Watershed Master Plan

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CENTER FOR WATER RESILIENCY
AND RISK REDUCTION
Florida Atlantic University

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1.0 DEFINING THE WATERSHED PLANNING PROCESS

A watershed is an area where all the water that falls on the land exits at one point. The Mississippi River is a very large watershed formed by many layers of smaller watersheds. The watershed master planning approach is based on the concept that many water quantity and water quality problems, like the accumulation of pollutants, are best addressed at the watershed level through the involvement of all parties in the watershed. The planning process encourages all of these stakeholders to communicate and solve regional problems that no one entity can address alone. As a result, the watershed focus helps identify the most cost-effective strategies to meet stakeholder goals while identifying issues that cannot be addressed adequately.

The Federal Emergency Management Agency (FEMA) looks at flood control at the watershed level. Its National Flood Insurance Program (NFIP) sets insurance discounts based on flood resilience and preparedness through its Community Rating System or CRS program. The CRS program is designed to be used to reduce flood insurance premiums for residents. All local governments that have residents living in flood zones should participate to take advantage of potential discounts. The watershed master plan is a pre-requisite to gaining a Category 4 in the National Flood Insurance Program's rating system.

The NFIP was FEMA's attempt to address a common property loss problem – flooding. Flooding is the most common and costly type of disaster with over 98% of counties having experienced a flood within the last 20 years (FEMA 2018). Just one inch of water can cause up to $25,000 in damage per household (FEMA 2022 - https://community.fema.gov/story/Myths-vs-Facts:-The-True-Cost-of-Flooding?lang=en_US.%252F%252F). The average flood insurance claim payment over the past five years was about $69,000 (FEMA 2022 - https://community.fema.gov/story/Myths-vs-Facts:-The-True-Cost-of-Flooding?lang=en_US.%252F%252F).

Flooding has cost US taxpayers more than $850 billion since 2000 and is responsible for ⅔ of the cost of all natural disasters (Flood Defenders 2020 - Flooding is America's most frequent and expensive disaster (https://www.flooddefenders.org/problem). To meet the longer-term goals of protecting life and property, FEMA created the National Flood Insurance Program's (NFIP) Community Rating System (CRS) in 1990. The CRS is a voluntary program for encouraging and recognizing 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 (Congressional Research Service, 2023 - https://crsreports.congress.gov/product/pdf/IF/IF10988).

Watershed Master Plans (WMPs), as conceived by the National Flood Insurance Program (NFIP) Community Rating System (CRS) program, provide an outline for communities interested in reducing local flood risk. According to the CRS Coordinator's Manual, "the objective of watershed master planning is to provide the communities within a watershed with a tool they can use to make decisions that will reduce flooding from development on a watershed-wide basis." Successful watershed master plans consist of the following activities (Association of State Floodplain Managers, 2020):

1. Evaluation of the watershed's runoff response from design storms under current and predicted future conditions
2. Assessment of the impacts of sea level rise and climate change
3. Identification of wetlands and other natural areas throughout the watershed
4. Protection of natural channels
5. Implementation of regulatory standards for new development such that peak flows and volumes are sufficiently controlled
6. Specific mitigation recommendations to ensure that communities are resilient in the future
7. A dedicated funding source to implement the mitigation strategies recommended by the plan

The United States Environmental Protection Agency (USEPA) notes five basic steps to develop and implement a watershed master plan (2013).

The first step is to build partnerships with surrounding communities. Few communities can resolve such impacts on their own, since water flows out from watersheds upstream of the community, impacting other communities downstream and overwhelming their flood control system. As a result, there needs to be a series of questions developed to help a facilitator guide stakeholders through the process of acquiring relevant information while simultaneously navigating the existing regulations and policies. The first series of questions would, ideally, stimulate thought-provoking inquiries into what the community and its neighbors can do and are doing in a holistic sense. After gaining inputs, the answers can be organized into a coherent set of goals based on the stakeholder input, with the result being a clear path forward for watershed management. The second series of questions would be designed for the same kinds of managers to thoughtfully examine their previously established WMP to comply with the regulations that require a review on a 5-year cycle. This way the plan can be recalibrated to adapt to evolving management goals and meet the CRS scoring criterion.

The second step is to characterize the watershed. Note that obtaining watershed-related information with precision is difficult, and a balanced approach is needed to address this concern. For example, groundwater is relevant when the ground and surface waters are directly connected, and the soil lacks the capacity for storing all infiltration.

The third step involves identifying measures to reduce impacts (watershed, regional, and local). At the watershed level, this is difficult to do because the scale of a watershed is far larger than individual neighborhoods, but the development of the data for the entire watershed should include the ability to use collected data to drill down to the local level.

An example process that USEPA (2013) suggests for capital plans is:

1. "Inventory existing management efforts in the watershed, taking into account local priorities and institutional drivers
2. Quantify the effectiveness of current management measures
3. Identify new management opportunities

4. Identify critical areas in the watershed where additional management efforts are needed
5. Identify possible management practices
6. Identify relative pollutant reduction efficiencies
7. Develop screening criteria to identify opportunities and constraints
8. Rank alternatives and develop candidate management opportunities"

The Sarasota County Comprehensive Plan, Volume 1, Element 6, Chapter 12, Water Policies 1.1.3, 1.1.4, 1.2.1, 1.3.2, and 1.3.3 also have procedures for implementing these types of plans (https://www.scgov.net/government/planning-and-development-services/planning-and-zoning/planning/-folder-282#docan10233_11700_7058). The inventory of existing management efforts is generally completed through the following measures:

- Review and evaluation of existing watershed data, including identification of features requiring immediate maintenance
- Development of preliminary watershed model diagram
- Establishment of a GIS database for watershed resource features and parameter inventory through desktop and field reconnaissance

Floodplain analysis includes developing a watershed model and identifying associated inundation polygons. It builds upon information generated from the watershed evaluation so that planning and management decisions can be formulated. Floodplain analysis may include the following tasks:

- Completion of the watershed resource feature and parameter inventory GIS database for the watershed using the acquired information
- Assembly of GIS database information into a specific format for a selected computer program which predicts the watershed's response to the hydrologic cycle
- Watershed model development, calibration, and verification
- Floodplain delineation

The fourth step involves implementation, which means local communities participate in defining projects and solutions as well as the timing and means to fund them. This is where many watershed plans fail – the ability to fund outside a jurisdiction is fraught with many difficulties. Capital plans, bond issues, etc. are all part of the plan.

The final step involves monitoring progress so that updates can be made. USEPA recognizes that the processes involved in watershed assessment, planning, and management are iterative and that targeted actions might not result in complete success during the first or second cycle.

1.1 Overview of the Watershed

The City of Sarasota is located in the Sarasota Bay-Peace-Myakka TMDL/HUC8 region of Florida (see Figure 1). It is part of the North Port–Sarasota-Bradenton combined Metropolitan Statistical Area (MSA) and is the home to the City of Sarasota, the Town of Longboat Key, the

City of North Port, and the City of Venice in Sarasota County. The watershed includes several islands (keys), including Lido Key, St. Armands Key, Otter Key, Casey Key, Coon Key, Bird Key, and portions of Siesta Key, and therefore the king tides and tropical storm-induced rainfall are the major flood concerns. 57,005 people live in the City (see Figure 2), which is part of the Southwest Florida Water Management District.

