistical interpolation method that automates most aspects of building a valid kriging model. Compare to other methods have to adjust the parameters to receive accurate results, but EBK has automatically calculated those parameters through the process of subsetting and simulations. Standard error prediction is more accurate. The input parameters are described based on the output requirement such as cell size, transformation, maxlocalpoints, overlap factor, number of semivariograms, radius, angle, maxneighbours, minineighbours. sector type and output type. Cell size is the resolution of the interpolation surface. The semivariogram model depends on the transformation set to be none, so the default Power model will apply on the data, it relatively fast and flexible model. It balances performance and accuracy. The water table elevation, shown in Figure 3.6, shares a similar spatial pattern with the DEM. This is attributed to the fact that groundwater typically follows topography.

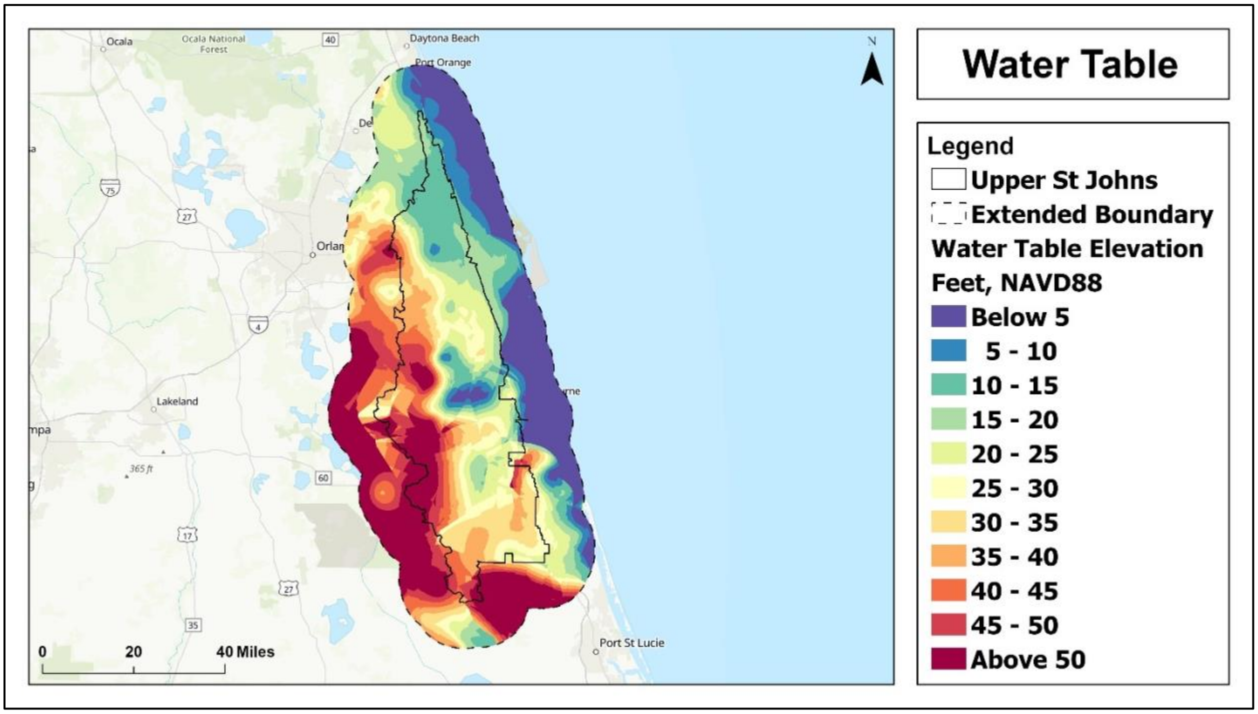

Figure 3.6: Water Table Elevation

After the water table elevations were developed, the unsaturated zone depth, the water table elevation layer, as influenced by the wells and stations elevation, was determined as the difference from the topographic layer and groundwater to yield the apparent unsaturated zone depth. In Figure 3.7, the blue indicates the unsaturated zone, also called the vadose zone. It contains the least amount of water. It varies thickness can range from zero to hundreds of meters as when a lake or marsh is at the surface. Figure 3.7 shows the unsaturated zone depth in the Upper St Johns Basin.

