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Lower St. Johns River Basin Case Study

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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 Lower St. Johns River Basin located in Northeast 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

Lower St Johns River basin is located in Northeast Florida from Putnam County to the river's mouth in Duval County (see Figure 1) and is an elongated estuary that extends about 101 miles from its union with the Ocklawaha River to the Atlantic Ocean and joined near its mouth by the Atlantic Intracoastal Waterway. The source of the river is a large marshy area in Indiana River County, it flows from the north and turns eastward at Jacksonville top its mouth in the Atlantic Ocean. The greatest tidal effects are felt near the mouth at Jacksonville. Jacksonville is the only metropolitan area in the basin, has a population of more than one million residents. The lower portion of the St Johns River basin is extending from Lake George to the river's mouth at May port. The Lower basin covers an area of 2820 square miles in Northeast Florida and its part of nine counties such as Alachua, Baker, Bradford, Clay, Duval, Flager, Putnam, St. Johns and Volusia. The basin is highly varied and influenced mainly by the interaction of tide, wind, freshwater flows and confines of the river banks and bottom.

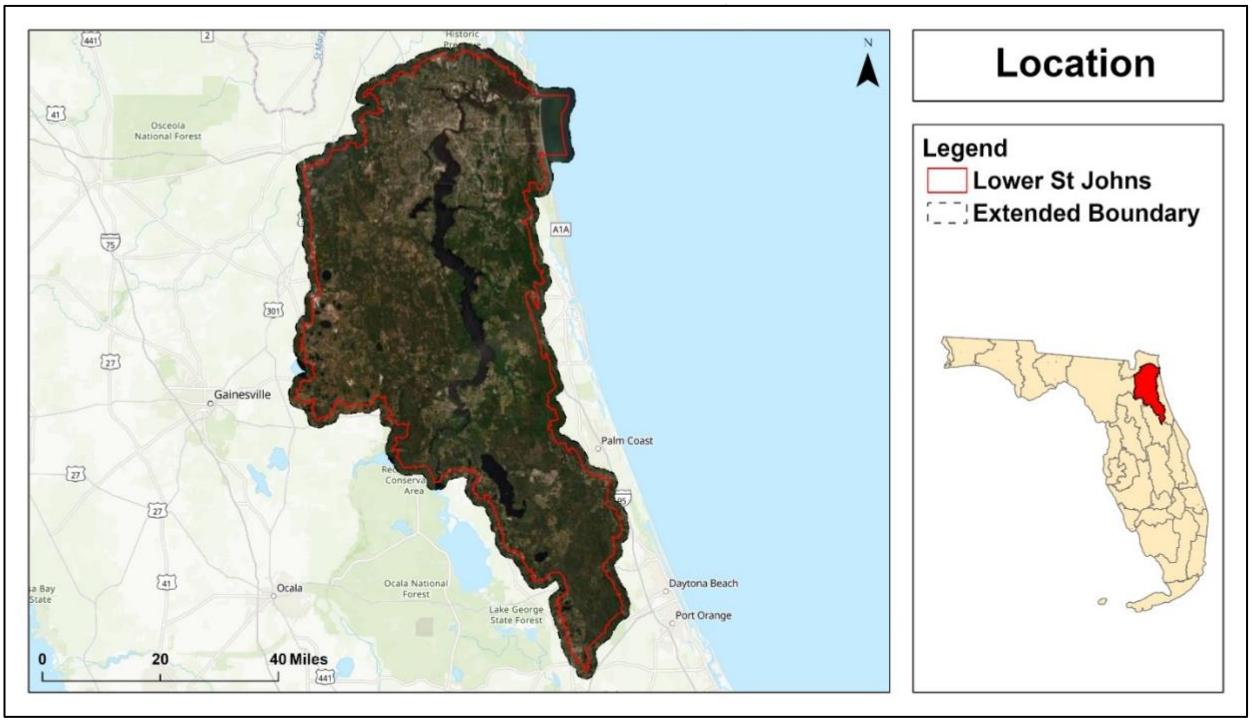

Figure 1: Location of Lower St Johns Basin, Florida

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. Temperature is always high on average. 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. The river extends long backwater. Based on the expected salinity differences ecology zones will be differentiated in Lower St Johns River Basin.

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 Lower St Johns Basin. All data was gathered for a few miles extended boundary to ensure complete coverage of the study area. The primary surface water features of the watershed driving the flow of water from south to north are as follows: river and tributaries such as Arlington River, Black Creek, Deep Creek, Sixmile Creek, St. Johns River, Etonia Creek, Julington Creek, McCullough Creek, Broward River, Dunns Creek, Ortega River, Trout River and Atlantic Intracoastal Waterway. Lakes such as Crescent Lake, Lake Ross, Cue Lake, Leeds Pond, Lake Disston, Kingsley Lake, Lake Geneva, Lake Lowery and Doctors Lake. Swamps such as Rice Creek Swamp, Twelvemile Swamp, Tiger Hole Swamp and Pottsburg Creek Swamp.

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.

2.2 Socio-economic Conditions of the Watershed

2.2.1 Demographics (US Census, 2018)

As of the 2018 5-year ACS, Lower St Johns Basin had 1,423,852 people as shown on Table 1.

Table 1: Demographics of Lower St. John's River Watershed

Name	Total	Percentage(%)
Total Population	1,423,852	
Total: Households	533,561	37.47
Population Male	695,975	48.88
Population Female	727,877	51.12
Population White alone	970,912	68.19
Population Black or African American alone	320,939	22.54
Population American Indian and Alaska Native alone	3,186	0.22
Population Asian alone	56,095	3.94
Population Native Hawaiian and Other Pacific Islander alone	948	0.07
Population Some other race alone	24,237	1.70
Population Two or more races	47,535	3.34
Population Hispanic or Latino by Race	131,635	9.24
Not Hispanic or Latino:White alone	875,187	61.47
Average household size Total: Average Household Size of Occupied Housing Units by Tenure	1,801	0.13
Total: Household Type by Relatives and Nonrelatives for Population in Households	1,395,722	98.02
Population in family households	1,160,145	81.48
Population in nonfamily households	235,577	16.55
Family households	351,651	24.70
Average family size (Total Population In family households/Family households)	2,302	0.16
Population Under 5 years	89,472	6.28
Population 5 to 17 years	236,033	16.58
Population 18 to 21 years	69,511	4.88
Population 40 to 49 years	181,938	12.78
Population 50 to 64 years	283,866	19.94
Population 65 and up	210,993	14.82
Population 85 years and over	22,481	1.58
Median age for population	28,199	1.98
Households Total: households for poverty status in the past 12 months by household type by age of householder	533,561	37.47
Population Total: Poverty Status of Individuals in the Past 12 Months by Living Arrangement	1,393,565	97.87
Total Housing Units	607,327	42.65
Total Vacant housing units	73,766	5.18
Households with No public assistance income	520,023	36.52
Households with public assistance income	13,538	0.95
Single Family	414,095	29.08
Mulit Family	140,432	9.86

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. It mostly covered industrial areas in Jacksonville. The community is primarily residential with small concentrations of commercial activities along the US, the beach and the larger cities.

2.2.3 Economic Activity/Industry

Many advancing cities and industries of the Florida state are in the Northeast region. Thousands of tourists attracting to the historical sites year-round is one of the oldest city-state St. Augustine. Jacksonville, in Duval County, was topped No. 2 by Data Fox for the "Best Cities for Tech" in 2016. This space borders between the Atlantic, creating it a first-rate space for international trade and marine industries. Exceptional economic diversity and a variety of manpower opportunities available in three counties of Northeast Florida.

Six major cities are covered in the northeast region such as Fernandina Beach, Amelia Island, Jacksonville, St. Augustine, Palm Coast and Bunnell bordering the Atlantic coastal line. These cities are key players in finance, technology and even manufacturing and also popular for tourism. Across the St. John's River basin has several major cities in manufacturing as well as logistics and transportation.

Major corporations have opened up their locations, including Ernst & Young, Citibank, Southeastern Grocers, LLC and Amazon. Major importers like BMW North America additionally attract more business to the coastal regions.

The regions are base for a strong educational system, with eight colleges and six high schools earning places within the U.S. News & World Report's "2016 Best High Schools.", University of North Florida (UNF), was also considered one of the top colleges and largest college campus. It is a public Florida university, with strong medical and nursing programs.

Students and young talent have a lot of chance to grow their careers in Northeastern Florida. Research and Analysis centers giving hands-on experience with some of the best in medical, pharmacology and nursing fields in the city. The region also has many technology startups to attract staff from outside the state.