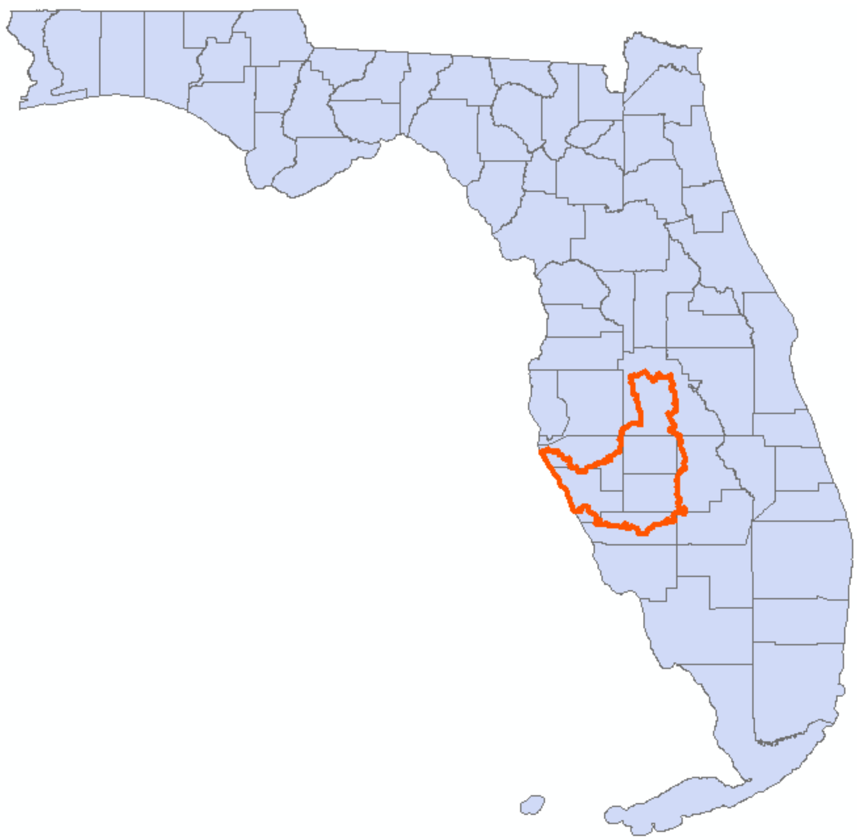

Figure 1. Location of the Sarasota Bay- Myakka TMDL in Florida

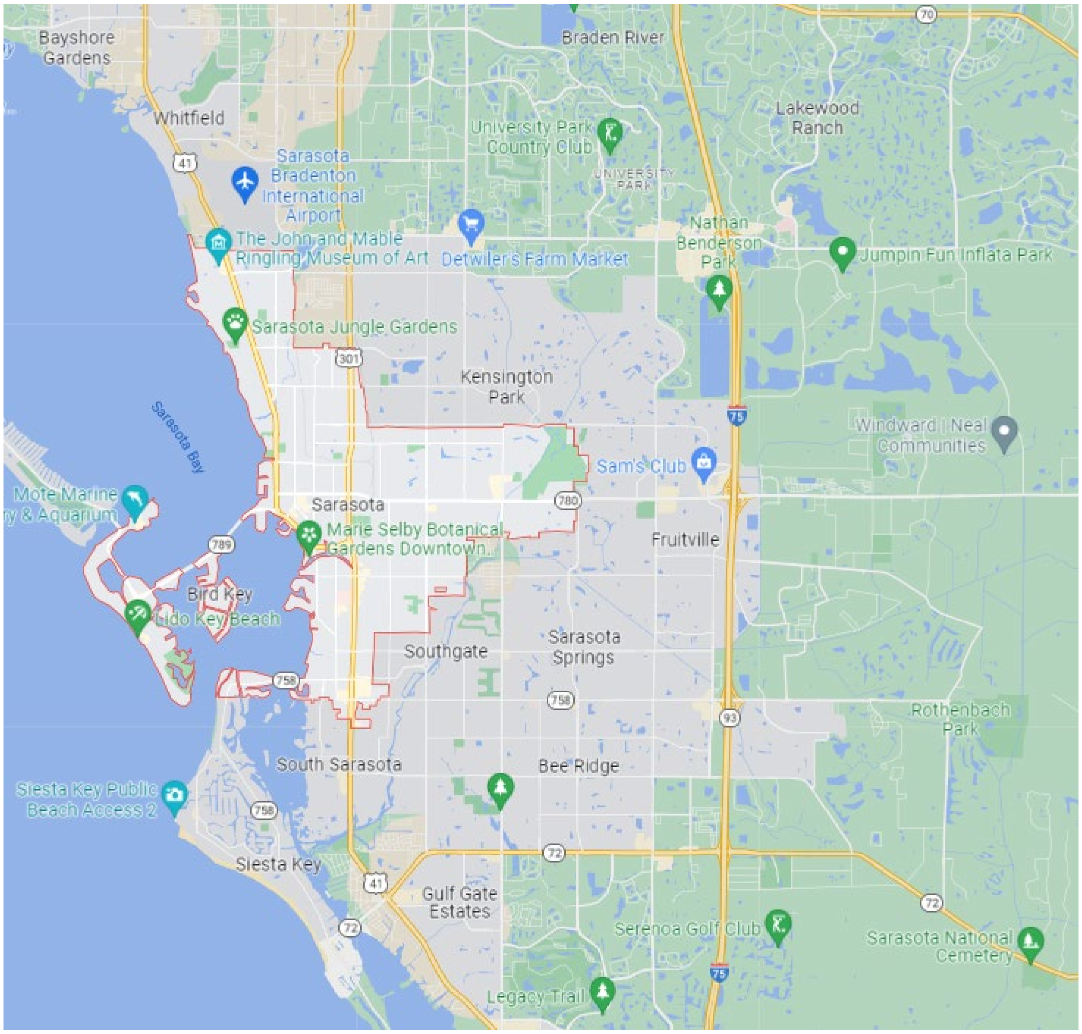

Figure 2. Map of the City of Sarasota

The watershed impacting the City includes portions of Manatee and Sarasota Counties. The primary surface water features of the City are Sarasota Bay and the Gulf of Mexico. Since open surface water bodies represent a substantial portion of the watershed, these special features must be taken into consideration when assessing the watershed’s flood response to a rainfall event. The low land elevations along the coast and shallow water table driven by the surface waters will likely contribute to flooding, which is expected to occur adjacent to the rivers and coastline.

The ground surface elevations in the watershed are lowest along the coast between 5 feet and 15 feet NAVD88. The low elevations and subtle changes in topography may contribute to flooding as excess rainfall overflows from open surface water bodies, imposing risk on nearby areas. Additionally, high tides move large quantities of water into the estuaries, which can spill over into low-lying coastal areas.

Groundwater and surface water are interconnected due to the shallow water table, low land elevations, and controlled drainage system. Historically, the drainage system of the region has not been controlled as there were no canals or structures to direct the flow of water. Today in the watershed, there are a variety of sandy soils. This type of soil may improve drainage; however, impervious surfaces in coastal cities may increase surface runoff by preventing soil infiltration.

This region has a humid, subtropical climate with both a wet and dry season. The average temperatures range from approximately 60° F to 80° F in the winter and summer, respectively. Southwest Florida typically experiences heavy rains in the summer and fall months, which can be further intensified during hurricane season (Webb, 1999). The rainy season lasts from June to September, and the dry season lasts from October to May.

The study area belongs to the Southeastern Conifer Forests, which is a temperate coniferous forest ecoregion. The vegetation in drier soils is a mixture of pine forests, scrub, and prairies, while in wetlands are marshes and cypress domes, where development has not displaced the native ecosystem. The soil in this area is classified as Central and South Florida Flatwoods, which are mostly Spodosols and Alfisols. Most of the area belongs to the sub-category of the Myakka-Immokalee-Waveland Association. This sub-category is the nearly level poorly drained sandy soils with a dark sandy subsoil and soils with a cemented sandy subsoil. The part of the watershed is classified as an urbanized area, wetland area, and coastal area, which are nearly level lands with poorly drained soils.