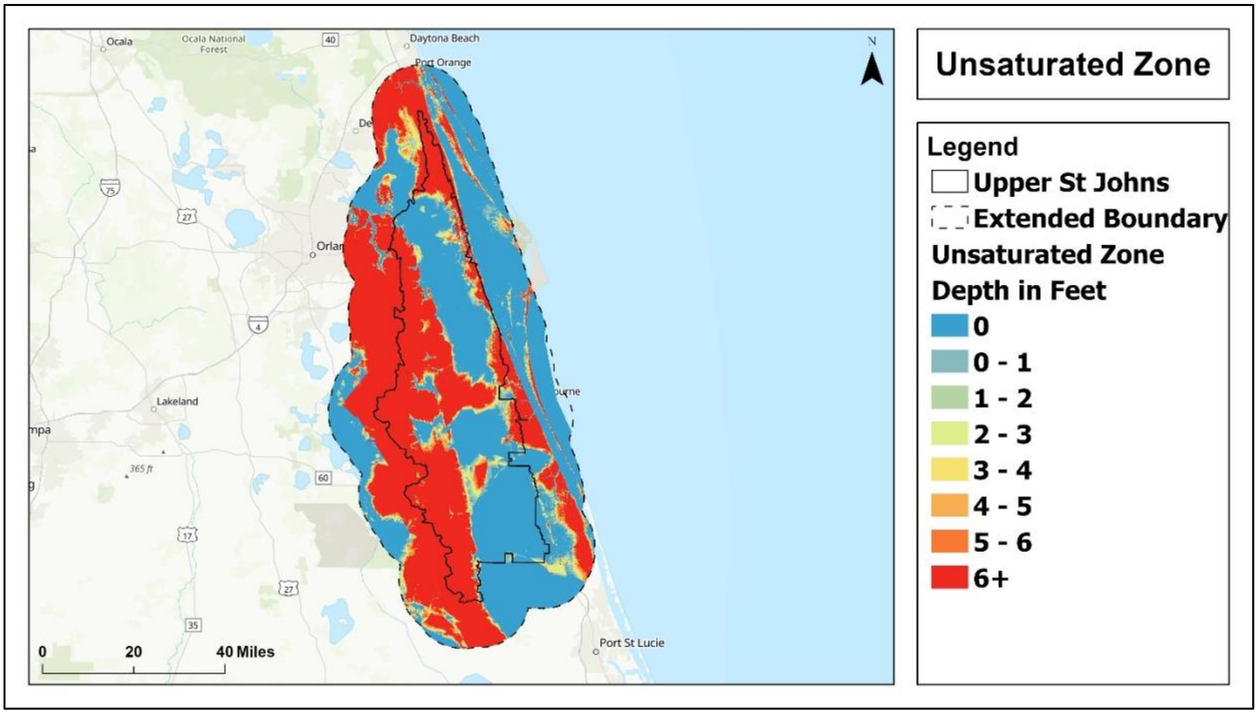

Figure 3.7: Unsaturated Zone Depth

The rainfall event is a major consideration for water storage in the soil. There will several feet distance between the land surface and the groundwater table. The main characteristics of any soil is depending on the amount of water that the soil can absorb and store it. The soil storage capacity is calculated by multiplying the unsaturated zone depth surface by the water holding capacity ratio surface. To represent groundwater storage conditions, the output surface is multiplied with land areas from existing water bodies and impervious surfaces were set to zero storage capacity. The final soil storage capacity surface is represented as the soil's characteristics and land classification type is shown in Figure 3.8.

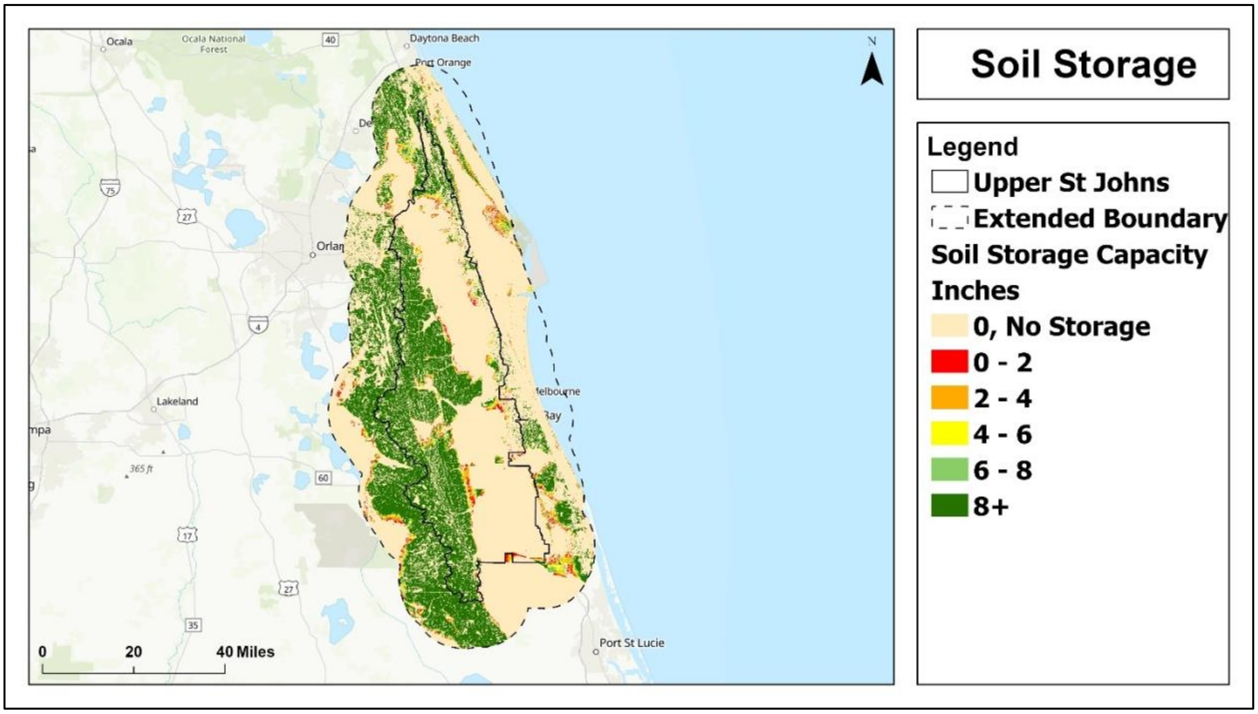

Figure 3.8: Soil Storage Capacity

The CASCADE 2001 simulation model allows for a study into the watershed's response to flooding under different rainfall events. The selected design storm for FAU's simulation is based on the SFWMD 3-day, 25-year storm. This standard-design storm represents a frequently occurring rainfall event to provide a realistic flooding scenario. The 3-day, 25-year rainfall map based on the NOAA Atlas 14 dataset is shown in Figure 3.9.