Just outside Northeast Florida are beaches and traveler attractions that bring guests from out of state. Tourism in this region is not as prominent as it is in other parts of the state, however, the other regions bring a healthy influx of workers. Newly emerging markets of northeast Florida is a great place to work and grow business.

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 lands areas are a higher possibility of getting floods than high land 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 240 ft above the ground level adjacent to Kingsley valley. The basin has small lakes and ponds and ended up Jacksonville and Ponte Vedra Beaches. Project the elevation surface into NAD 1983 UTM Zone 17 N coordinate system, converting vertical units into feet.

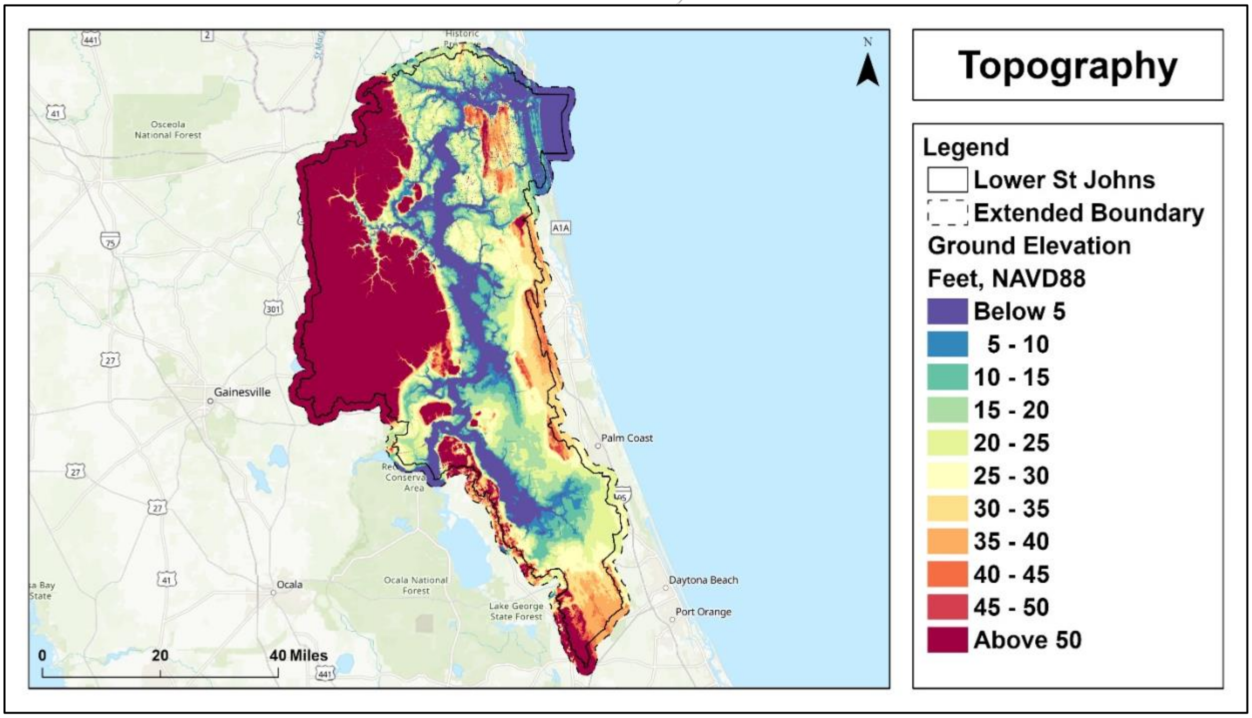

Figure 3.1: High Resolution Digital Elevation Model

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 December 12th 2018 for the Lower 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 many areas of Florida, espeiclaly where there is limited topographic relief, such as this watershed. When there is little topographic relief, groundwater is controlled by the canals, rivers and tides. The Lower St Johns River Basin has a large number of groundwater monitoring stations, so 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 December 12th 2018 for the Lower 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 24 station observations available on this date.

The Mayport Bar Pilots Tidal station at the Lower St Johns Basin 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 August 1995. The tidal gauge observation was gathered from the station dated December 12th 2018. As shown in Figure 3-2, there is one station observation available on this date.

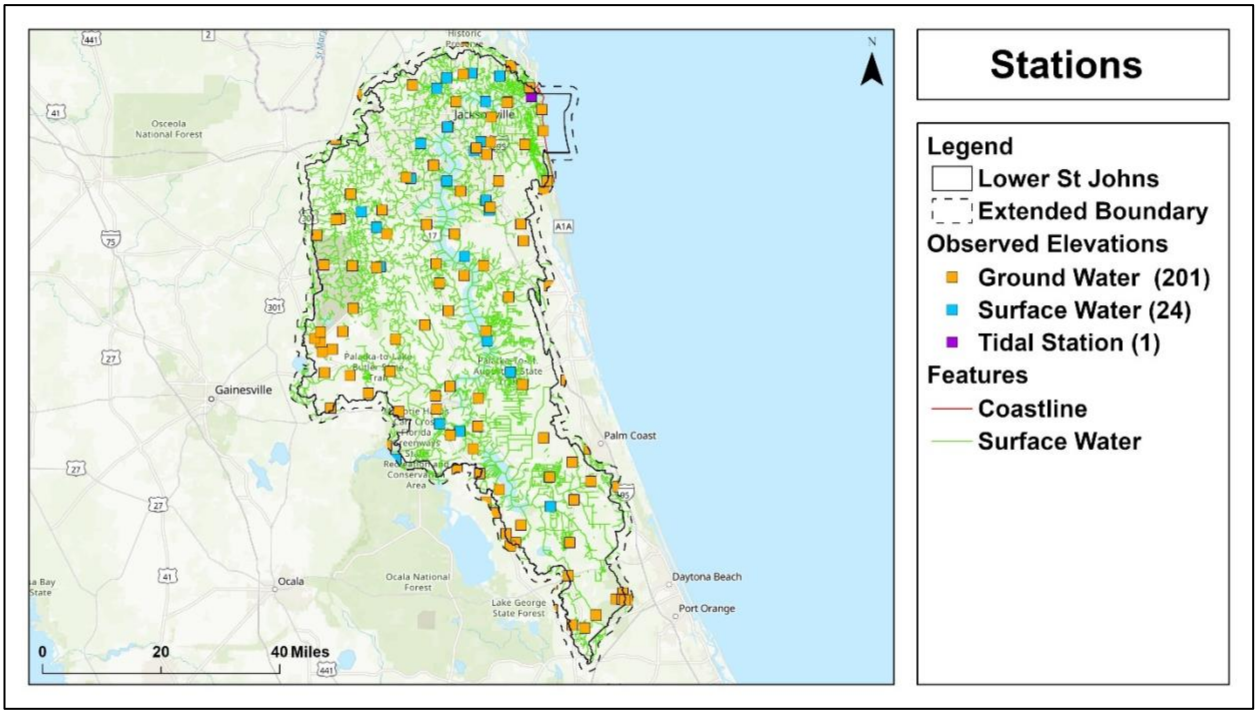

Figure 3.2: Groundwater, Surface Water and Tidal Station Locations

3.1.4 Open Space

Impervious area 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.