The coastal area has been classified as an Undifferentiated Superficial Aquifer, which consists of sand and limestone. The inland portion of this watershed is a part of the Floridian aquifer system, which contains a sequence of Paleogene carbonate rock (mostly limestone and dolostone) and can be classified as Upper and Lower Floridian aquifers. The Floridian aquifer system is an important source of freshwater in this area, and the groundwater is mostly near the surface.

Most of the City is classified as urbanized areas, wetland areas, and coastal areas, which are nearly level lands with poorly drained soils. Since large urban areas in the watershed's cities contain many impervious surfaces, the increased surface runoff caused by heavy rains must be considered while assessing the watershed's flood response to a rainfall event. The watershed also affects local flood management. Currently, rain falls on impermeable land where the water collects in pools or runs off rapidly over the area where development has taken place. Stormwater is collected locally in neighborhoods in swales, ponds, small lakes, ditches, and small canals. These are connected through canals and conduits to the secondary system under the jurisdiction of local drainage districts, city, or county governments.

1.1.1 Geomorphological Considerations

The City is located in Sarasota County, along the coast, king tides and tropical storm-induced rainfall are the major flood concerns. Over 450,000 people live in the County, Figure 3 shows the City includes multiple HUC 12s that extend into both Sarasota and Manatee counties. Each HUC will need to be developed and integrated as a part of the 452b submission. As of 10/1/2022 CRS community rating both City and County of Sarasota are class 5 communities. The current information is located at: https://www.fema.gov/sites/default/files/documents/fema_october-2022-crs-eligible-communites.pdf.

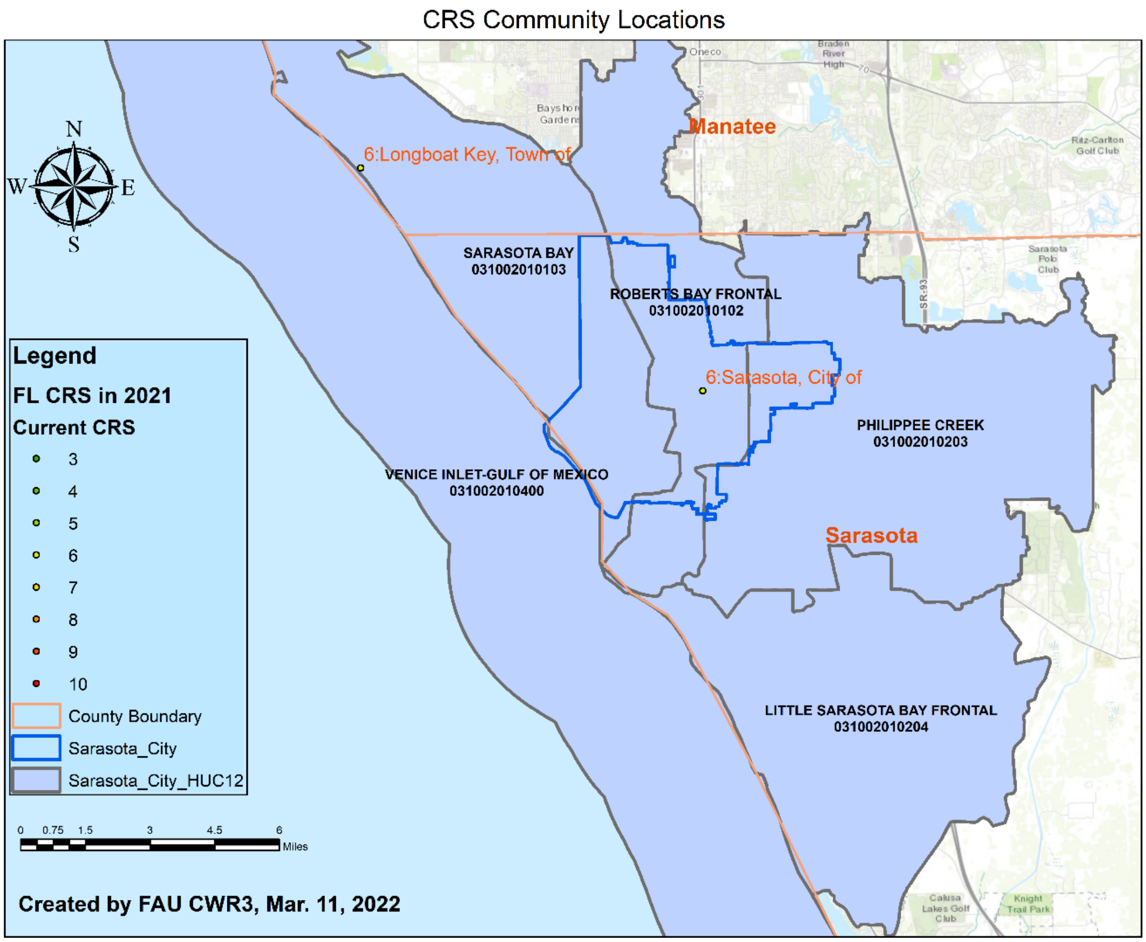

Figure 3. Map of the City of Sarasota showing the HUC 12 watersheds affecting the City

Manatee County, which is upstream of parts of the City's HUC 12s, has a total area of 893 square miles (2310 km^2), of which 743 square miles (1920 km^2) is land and 150 square miles (400 km^2) (20.7%) is water. The Cities of Bradenton, Palmetto, Anna Maria, Bradenton Beach, and Holmes Beach, and the Town of Longboat Key are the only incorporated municipalities in Manatee County. Eastern Manatee County is primarily agricultural. The western area includes some developed beachfront communities. Figure 4 shows the bathymetry for the coastal zone. Note the waters in the Gulf are relatively shallow near shore which increases wave action from storm events.