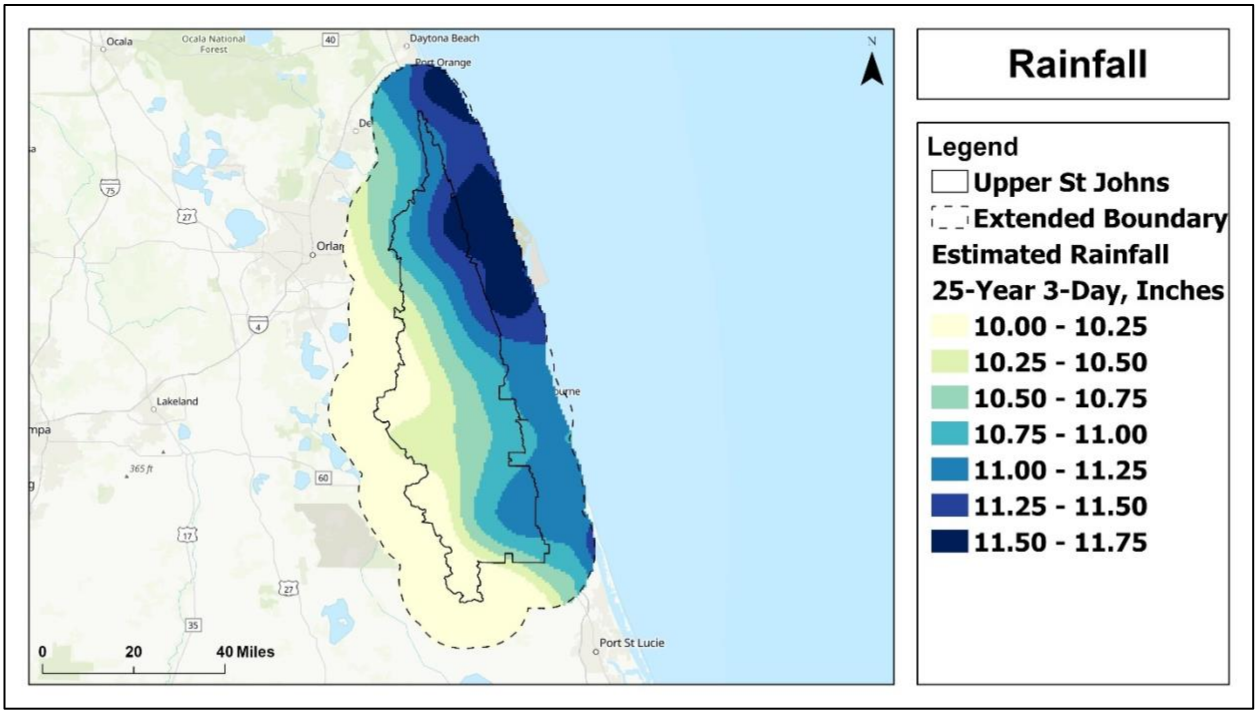

Figure 3.9: Estimated 25-Year 3-Day Rainfall

3.3 Modeling Results

3.3.1 Watershed pathways

The St John's River is split up into three basins, one of which is Upper St Johns Basin. Using the DEM data, Figure 3.10 delineates the drainage lines, drainage points and catchments within the watershed boundary using ArcHydro Tools in ArcGIS. This is advantageous as the CASCADE 2001 model supports multiple inputs for basins and drainage structures, which represent the characteristics and connections of upstream and downstream basins.

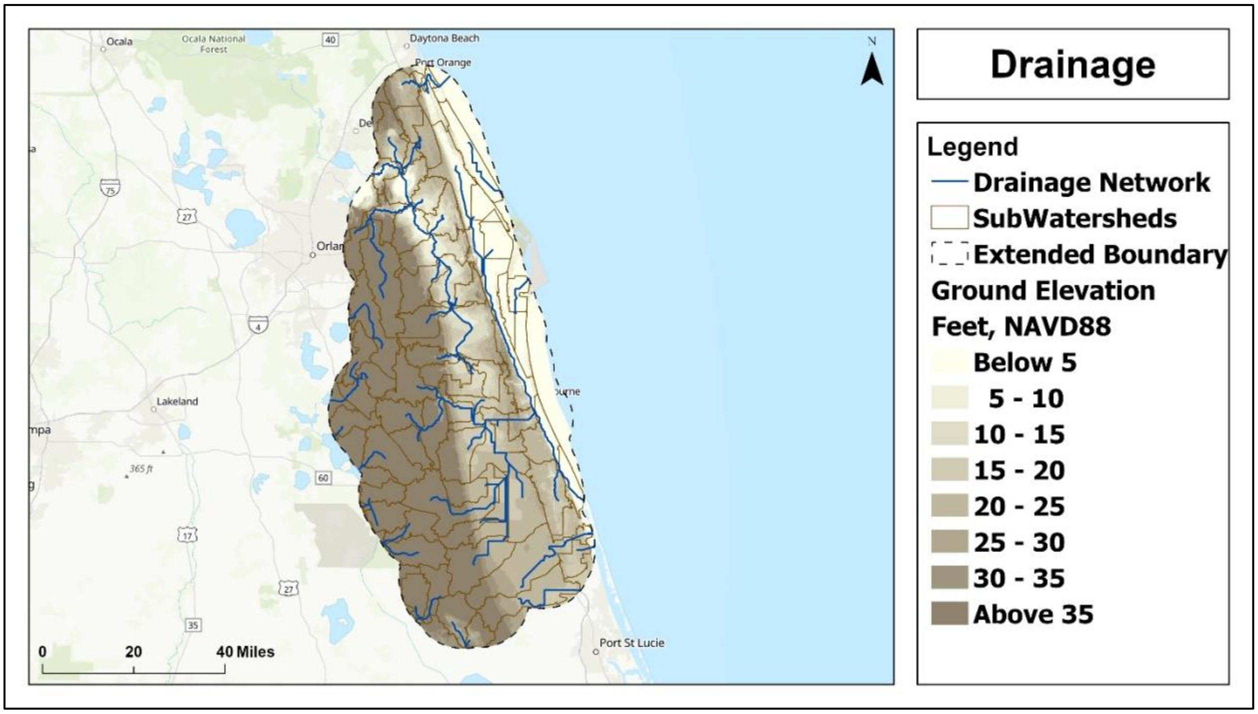

Figure 3.10: Catchment and Drainage Network

3.3.2 Cascade Results

After following FAU's modeling protocol, all required input parameters for CASCADE 2001 were calculated. The input parameters represent factors that influence flooding; for example, the topography, groundwater table elevation, and soil storage capacity. The original datasets and derived surfaces are GIS-compatible, so direct measurements and zonal average statistics were used to calculate the input parameters for each subwatershed. The drainage structures' information was obtained from the U.S. Army Corps of Engineers, the organization operating and maintaining these structures (USACE, 1993) as follows:

- Initial Stage (ft NGVD) = 2.24
- Ground Storage (Inches) = 9.96
- Rainfall for 25 Years, 3 Day (Inches) = 10.6
- Area (acres) = 3086451.12
- Time of Concentration (hrs.) = 25.28

To define the stage-storage relationship, click the calculate button and the stage levels need to be inserted. It starts from the initial stage and increases it to an upper limit of elevation in feet. We also need to add the sub-area of land or water and provide the low elevation in feet and the highest elevation of the land which is 262.18 ft.

After Input the values for the basin, we have inserted the structure for the basin, which controls the flow of water along the river line, which is connecting the offsite receiving body with a basin, based on the assumption and guidance that have been used the gravity sharp weir structure, setting the crest elevation is the initial stage of the basin. The length should be the width of the river channel.

Gravity Structure

- Crest Elevation (ft) = 2.24
- Length(ft) = 120

Under these constraints, the CASCADE 2001 model simulates the rise of floodwaters during a 3-day 25-year storm. The goal is to obtain the maximum headwater height in each subwatershed as any land areas below this elevation will be flooded. The identification of flood-prone areas within the Watershed is crucial to inform the decision-making process of prioritizing and allocating funding.After the Set-Up of the project is completed, the next step is to run the model. The final results were shown as a PDF document. The Headwater Height of Upper St Johns Basin is 10 feet. The flooded areas during a 3-day 25-year storm in the Watershed are shown on the map in Figure 3-11.