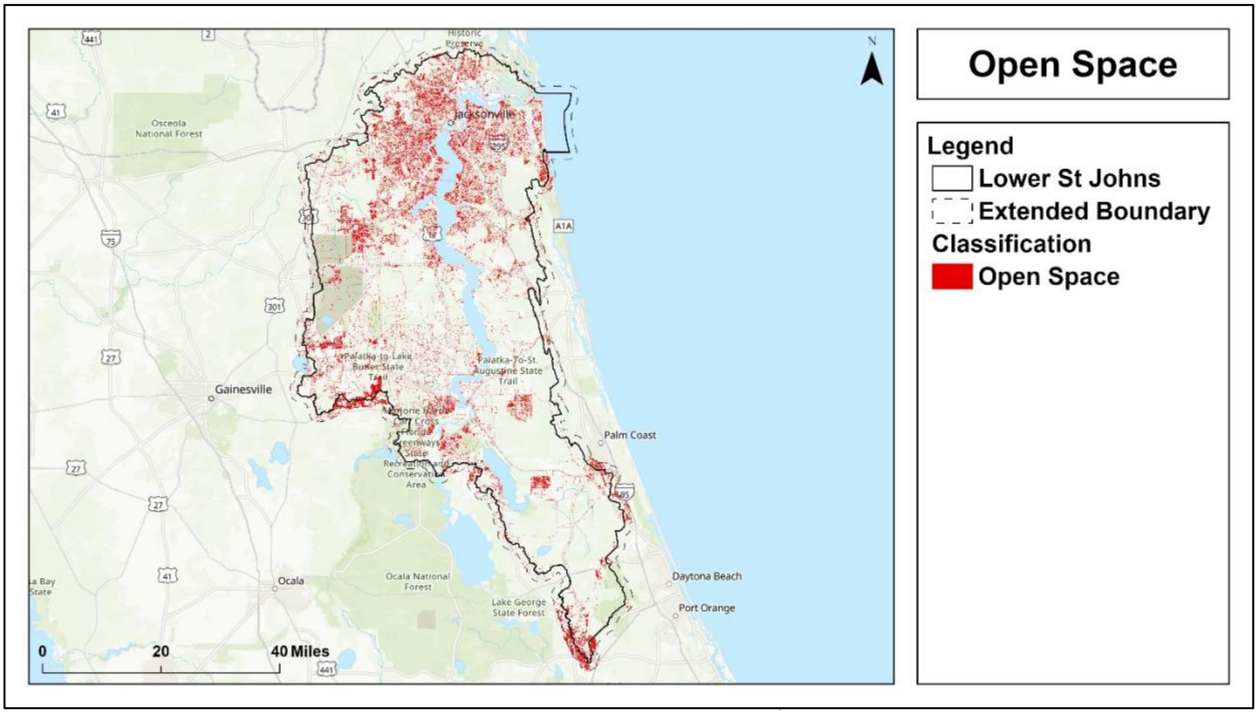

Figure 3.3: Open Space Surface

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.

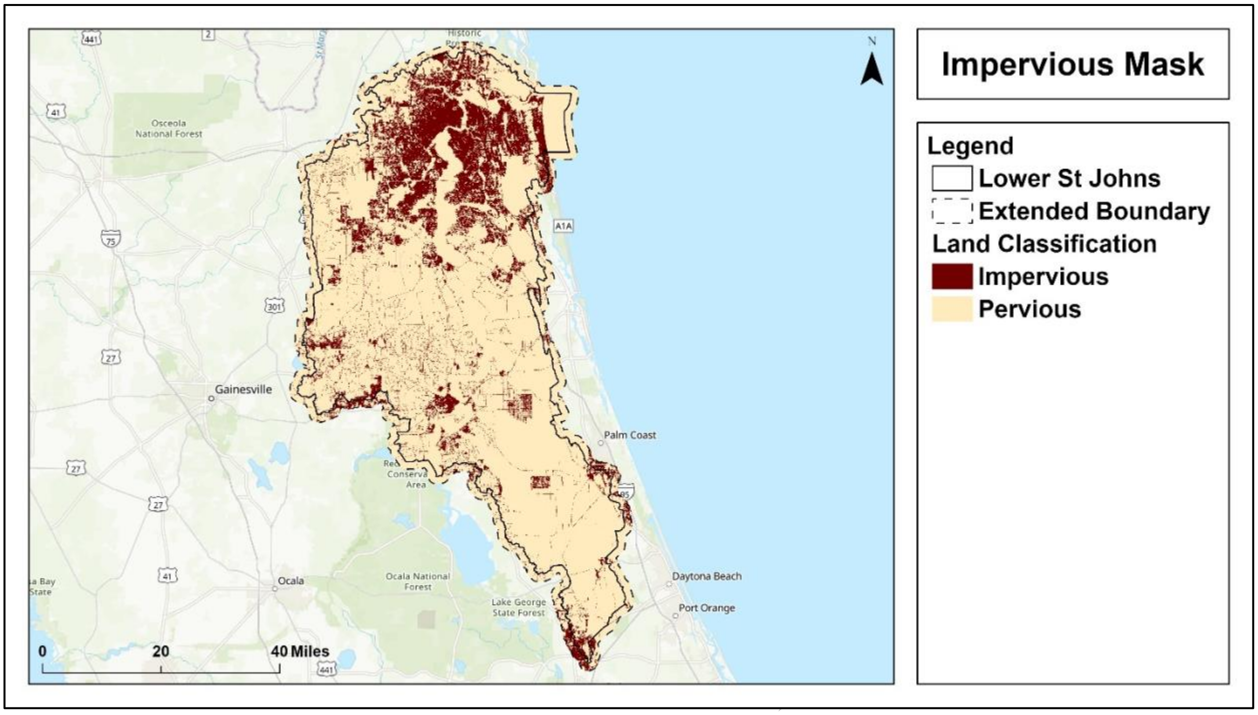

Figure 3.4: Impervious and Pervious Surface

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.

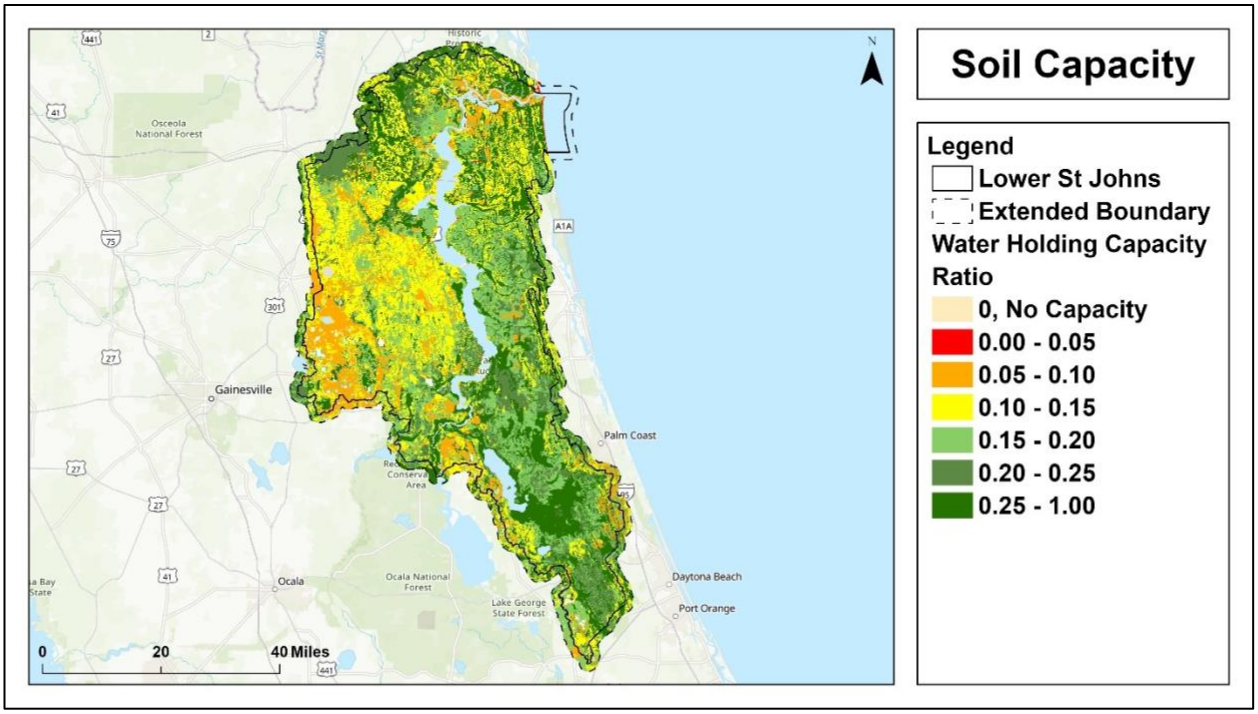

Figure 3.5: Soil Water Holding Capacity

3.2 Modeling Protocol

There are many contributing factors to flooding in the Lower St. John;s River Watershed, including the low land elevations, high groundwater table, and low soil storage capacity. To accurately identify land areas within the watershed that are vulnerable to flooding, all these factors were included in the flood risk model. The previously discussed datasets were used to calculate input parameters needed to run a flood simulation model called CASCADE 2001, which was developed by the South Florida Water Management District. The advantage of this model is that it incorporates several characteristics unique to each watershed, including the topography, groundwater, surface water, tides, soil type, land cover, and rainfall. By following FAU's modeling protocol for the Caloosahatchee Watershed, all the necessary input parameters to run CASCADE 2001 were either directly calculated or derived from existing datasets. Several surfaces were derived from the data and used to determine characteristics of the watershed, which represent the primary contributing factors to flooding. While a contributing factor such as the land elevation in the watershed can be directly observed using data collection methods such as LiDAR, other factors require further data processing and modeling.