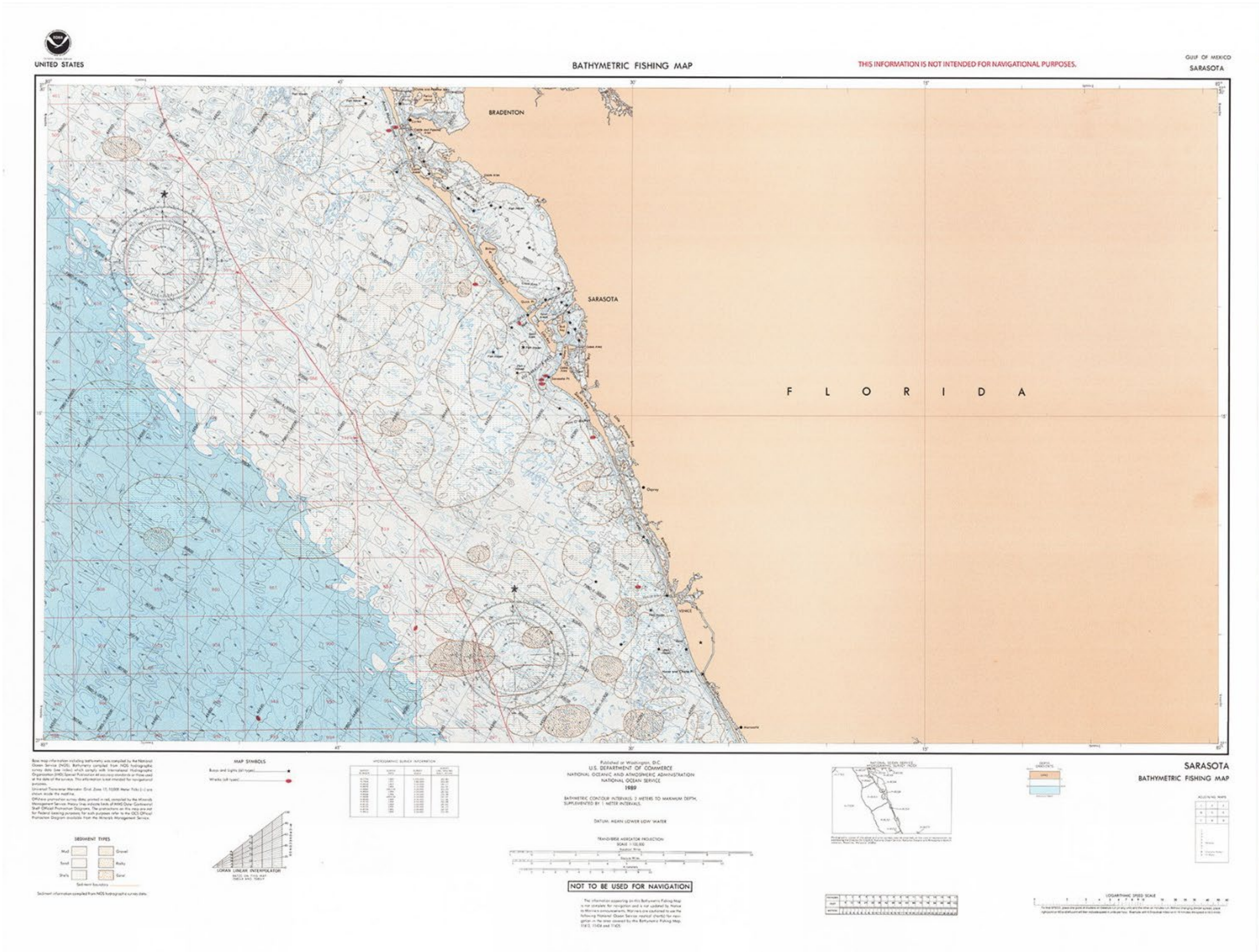

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Figure 4. Bathymetry map of Sarasota County and the City of Sarasota

The health of coastal ecosystems relies on robust communities of seagrasses, oyster beds, and mangroves for juvenile fish and other species. Important issues to evaluate the health of the watershed in the coastal zone are the emergent and submerged lands. Figure 5 shows the coastal ecosystem of Sarasota. As a part of the local ecosystem, issues such as the location of seagrasses and changes in seagrass habitat (Figure 6), the location of hardbottom for oyster beds (Figure 7), and the location of coastal mangroves (Figure 8) are relevant.

Figure 5. Coastal ecosystem for Sarasota County

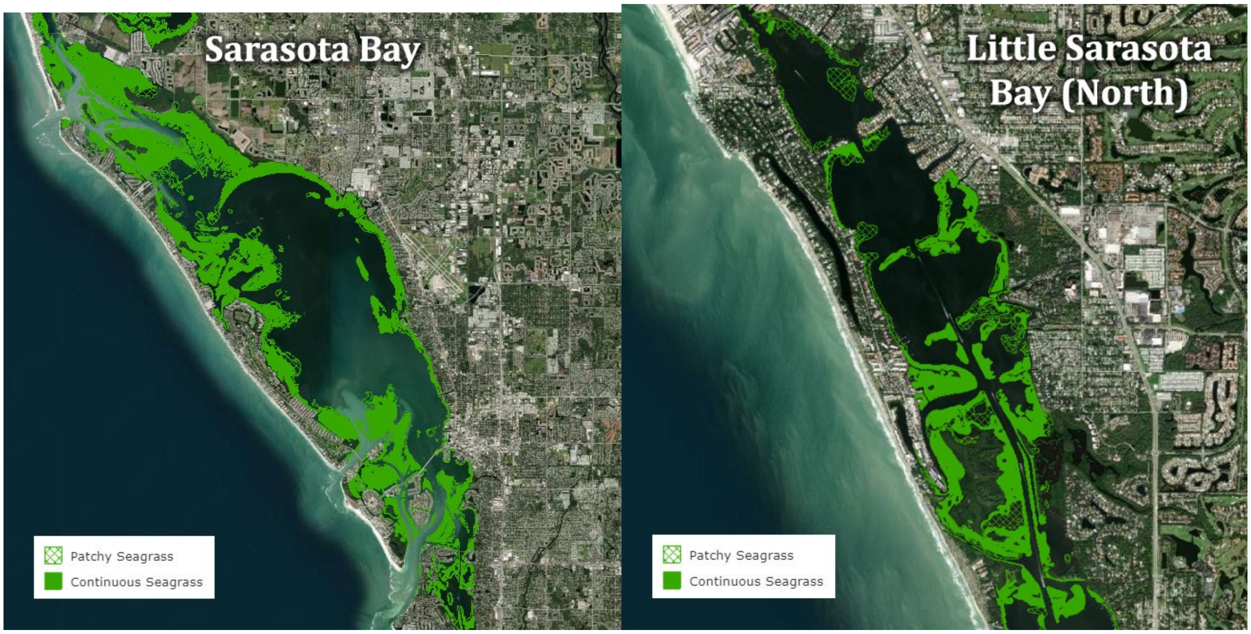

Figure 6. Seagrass habitat map along the coastal zone (Seagrass - Sarasota.WaterAtlas.org (usf.edu))