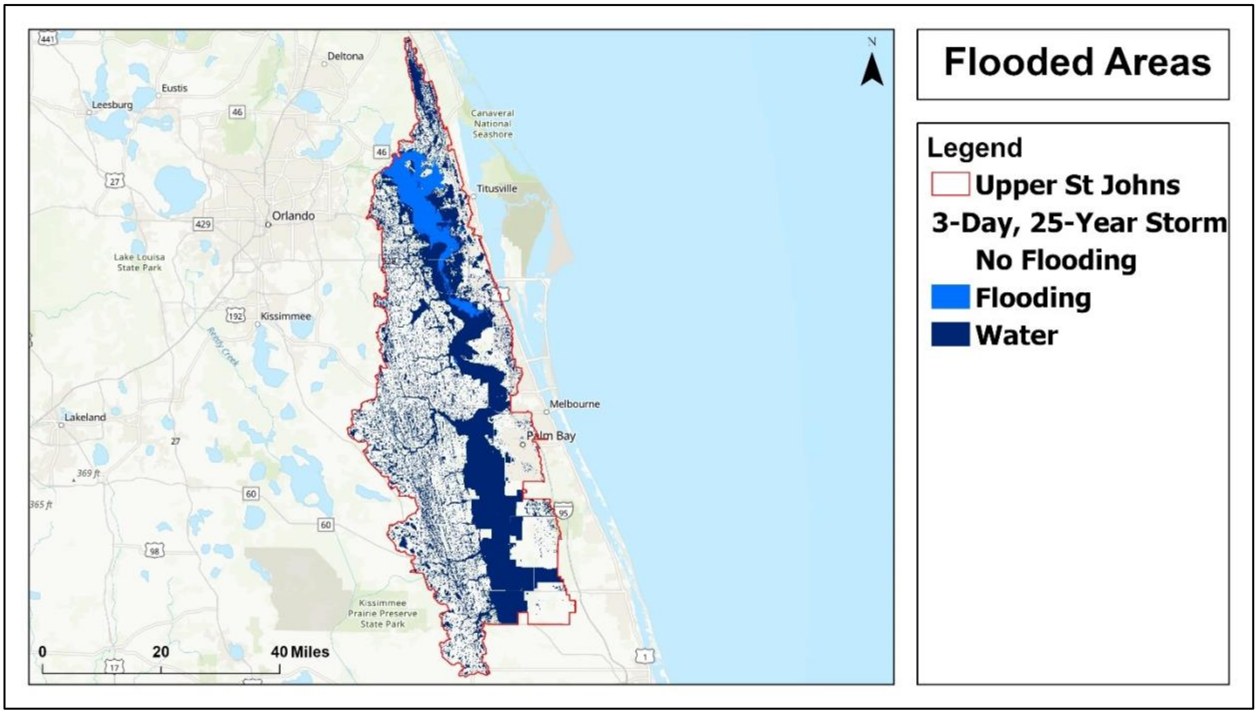

Figure 3.11: Flooded areas

3.3.3 Vulnerability to Flooding

To accurately delineate the flooding areas in Upper St Johns River, Florida. We have used a high resolution of topographic data derived from LiDAR with groundwater table, Rainfall, Soil storage Capacity to the prediction of headwater height resulting from hydrological modeling using Cascade CRT (SFWMD, 2001). Flood risk is defined as the probability of inundation based on ground elevation data. It's a simple bathtub mapping approach taken into consideration that vertical accuracy error in the elevation datasets which may vary depending on the available data spatial resolution. The uncertainties associated with the DEM vertical accuracy estimated depths to the groundwater table and the modeling approach itself are incorporated in the RMSE computation. We have used the below formula for the Cumulative Probability. we will use the value suggested by NOAA for the compact counties coastal vulnerability assessments which are 0.46.

Z-Score = [(high headwater height)- (Ground Elevation from LiDAR DEM)]/ SQRT(RMSE_LidaDEM2+RMSE_CRT2001Model2)

Z - Score = ((Headwater Height –LIDAR DEM Elevation)/ 0.46

After Z Score raster surface has been calculated using Raster Calculator from ArcGIS, the risk must be reclassified into 4 classes with cutoff z values in Table 2. The result is a risk of v=flooding as shown in Figure 3.12.

Table 2: Risk of Flooding based on Z Scores

Risk of Flooding	**Range of Corresponding Z values**
Low-Moderate Risk (Below 50%)	<-1.282 to 0
Moderate-High Risk (50%~75%)	0 to 0.675
High Risk (75%~90%)	0.675 to 1.282
Higher Risk (Above 90%)	>1.282