For example, determining water table elevations throughout the watershed requires spatial interpolation and extrapolation methods as well as modeling. Since the high groundwater table greatly contributes to flooding in the region, it is necessary to expend the additional effort to incorporate this factor into the model. Observed water levels are only available at single locations, groundwater wells and surface water stations. The South Florida Water Management District's DBHYDRO database was used to access their station observation data.

Flood Modeling requires various inputs to simulate the model based characteristics that 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 Lower St Johns basin, all the necessary input parameters to run CASCADE 2001 were calculated from existing datasets. Several surfaces that were derived from the data 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 Lower 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 Mayport 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 Lower 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.

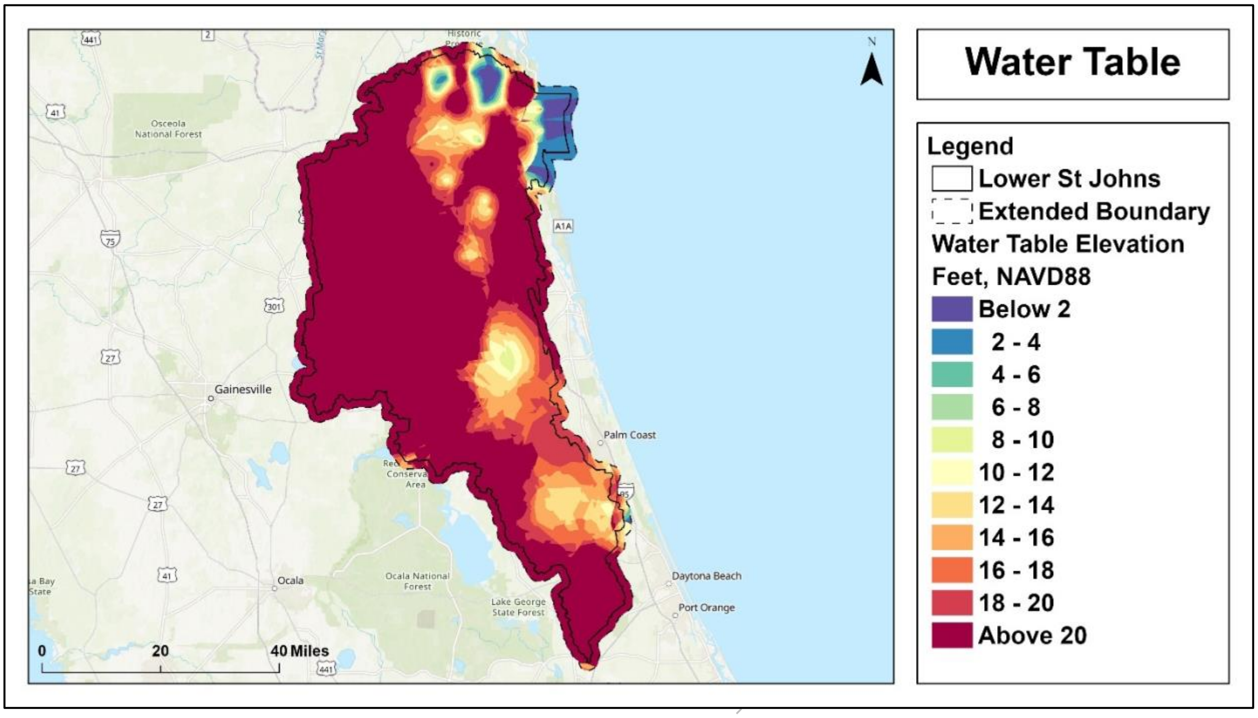

Figure 3.6: Water Table Elevation

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 Lower St Johns Basin.

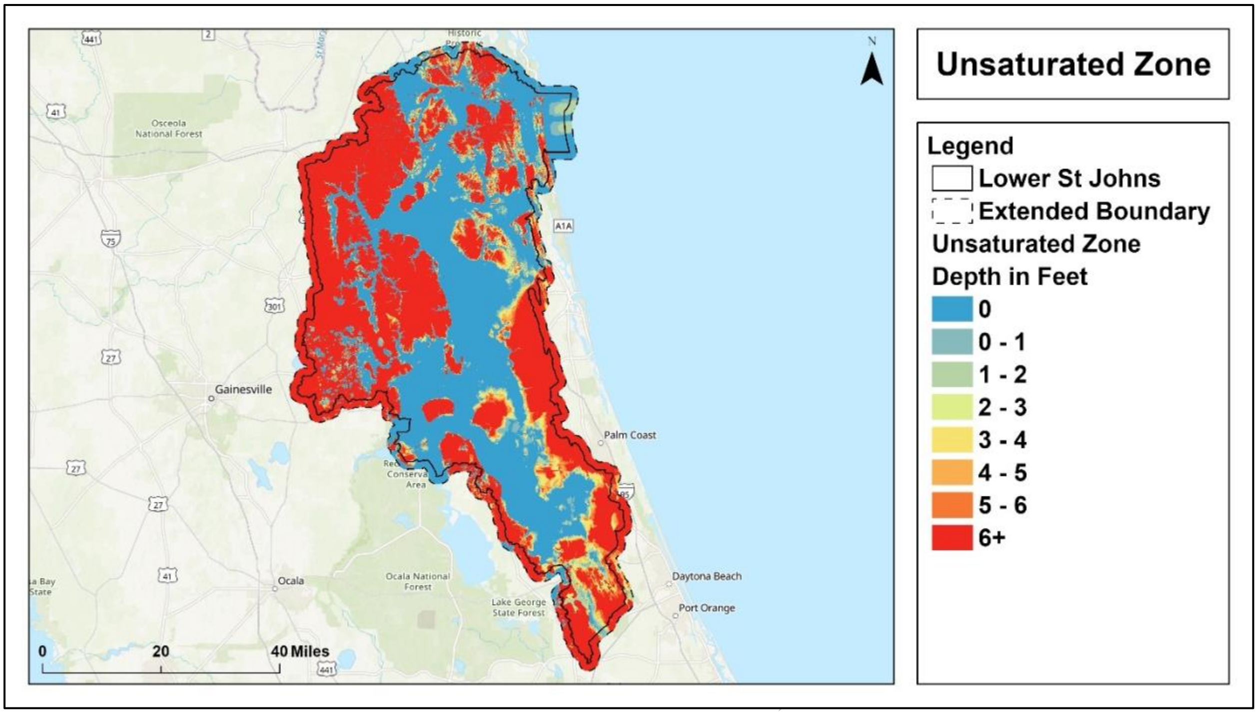

Figure 3.7: Unsaturated Zone Depth

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.

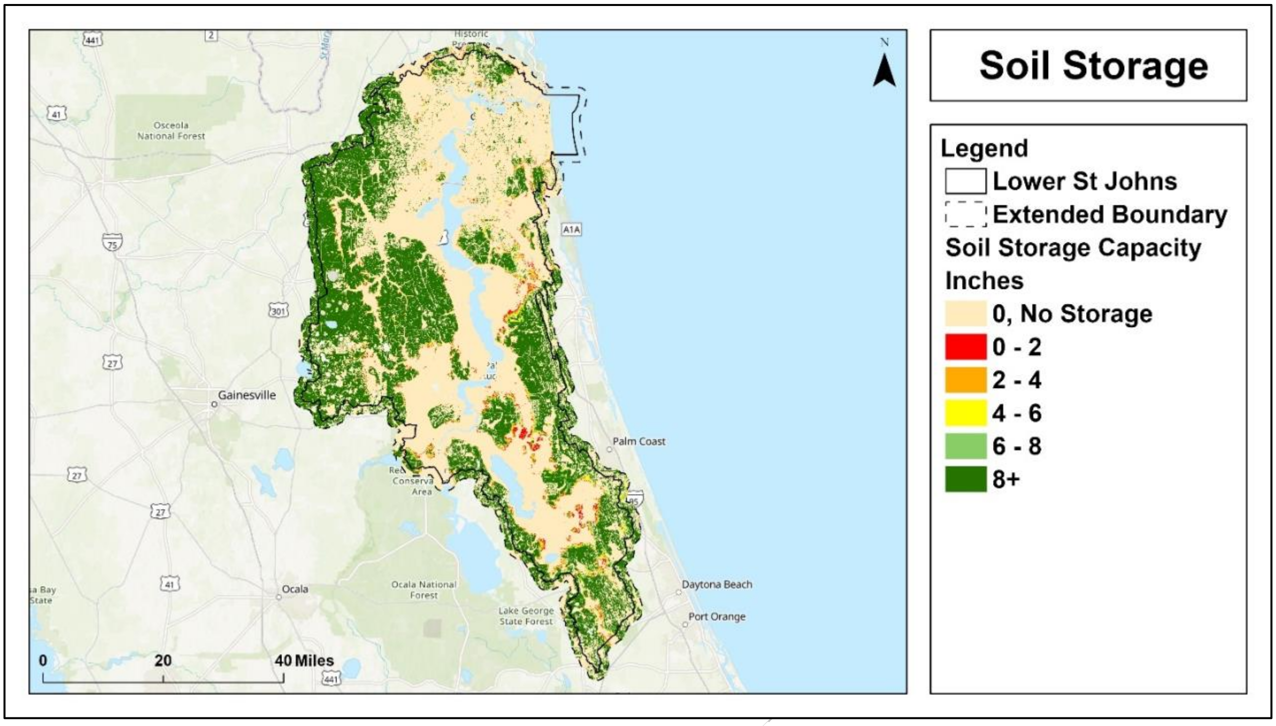

Figure 3.8: Soil Storage Capacity

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.