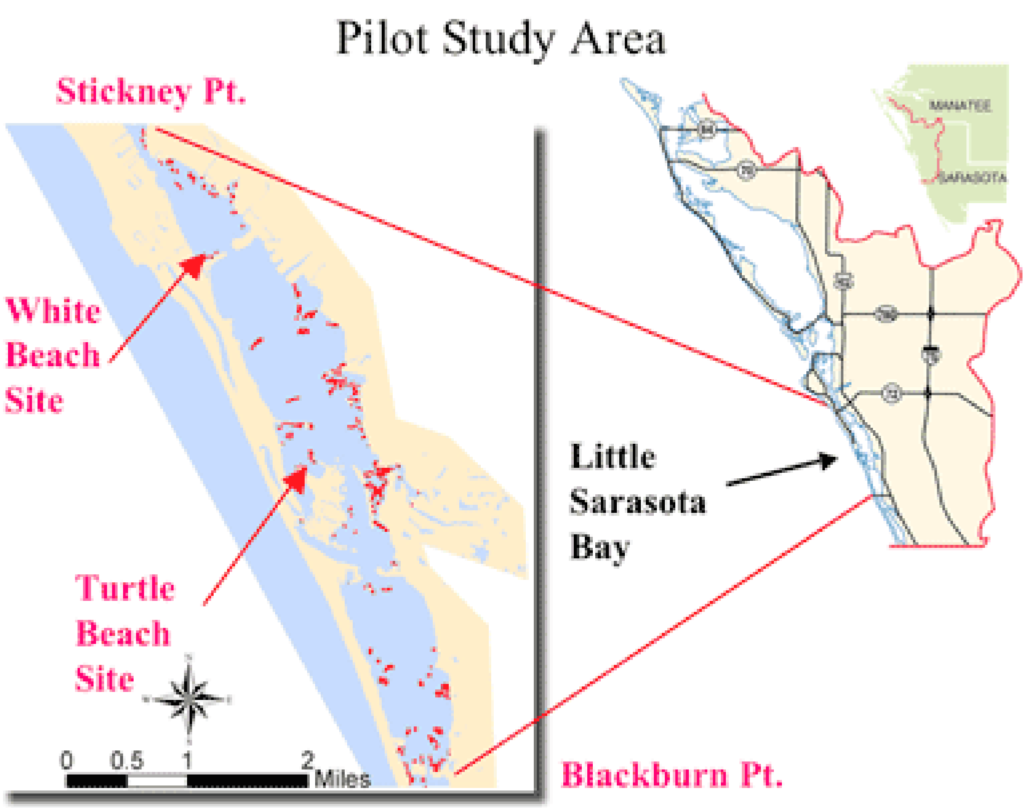

Figure 7. Locations of oyster bed pilot study off Sarasota, FL

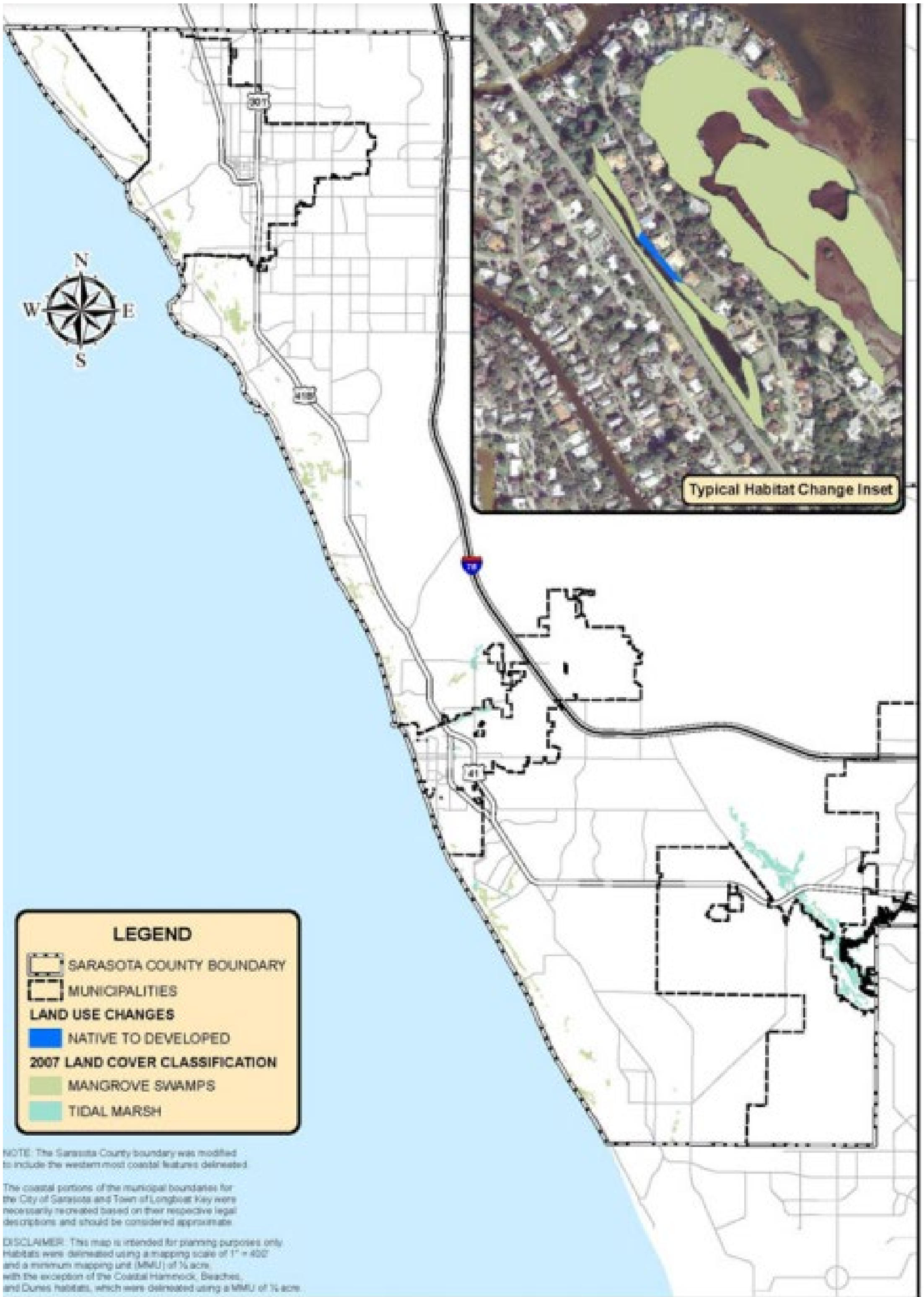

Figure 8. Locations of mangrove habitat in Sarasota County

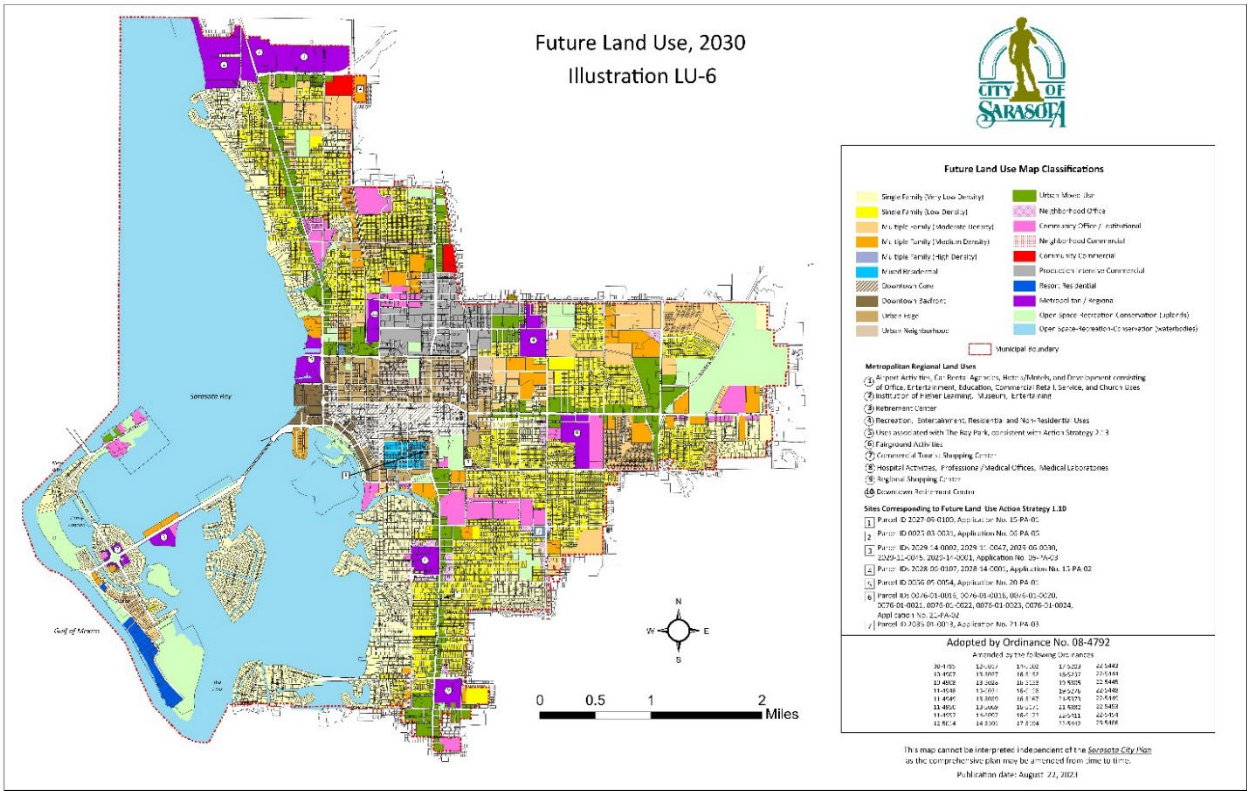

Figure 9. Land Use for the City of Sarasota.