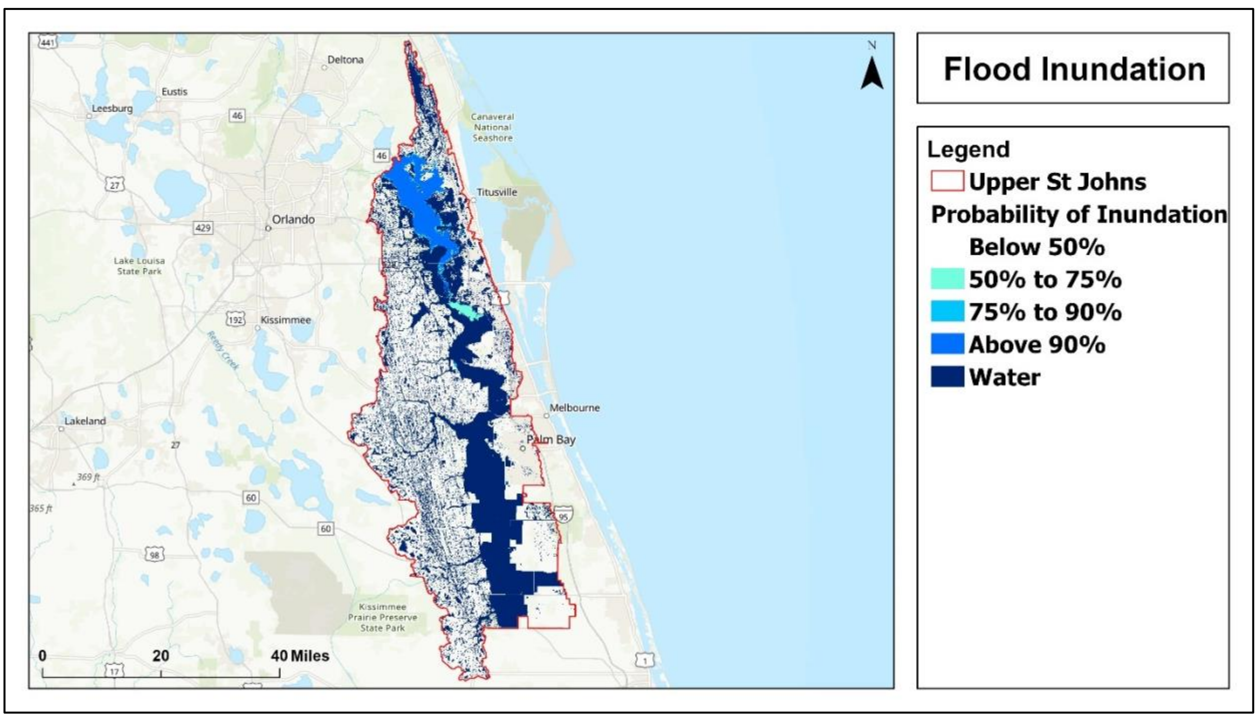

Figure 3.12: Flood Inundation of Upper St Johns Basin.

3.3.4 FEMA Flood Map Comparison

The Federal Emergency Management Agency is an agency of the United States Department of Homeland Security. The agency's primary purpose to coordinate the response to a disaster that has occurred in the United States. FEMA manages the National Flood Insurance Programs. The National Flood Hazard Layer (NFHL) datasets represent the effective flood for the whole United States. The maps available on the website are considered as the best online resources to use for official National Flood Insurance program purposes when determining the locations with regulatory flood hazard information. Based on the modeling protocol by Florida Atlantic University mapped the flood zone of Lower St Johns Basin compare the flooded areas with FEMA Risk Maps.

The 3-day 25-year design storm was selected by FAU to model the watershed's flood response and generate flood risk maps. The existing Flood Insurance Rate Maps (FIRMs) released by FEMA focus on identifying Special Flood Hazard Areas (SFHAs) and classifying the flood risk associated with SFHAs. However, FEMA utilizes the 100-year flood event where there is a 1% annual chance of flooding and the 500-year flood event where there is a 0.2% annual chance of flooding to generate FIRMs. Despite using different flooding scenarios, it is still useful to make the comparison between FAU's recently developed flood risk maps and FEMA's existing FIRMs. Both maps identify vulnerable areas and classify the risk associated with areas that are prone to flooding.

However, FEMA modeled the flood zone based on the 100-year event, so as compare to FAU based probability of Inundation does not match with that, but some of the places covered the same probabilities for flooding that FEMA. FEMA flood hazard areas identified on the Flood Insurance Rate Map are identified as a Special Flood Hazard Area (SFHA). SFHA are defined as the area that will be inundated by the flood event having a "1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. SFHAs are labeled as Zone A, Zone AO, Zone AH, Zones A1-A30, Zone AE, Zone A99, Zone AR, Zone AR/AE, Zone AR/AO, Zone AR/A1-A30, Zone AR/A, Zone V, Zone VE and Zones V1-V30. Moderate flood hazard areas, labeled Zone B or Zone X (shaded) are also shown on the FIRM and are the areas between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood. The areas of minimal flood hazard, which are the areas outside the SFHA and higher than the elevation of the 0.2-percent-annual-chance flood, are labeled Zone C or Zone X (unshaded). The Special Flood Hazard Areas designated by FEMA in the Lower St. John's River Watershed are shown on the map in Figure 3-13. The areas identified by FEMA as being in the 1-percent-annual-chance flood hazard region correspond to a high risk of flooding during the 100-year flood event.

FAU Flood risk Model results compared quantitatively with FEMA Flood Risk. We analyzed FEMA 1% chance to flood areas and our areas with a high probability to flood (> 90%), and quantified the difference, as shown in Table 3. The coverage of FEMA's 1% flood area is much larger than our protocol estimated vulnerable areas with a high probability. The overlapped areas between FEMA and our maps are 343.91 km2, accounting for 15% of total area of FEMA's 1% flood region, and 61% of our total identified vulnerable areas. This difference was expected because we used the 3 day-25 year precipitation scenario, while FEMA applied other assumptions. We had no intention to duplicate FEMA datasets.

FAU Flood risk Model results compared quantitatively with FEMA Flood Risk. We were analyzed FEMA 1% chance to flood areas and our areas with a high probability to flood (> 90%), and quantified the difference, as shown in Table 3. The coverage of FEMA's 1% flood area is much larger than our protocol estimated vulnerable areas with a high probability. The overlapped areas between FEMA and risk maps are 10 km2, accounting for 1% of total area of FEMA's 1% flood region, and 51% of our total identified vulnerable areas. This difference was expected because we have utilized the 3 day-25-year precipitation scenario, while FEMA applied other assumptions. There was no intention to duplicate FEMA datasets.

Table 3: Comparison between areas FEMA and FAU Flood model vulnerable areas

FEMA and our protocol	**Results**
FEMA 1% flood area (total: km_2)	4455.96
Our estimated area (total: km_2)	9.9023
Overlapped area (total: km_2)	5.8924
Percentage of overlap to FEMA (%)	0.13%
Percentage of overlap to our model (%)	51.2%