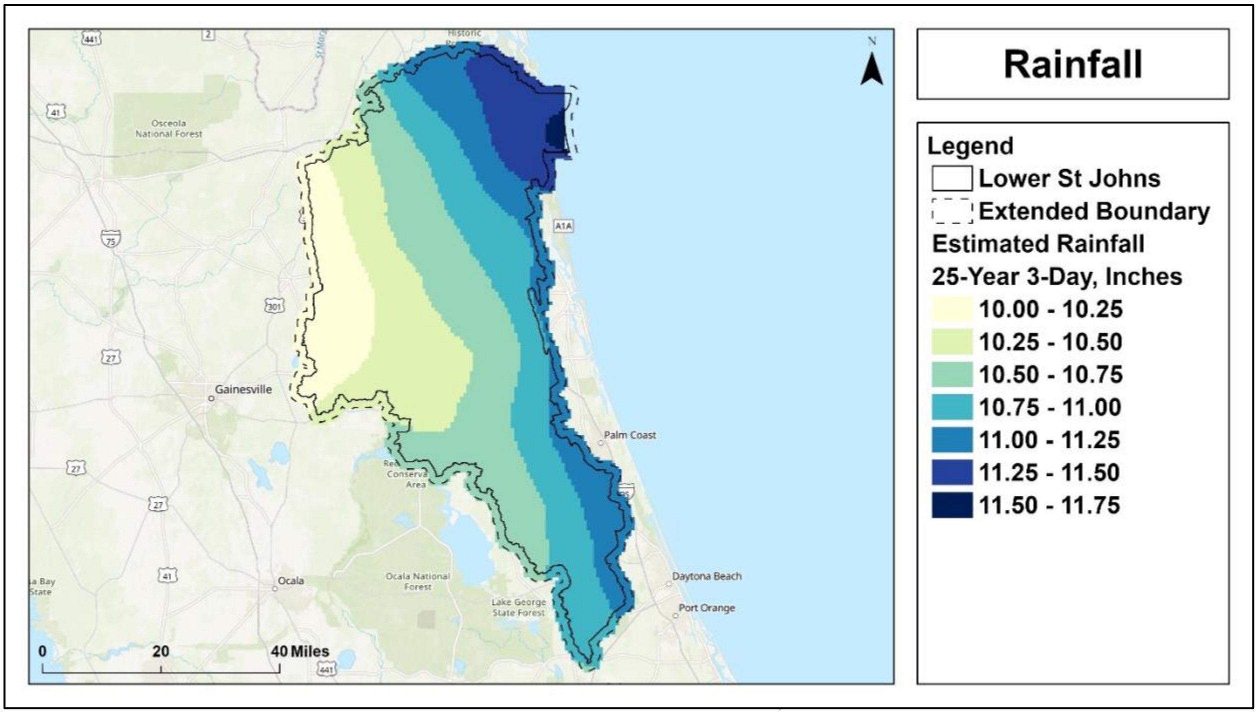

Figure 3.9: Estimated 25-Year 3-Day Rainfall

3.3 Modeling Results

3.3.1 Watershed pathways

The St John's River is split up into three basins, one of which is Lower 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.

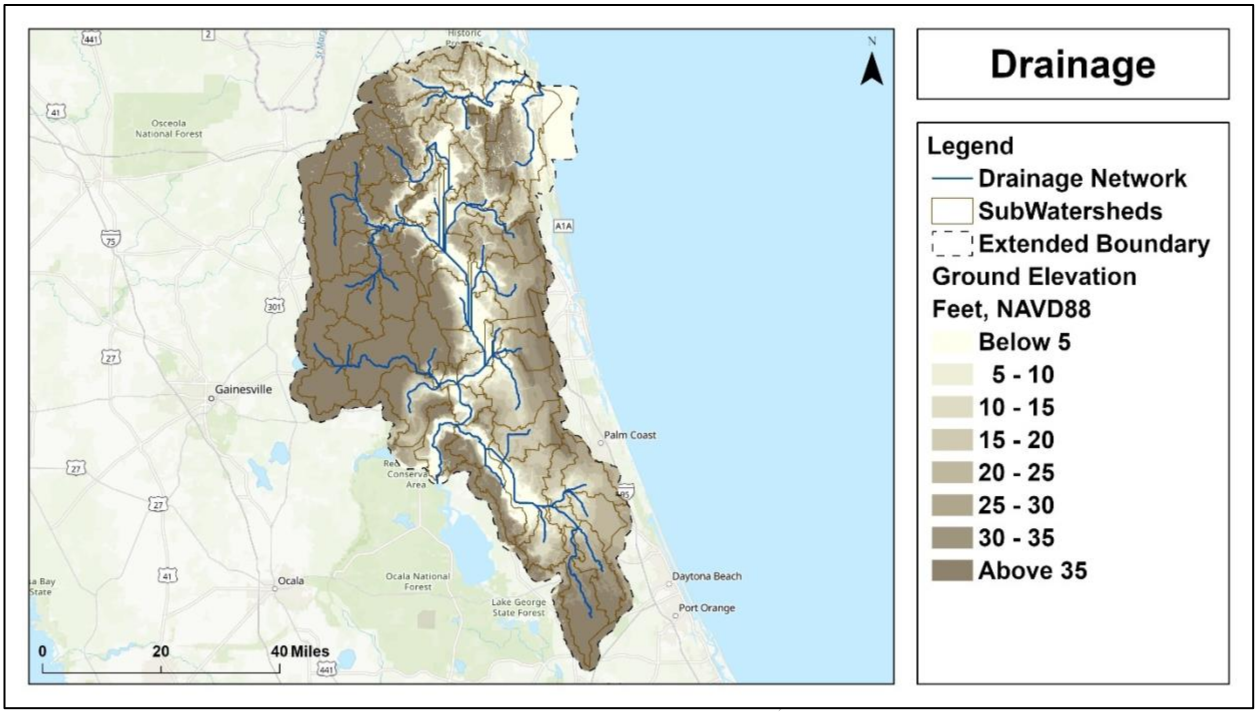

Figure 3.10: Catchment and Drainage Network

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) = 23.32
- Ground Storage (Inches) = 18.68
- Rainfall for 25 Years, 3 Day (Inches) = 10.7
- Area (acres) = 2092331.75
- Time of Concentration (hrs.) = 26.53

After input of the start and end date of the simulation for the lower basin is December 12th 2018, the total number of hours for the simulation is calculated automatically and displayed accordingly. The offsite receiving body for the model and input the pair of time in hours and water stagesis set in NGVD feet to simulate the ocean whose stage level doesn't change for a few days.

The highest elevation is 275.28 ft. The length should be the width of the river channel. The basics are:

- Crest Elevation (ft) = 23.32
- Length(ft) = 1800

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 Lower St Johns Basin is 24.31 feet. The flooded areas during a 3-day 25-year storm in the Watershed are shown on the map in Figure 3-11.