The City of Sarasota is a highly urbanized municipality consisting of approximately 14.66 square miles of land area. The August 22, 2023 edition of the Future Land Use Map is displayed below. This map is both prescriptive as it displays the future types of development expected in the city and regulatory as land development regulations and rezonings are to be consistent with the land uses depicted on map.

The most recent edition of the Existing Land Use Map was created in 2020. The predominant existing land uses are residential which total approximately 43.91% of the land area in the city (see Figure 10 and Table 1). Of the residential land uses, single family residential use is the largest and totals 30.98% of the land area. The next largest land use is utilities and right-of-way which total 15.57% of the land area. Utilities and right-of-way include streets and roads, stormwater retention areas, and various utilities facilities such as sewage pump stations. As of 2020, there were 479.72 acres of vacant land, or 5.12% of the city. There are no agricultural lands within the city.

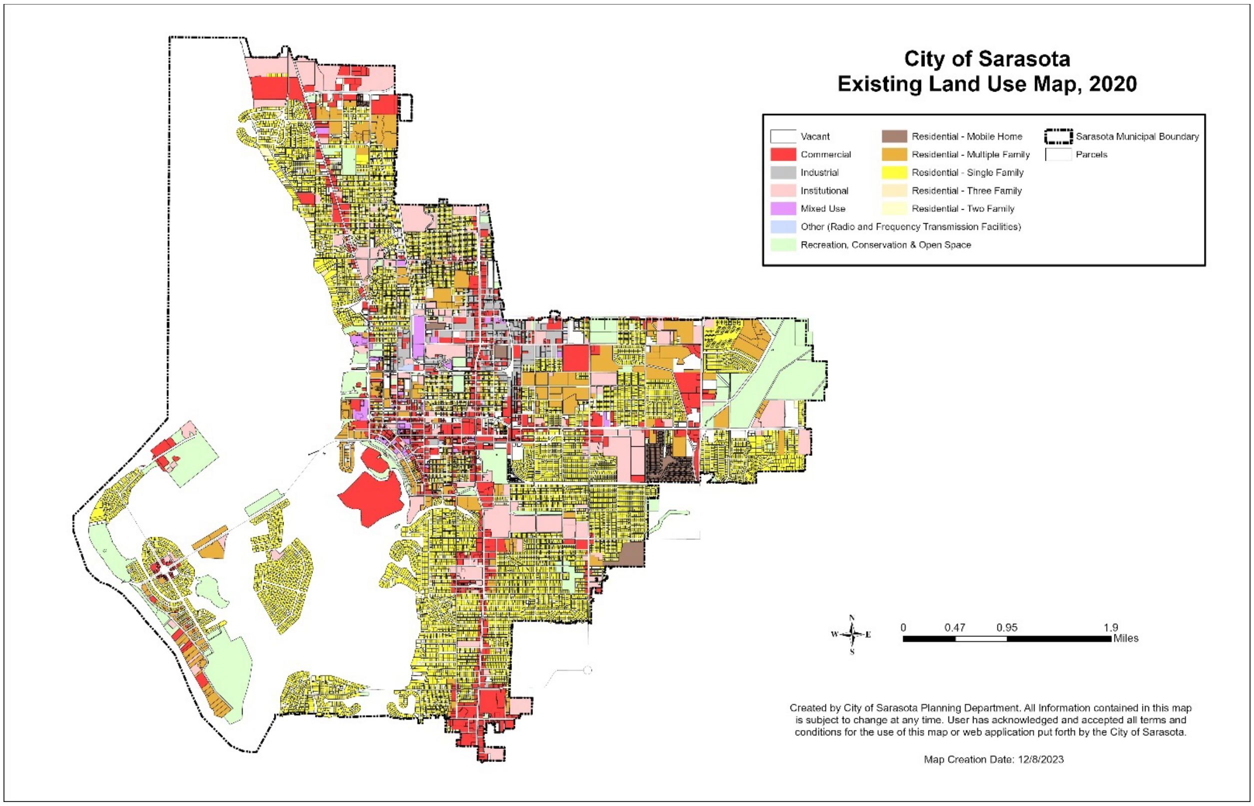

Figure 10. Existing land use in the City of Sarasota

Table 1. Existing areas of Different Land uses in the City from

Existing Land Use Map, 2020

Existing Land Use Map Categories	Approximate Acreage	Percent of Acreage
Commercial	1,126.36	12.02%
Industrial	196.13	2.09%
Institutional	876.33	9.35%
Mixed Use	98.58	1.05%
Utilities & Right of Way	1,459.20	15.57%
Parks & Open Space	1,020.52	10.89%
Residential - Mobile Home	133.56	1.42%
Residential - Multiple Family	795.59	8.49%
Residential - Single Family	2,903.38	30.98%
Residential - Three Family	30.13	0.32%
Residential - Two Family	253.30	2.70%
Vacant	479.72	5.12%
Total	9,372.80	100.00%

Numerous tributaries exist throughout both the freshwater and estuarine portions of the watershed and can influence the overall hydrology of the local waterways depending on rainfall and regional hydrological conditions. A network of secondary and tertiary canals throughout the City is intended to protect urban development (refer to Figure 11).

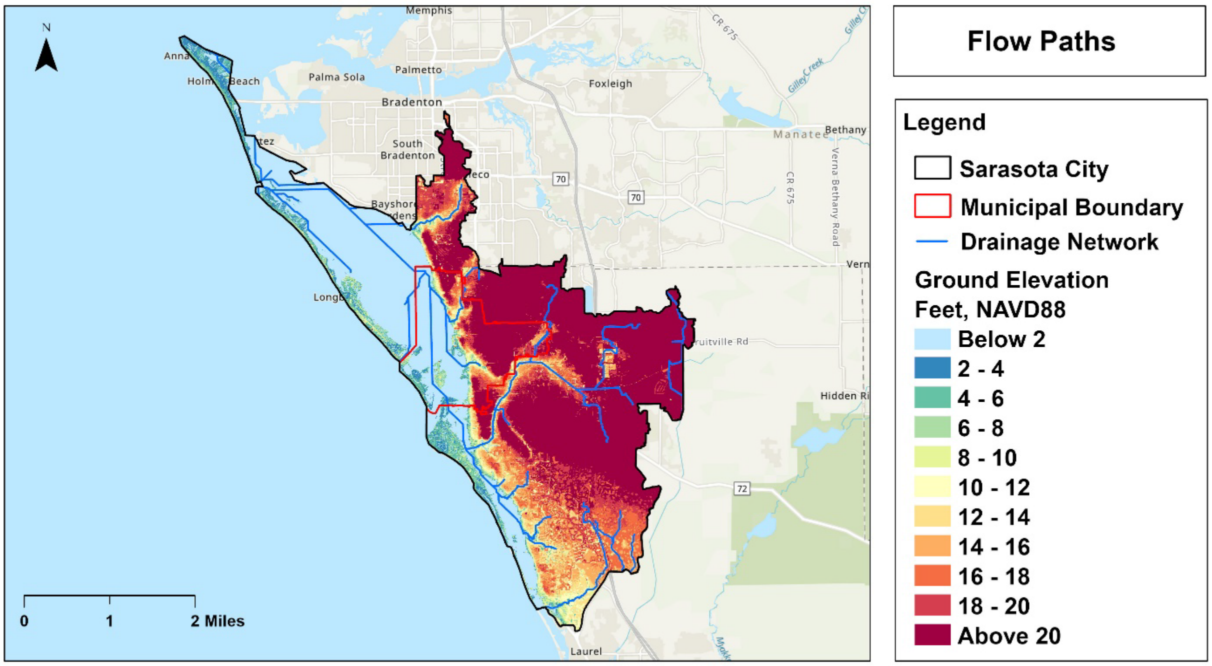

Figure 11. Flow paths for the City of Sarasota as generated by FAU CWR3.