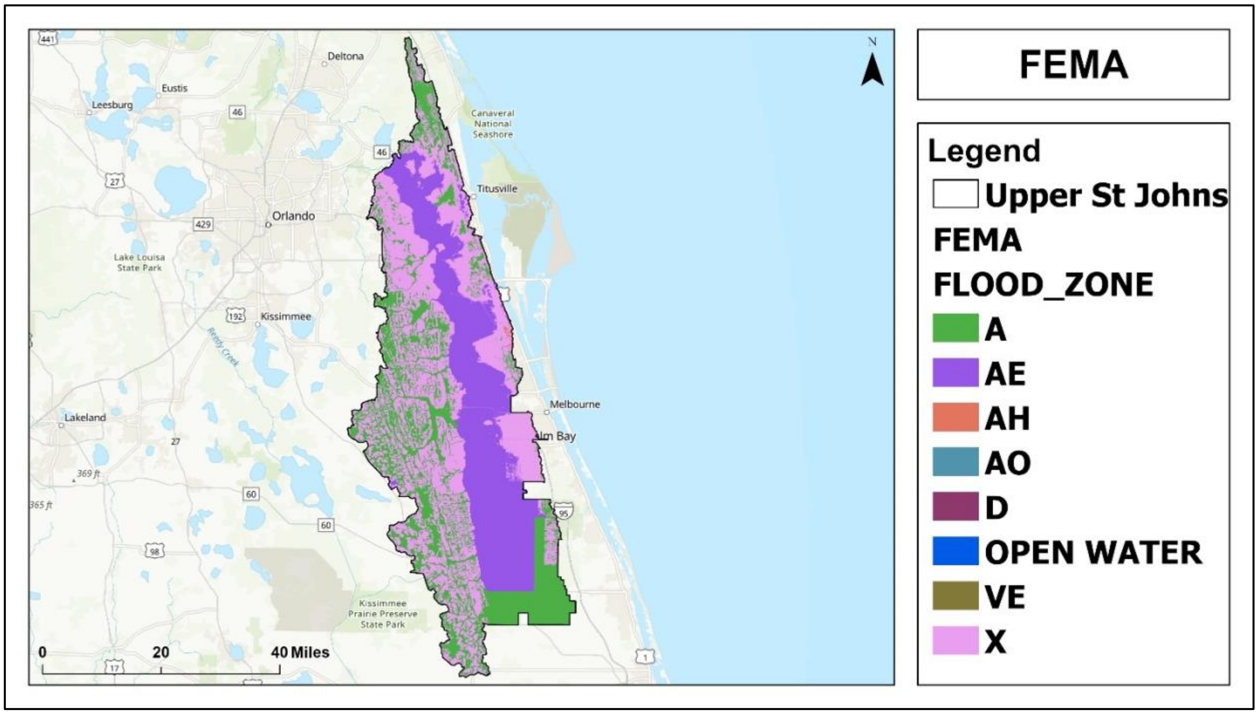

Figure 3.13: FEMA based Flood areas

3.4 Repetitive Loss

Figure 3.14 shows a comparison of the flood map and repetitive loss property locations for the basin. The loss areas coincide with the areas predicted by the FAU model as being at risk for flooding.

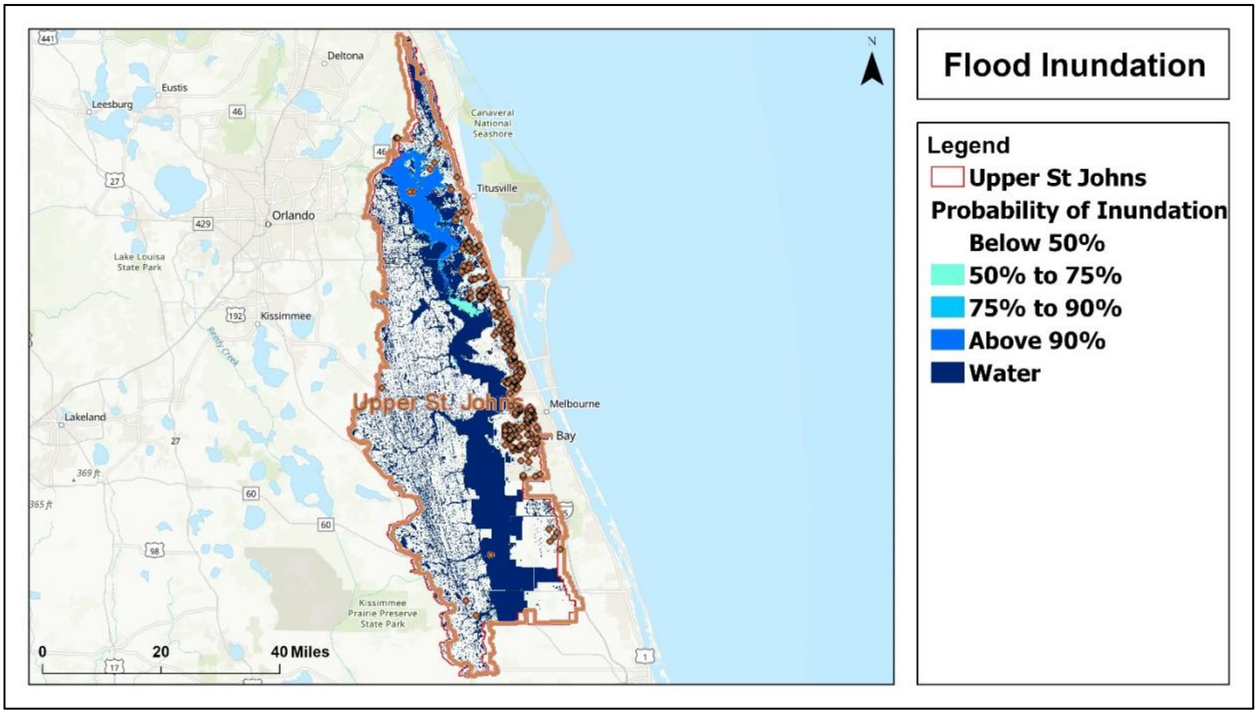

Figure 3.14: Repetitive loss areas from 2004 -2014 superimposed on the flood risk map created by FAU.

3.5 Drill down in Developed Areas Loss

Flood Inundation areas was further drilled down and compared to the developed areas within the watershed basin. Figure 3.15 shows the areas of the basin that are developed and flooded so further drill down could be conducted. The drill down maps show the Palm Bay, West Melbourne and Titusville areas of critical importance.

1) Palm Bay is one of the populous cities in the Brevard County and also is situated in the Central Florida. The area was lied turkey creek at the mouth of Indian river, which flows to the Atlantic Ocean. Turkey creek is source of water inlet into the city, which influences and makes the area vulnerable for flooding. Figure 3.17 shows the flooded areas in the city.
2) West Melbourne is also a city in Brevard County. The city is highest population growth percentage in the county. The total area of the city of 10.2 square miles of land and 0.20 square miles of water. Figure 3.18 shows Flood vulnerable areas in the city.
3) Titusville is also one of the city in Brevard County. The demographics of the city was drastically growing as of United States Census. The city is located along the Indian river and west of Merritt Island. The city extends total area of 34.2 square miles, 29.4 square

miles and its 15 percent of water. It is located on the Indian river Lagoon part of the Atlantic Intercoastal waterway which influences and makes the city vulnerable to flood. Figure 3.19 shows the flood model developed by FAU.