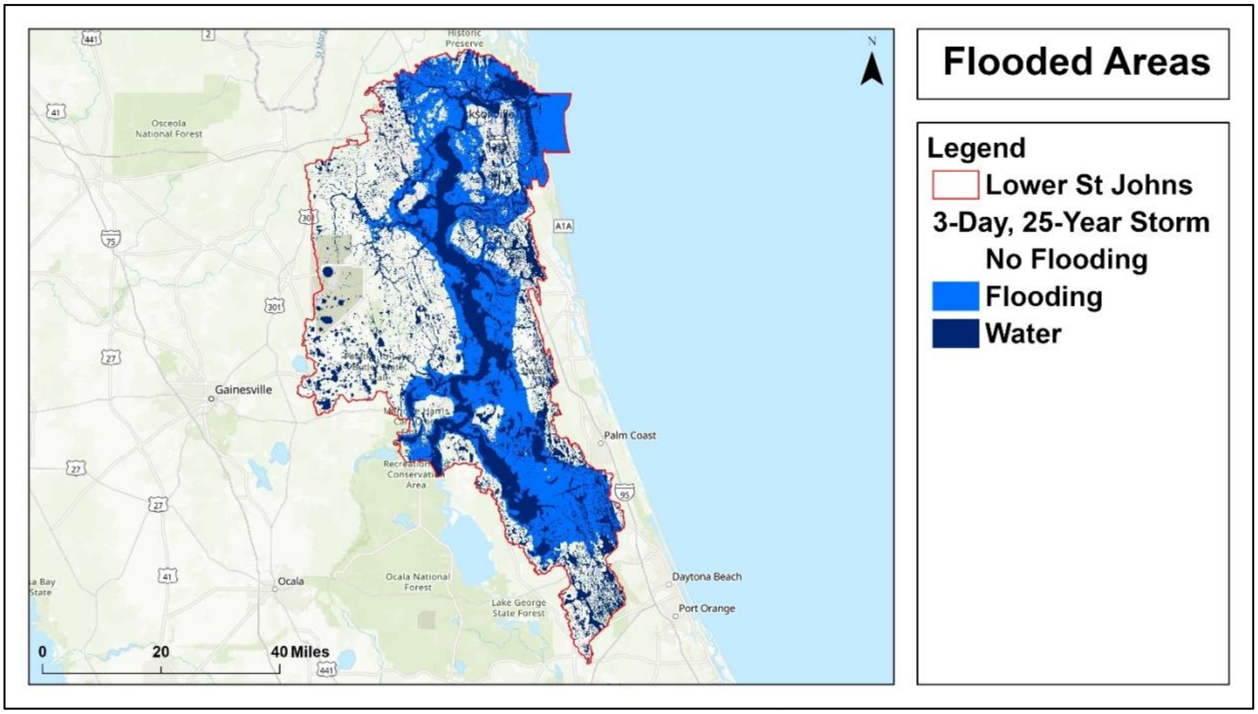

Figure 3.11: Flooded areas

3.3.3 Vulnerability to Flooding

After identifying areas within the watershed that are prone to flooding, it is important to classify the risk associated with those flooded areas. To accurately delineate the flooding areas in Lower St Johns River watershed, the FAU team applied further classifying flood risk as the probability of inundation, it is possible to improve the identification of critical target areas within the watershed. These areas are particularly vulnerable to flooding and are subject to further study. The probability of inundation surface was created by calculating Z-scores to describe the maximum headwater height's relationship to the ground elevations from the LiDAR DEMs. 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

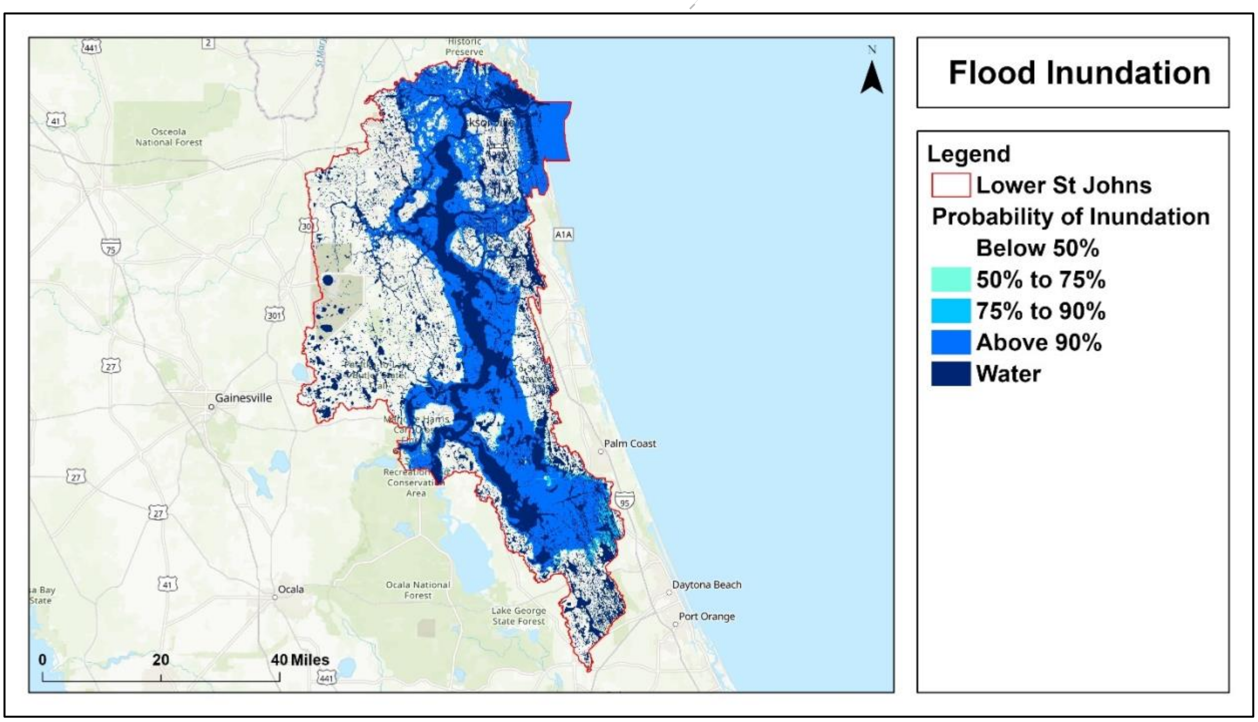

Figure 3.12: Flood Inundation of Lower St Johns Basin.

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. 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)	2173.22
Our estimated area (total: km^2)	1848.56
Overlapped area (total: km^2)	343.91
Percentage of overlap to FEMA (%)	15.8%
Percentage of overlap to our model (%)	61%

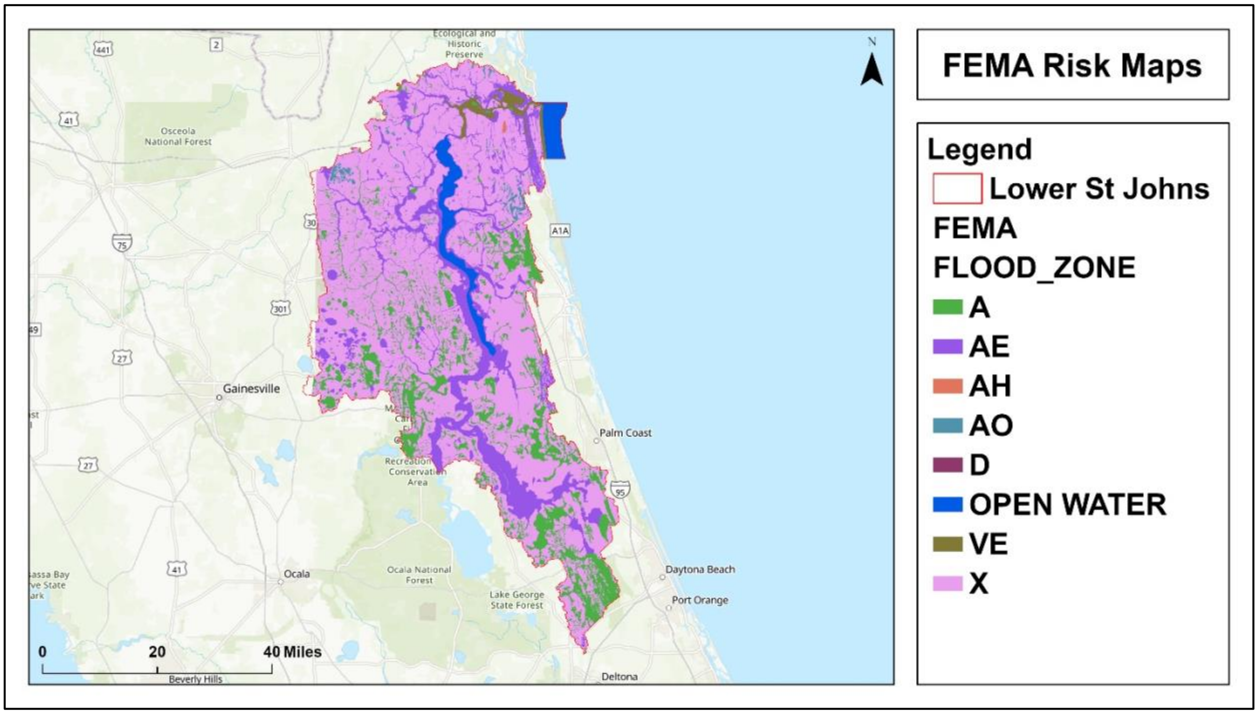

Figure 3.13: FEMA based Flood areas

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.