1.1.2 Waterway Features

An understanding of river- and stream-channel geomorphic responses to various human-caused and natural disturbances is important for effective management, conservation, and rehabilitation of rivers and streams to accommodate multiple, often conflicting, needs. Channel changes may have implications for the protection of property and structures, water supply, navigation, and habitat. The channel-bank erosion that accompanies natural channel migration on a floodplain represents a constant threat to property and structures located in or near the channel. Various anthropogenic and natural disturbances introduce additional instability to which rivers and streams adjust. Human-caused disturbances include reservoirs, channelization, in-channel sand and gravel extraction, and urbanization. A common natural disturbance is a flood or major storm event.

Water issues are regulated by the Southwest Florida Water Management District (SWFWMD) in the City. The SWFWMD has multiple planning areas for water supplies. The Southern Planning Region encompasses approximately 2,465 square miles, covering all of DeSoto, Manatee, and Sarasota counties and the portion of Charlotte County that lies within the Southwest Florida Water Management District (see Figure 12). Land-use types range from urban/built-up areas such as the cities of Bradenton and Sarasota to predominantly agricultural land uses in the inland portions of Charlotte and Manatee counties. This planning region is located within the Southern Water Use Caution Area (SWUCA).

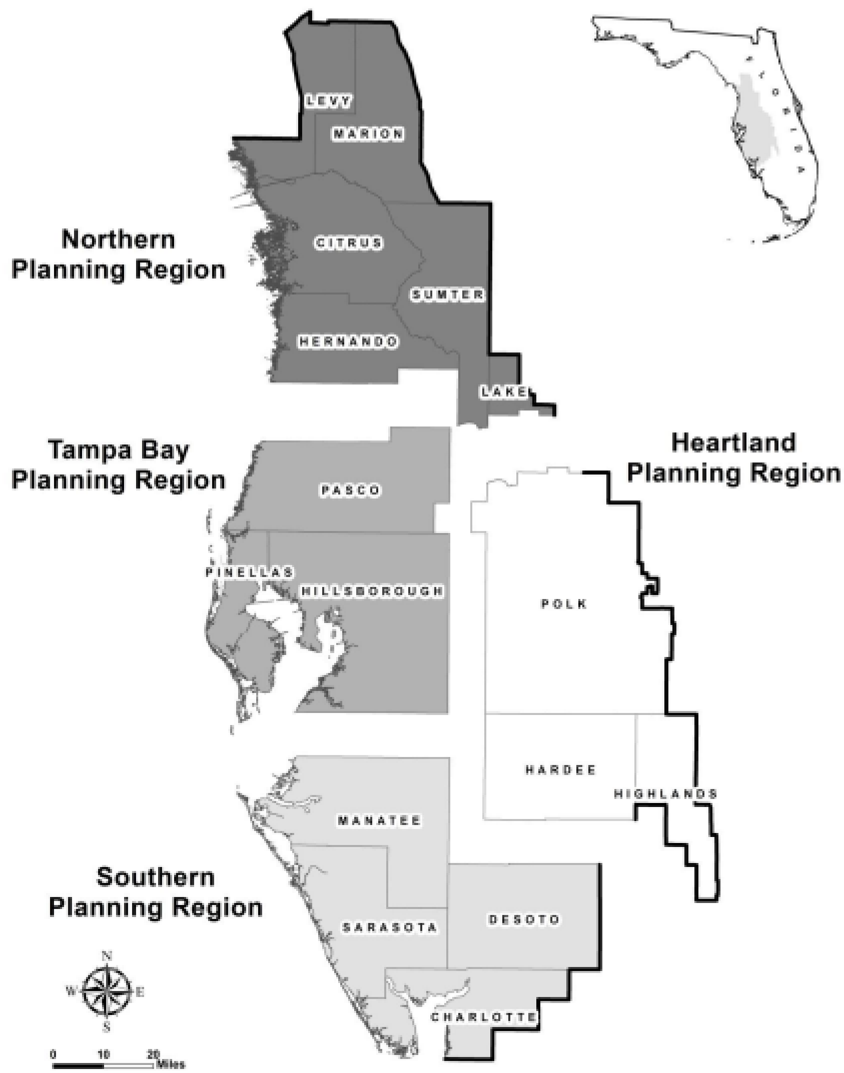

Figure 12. Southwest Florida Water Management District planning areas (SWFWMD, 2015)

The southern portion of Tampa Bay, the northern portion of Charlotte Harbor, and all of Sarasota Bay are major coastal surface water features in the planning region. The planning region contains all or part of seven major watersheds including the Braden, Manatee, Myakka, and Peace rivers, Myakkahatchee Creek (a tributary to the Myakka River), and Horse and Shell creeks (tributaries to the Peace River). There are multiple small tributaries running into these larger systems as well as several coastal watersheds drained by many small tidally influenced or intermittent streams. There are only a few named lakes in the planning region. These include Upper and Lower Myakka Lakes.

The major riverine systems that affect the City's HUC 12s are the Myakka River to the east (see

Figure 13) and Philippi Creek in the City. The Myakka River with headwater near the Hardee-Manatee County line and flows southwest and then southeast through Manatee, Sarasota, and Charlotte Counties to Charlotte Harbor. The river is 72 miles (116 km) long and has a drainage basin of 602 square miles (1559.2 km^2),[https://en.wikipedia.org/wiki/Myakka_River - cite_note-3](https://en.wikipedia.org/wiki/Myakka_River#cite_note-3) of which 314.7 square miles (815 km^2) lie in Sarasota county. The last 20 miles (32 km) of the river is tidal and brackish. A 34-mile (55 km) portion of the river in Sarasota County (including all of the park) was designated as a state *Wild and Scenic River* in 1985 by the Florida Legislature. Flows in the river are highest in September as noted in Figure 14.