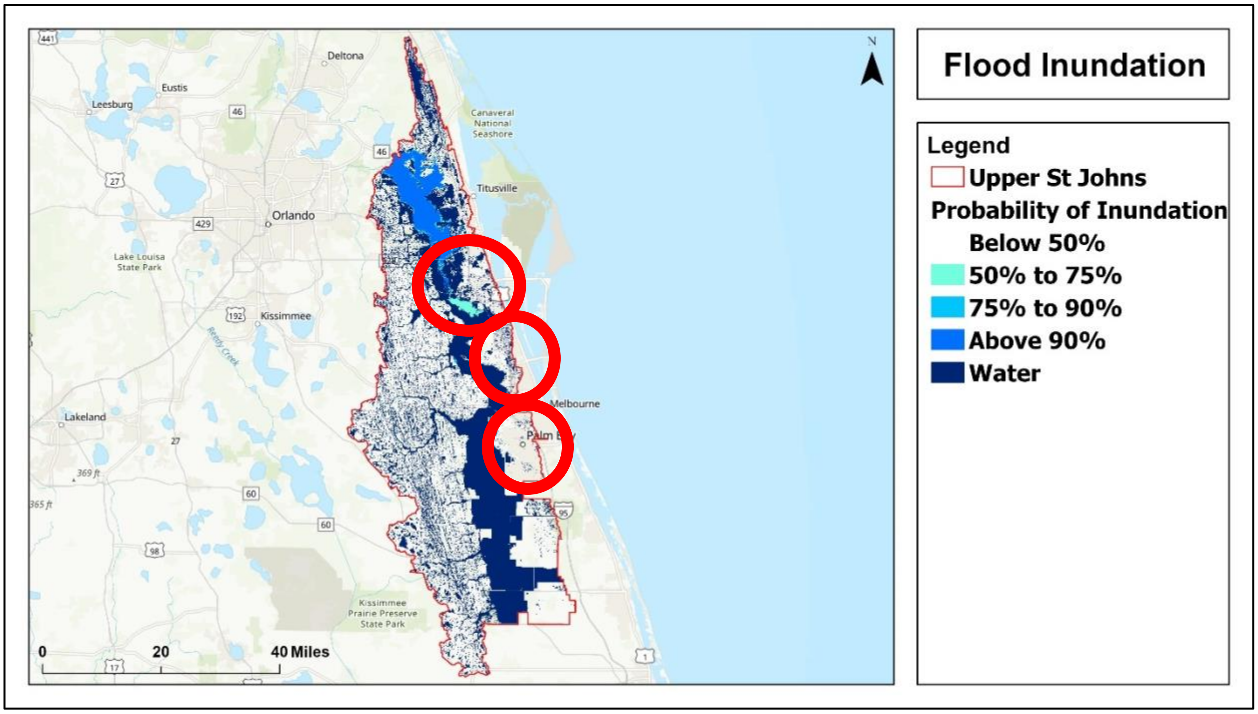

Figure 3.15 : Location of three drilldown areas

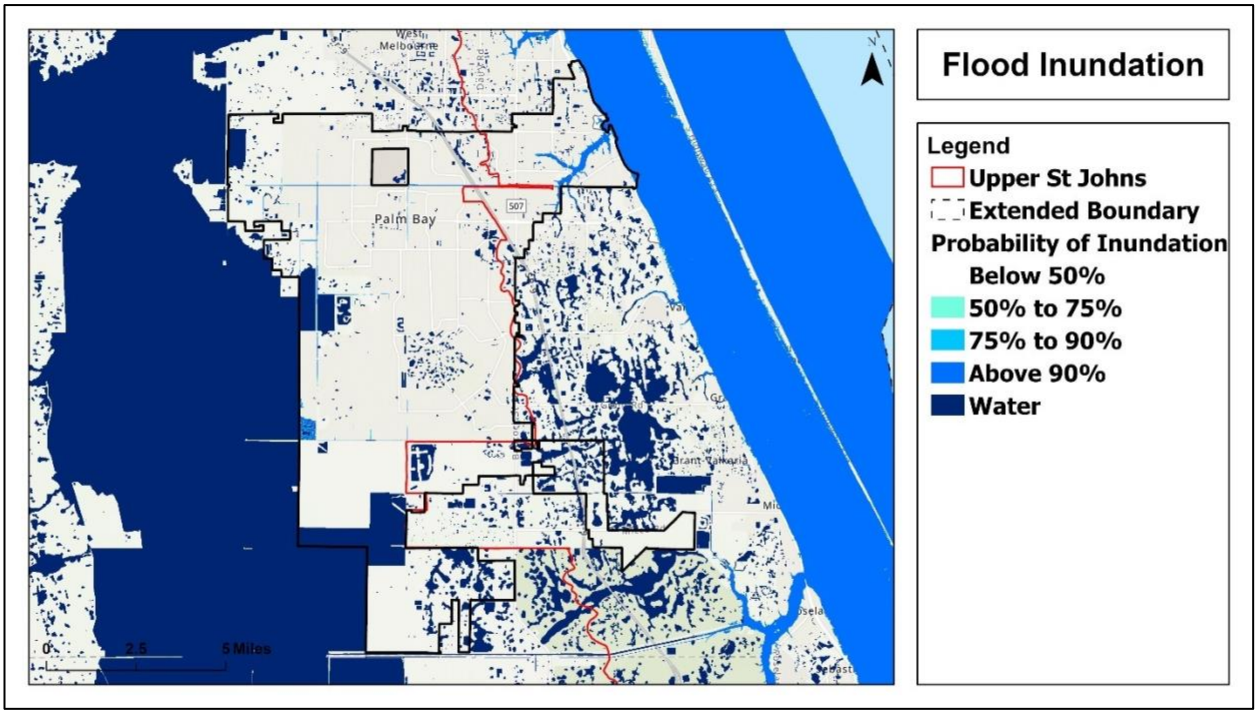

Figure 3.16 : Flood Inundation of Palm Bay

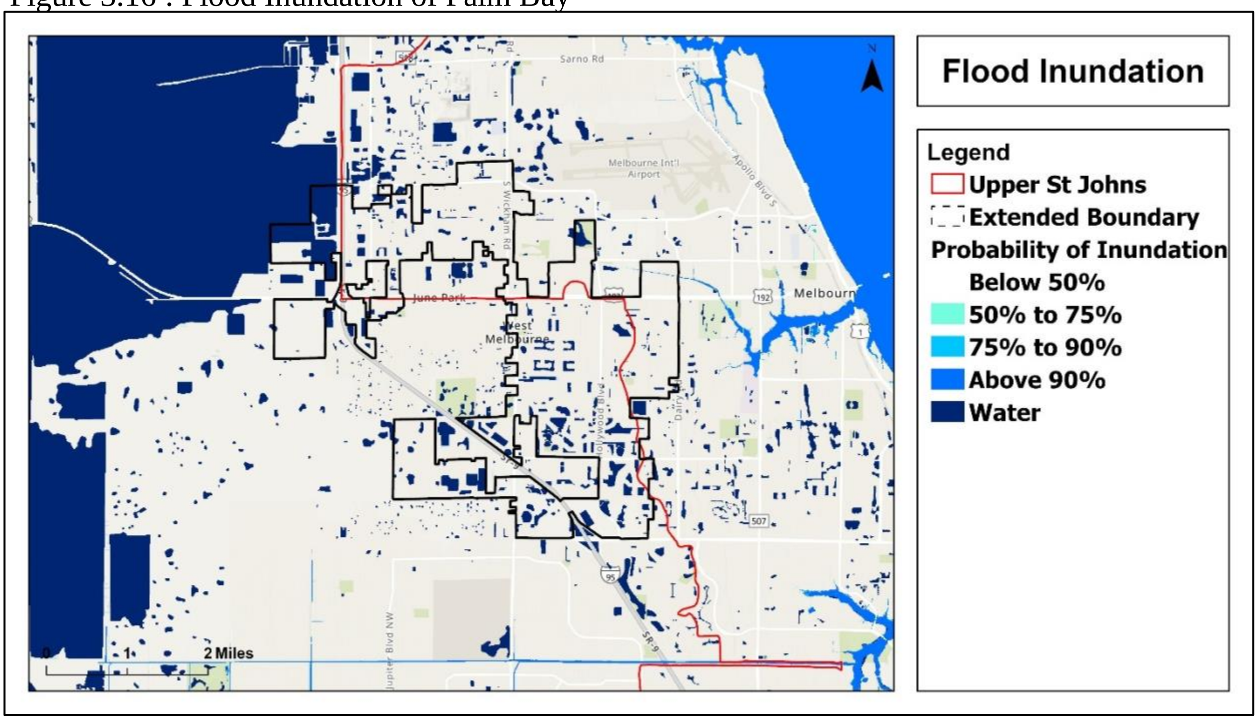

Figure 3.17 : Flood Inundation of West Melbourne

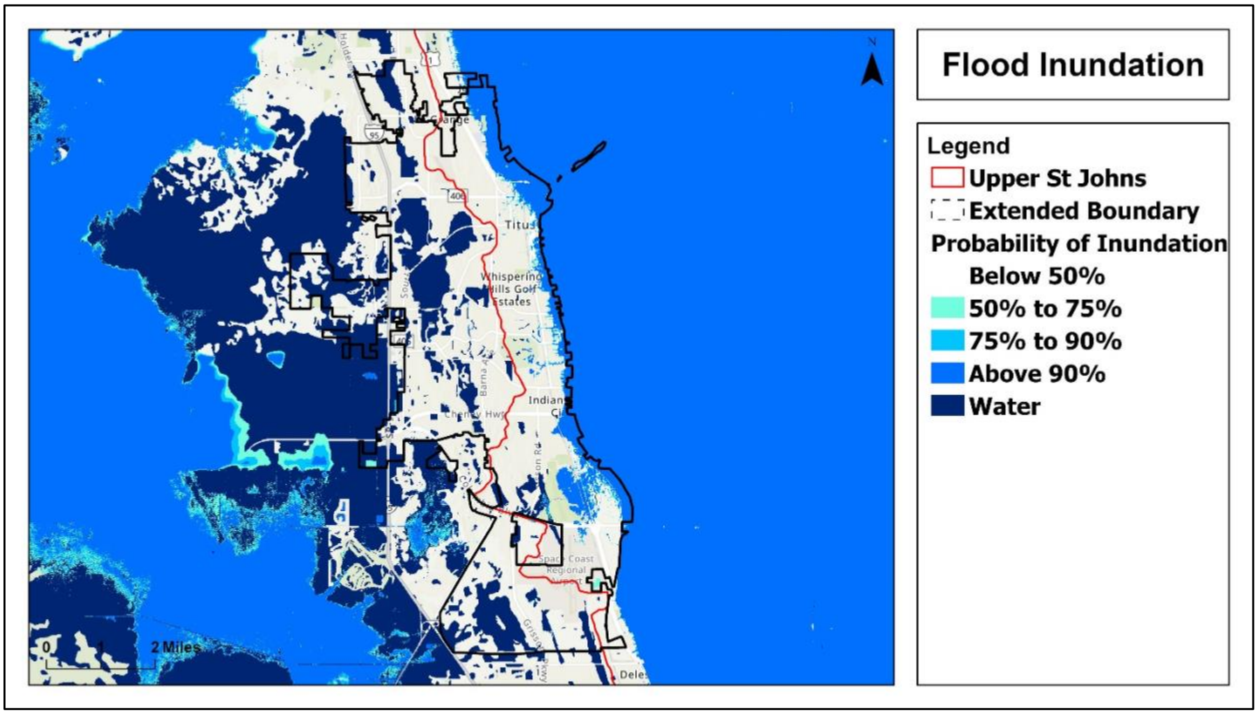

Figure 3.18: Flood Inundation of Titusville

4.0 Conclusion

Upper St Johns is divided from St Johns Basin longest river in South Central Florida. It flows towards the north direction from the south. The basin covers a full extended river line from end to end. The ground elevation is above 250 feet due to that water enters into the Lower Basin. In the modeling considered all aspects of data, which influence the flooding over the region. The terrain surface is the main influencer for flood happenings and groundwater table elevation, soil storage capacity, Land use and Landcover, Water bodies, Rainfall event for 25 years, drainage patterns, catchments of the basin. CASCADE 2001 is a multi-basin hydrologic/hydraulic routing model developed by the South Florida Water Management District (SFWMD). This software helps to simulate the basin more concisely to recreate the earth that users utilize to work on the Florida Watershed Modeling Project. The Output of Hydrologic Modelling shows the results for the headwater height of the basin, using the values to create flood inundation using the topographic surface. A flood happens in the basin, when the headwater height reaches above 10 feet, which will affect the most of the areas near or around the river line because when water increase in the river due to heavy rainfall event or water intrusion happens due to sea level rises from the coastal zone. The places near to the river line are the most probable flood zones and elevation will be very low, so the water gets drains from the higher elevation to lower elevation.

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