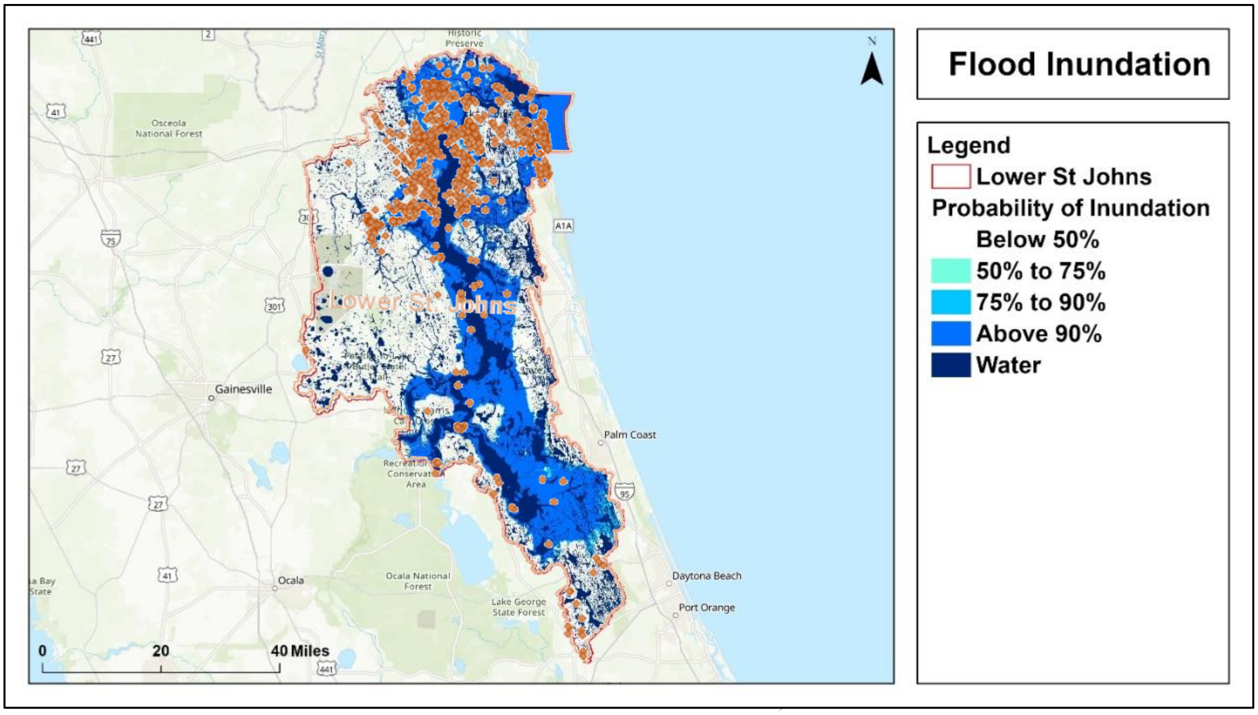

Figure 3.14: Repetitive loss areas from 2004 -2014 superimposed on the flood risk map created by FAU

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 shows the Duval County and Deltona drill down areas of critical importance.

Jacksonville is one of the most populous city in Northeast Florida. It is situated in Duval County and greater in size and placed most of the metropolitian population within the city limits. It extends of 22 miles of wide beaches and close to 40 miles Intracoastal Waterway Canal. According to US Census, the city has covered an area of 874.3 square miles from that 757.7 square miles is land and 116.7 square miles is water. Jacksonville surrounds by counties such as north lies Nassau County, West side lies Baker and Clay County, South part lies St. Johns counties, East side lies the Atlantic Ocean along with the Jacksonville Beaches. The city is majorly developed along both sides of the St. Johns River. The Trout River is a major tributary for the basin is located entirely within Jacksonville. Because of largest area, Drill down maps split into two parts based on the St

Johns river crossing in the city. The city is surrounded by river and at the mouth atlantic ocean, which make lot more areas are vulnerable for flood risk. Figure 3.16 & 3.17 show drill down areas of Jacksonville. Deland is also part of the Volusia County. The city has an area of land 17.8 square miles and 0.19 square miles of water, which is 1.06%. Deland is drained into the St Johns River. Figure 3.18 shows flood vulnerable areas in both cities.

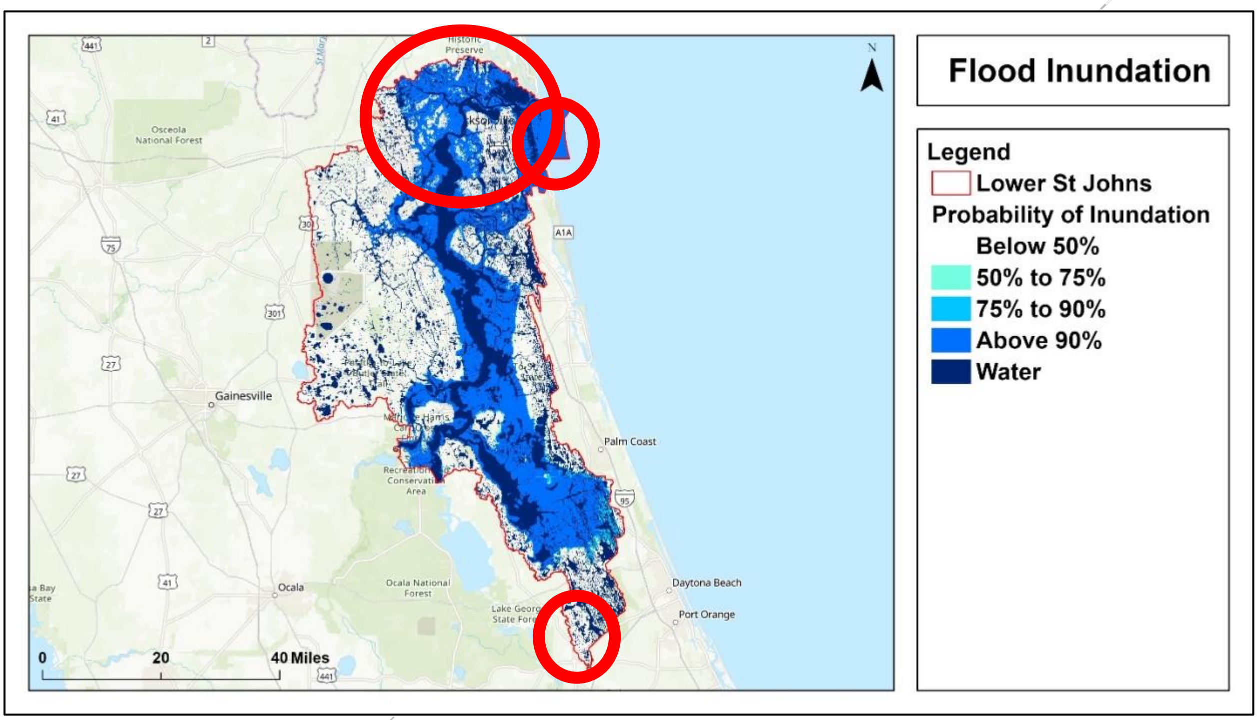

Figure 3.15: Location of drilldown areas

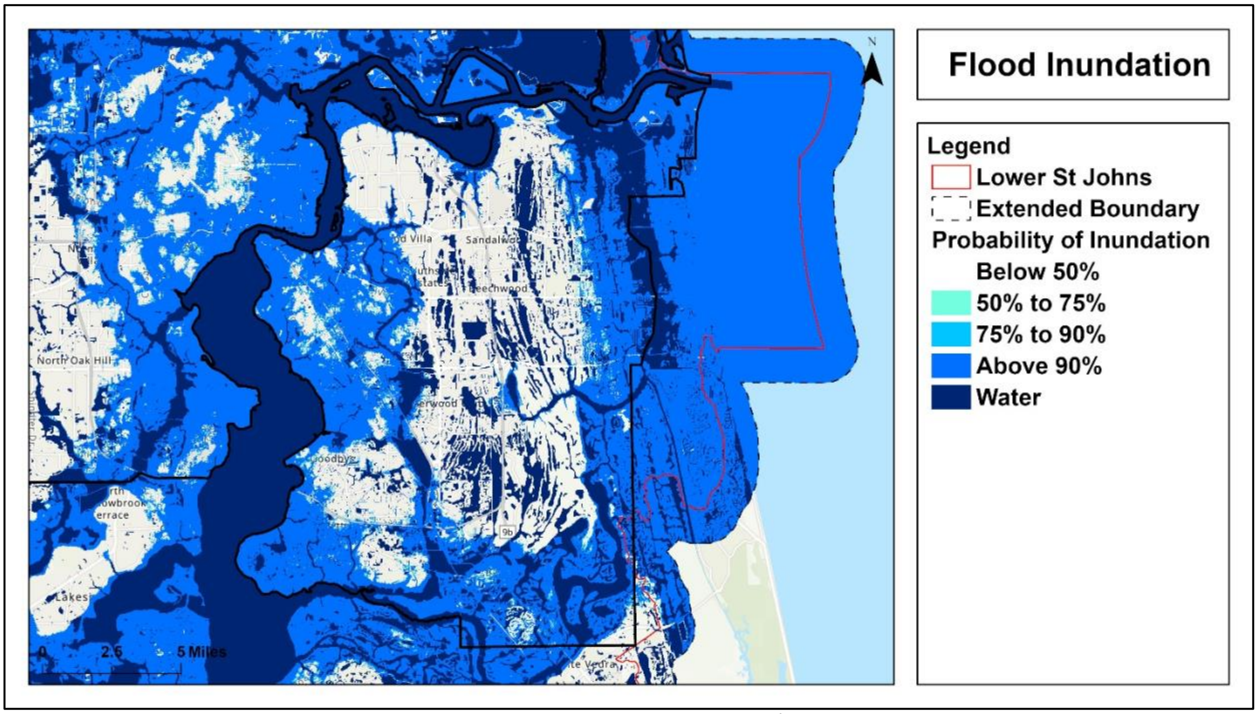

Figure 3.16: Flood inundation of Jacksonville below the river line

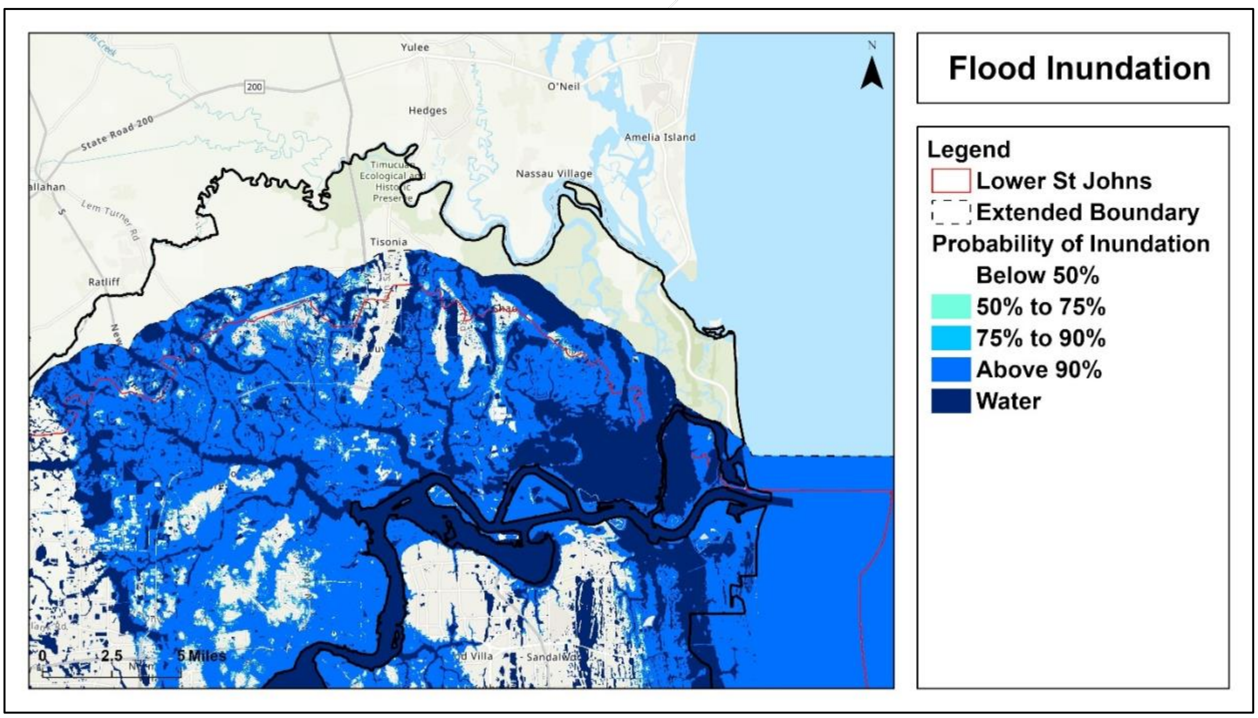

Figure 3.17: Flood inundation of Jacksonville above the river line

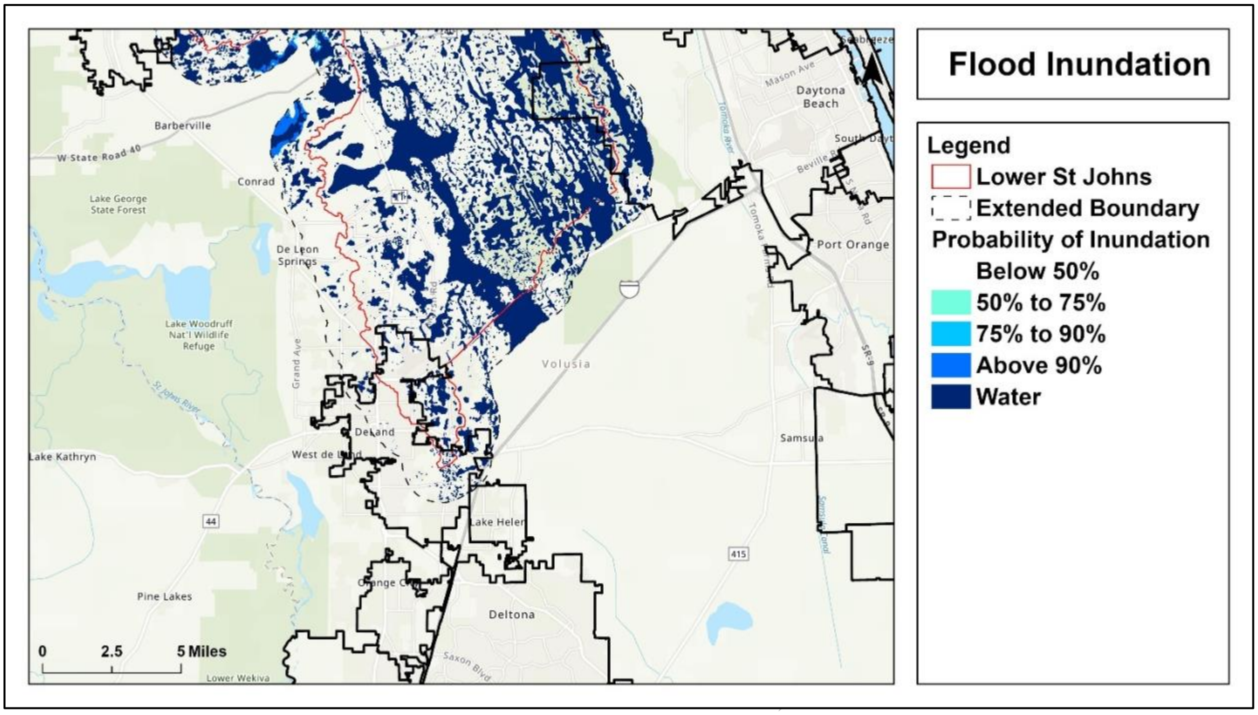

Figure 3.18: Flood inundation of Deland.

4.0 Conclusion

Lower St Johns is divided from St Johns Basin longest river in Northeast Florida. The Lower St. John's River basin primarily includes the Jacksonville/Duvall County metropolitan area, including the beach. The river 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 200 feet from west to east, due to that water enters into the sea. 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 24 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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