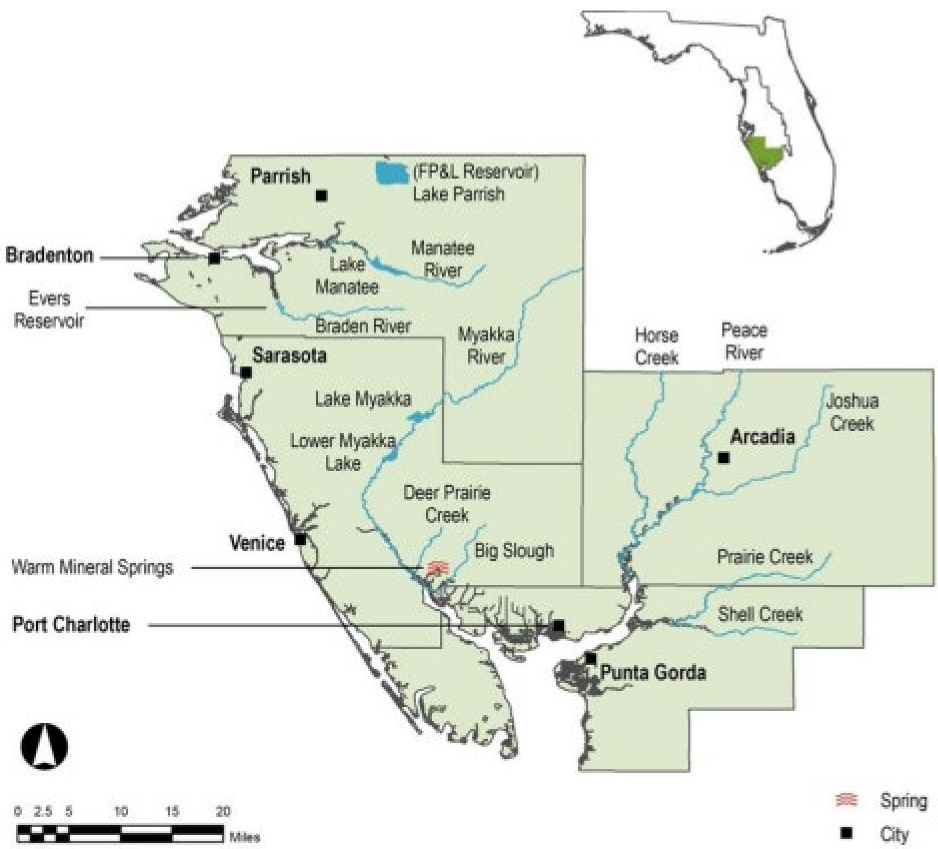

Figure 13 Myakka and other rivers in the vicinity of the City of Sarasota

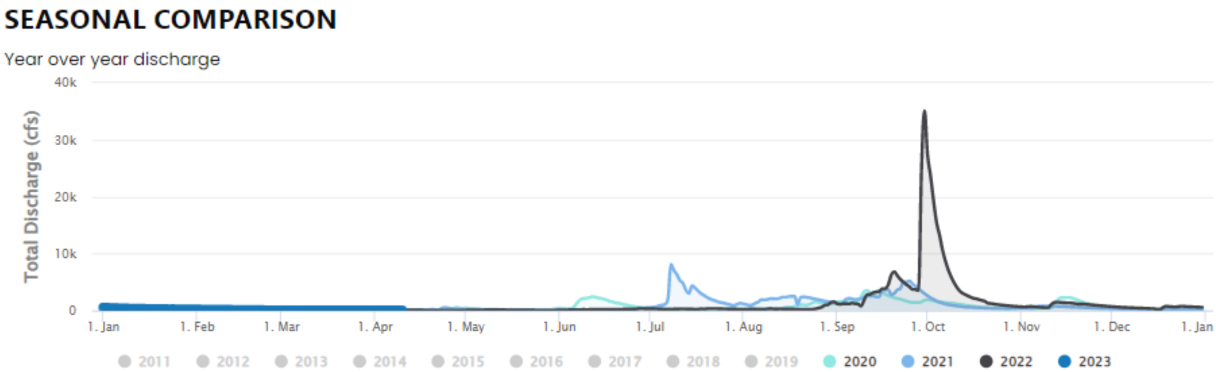

Figure 14. Flows in the Myakka Rivers 2020 – date (by month)

1.1.3 Hydrologic Boundaries

By definition, watershed master planning focuses on a watershed, which is a geographic area that is defined by a drainage basin. The geographic area should be clearly defined to ensure that implementing the plan will address all the major sources and causes of impairments and threats to the waterbody under review. Although there is no rigorous definition or delineation of this concept, one way to identify the geographic extent of the watershed master planning effort is to consult the USGS map of hydrologic units. A hydrologic unit is part of a watershed mapping classification system showing various areas of land that can contribute surface water runoff to designated outlet points, such as lakes or stream segments. USGS designates drainage areas as sub-watersheds (including smaller drainages) numbered with 12-digit hydrologic unit codes (HUCs), nested within watersheds (10-digit HUCs). These are combined into larger drainage areas called subbasins (8 digits), basins (6 digits), and subregions (4 digits), which make up the large regional drainage basins (2 digits).

Region>>Subregion>>Basin>>Subbasin>>Watershed>>Sub watershed

The HUC 12 basin map for the City is shown in Figure 3. The Hudson Bayou, Whitaker Bayou, and Philippi creek are the major outlets for draining much of the City.

1.1.4 Wetlands and Natural Areas

Wetlands serve multiple purposes, including acting as recharge areas, filters for contaminants, and buffers that mitigate temperature changes in adjacent areas. In southwest Florida, due to hydrologic modifications over the past 100 years, the natural storage and buffering capacity of wetland areas in the basin have decreased. As a result, water levels in the watershed can rise substantially in short periods of time. The water levels occur outside desirable ranges either too high or too low with rapid water level fluctuations. Wetland areas are shown in Figure 15 as developed from the National Land Cover Database (NLCD) of nationwide data on land cover.

The database is designed to provide cyclical updates on United States land cover and associated changes.

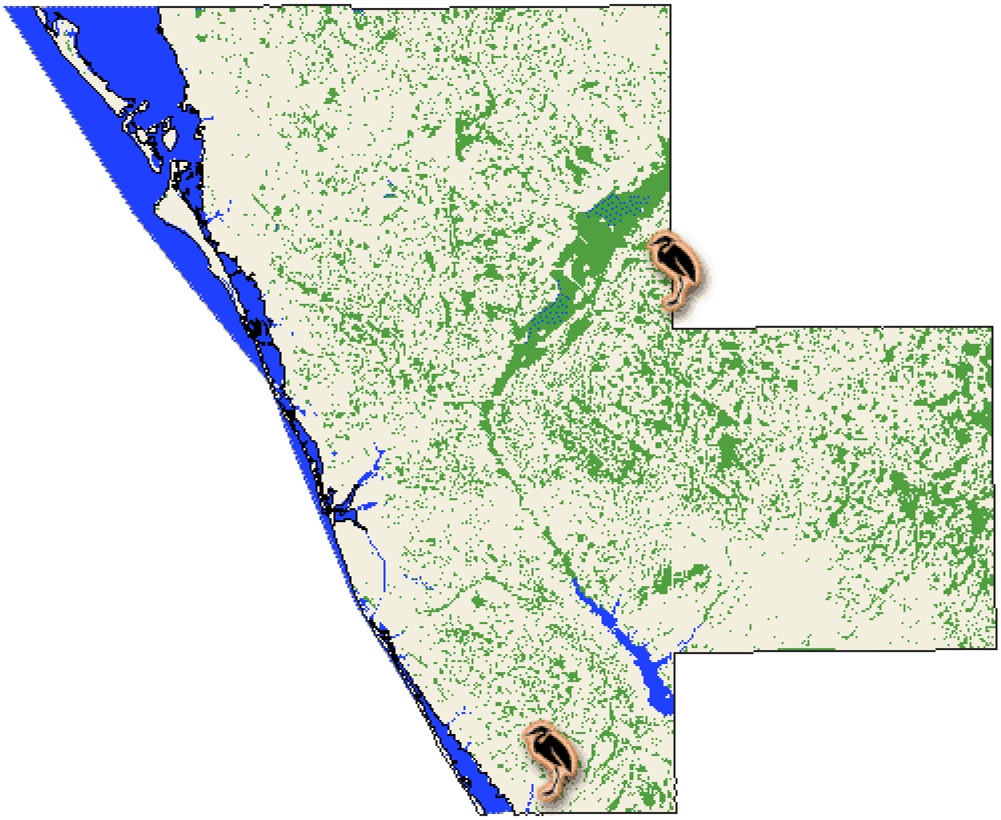

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Figure 15. Wetlands in Sarasota County

Upland areas, pines and palms. provide habitat for certain species like the Florida Panther. Many of these areas are either protected or have limitations on development. Pines and palms are important for the endangered Florida Panther. Conservation areas and parks/wetlands are extensive in Sarasota County (see Figure 16 and Figure 17 respectively).

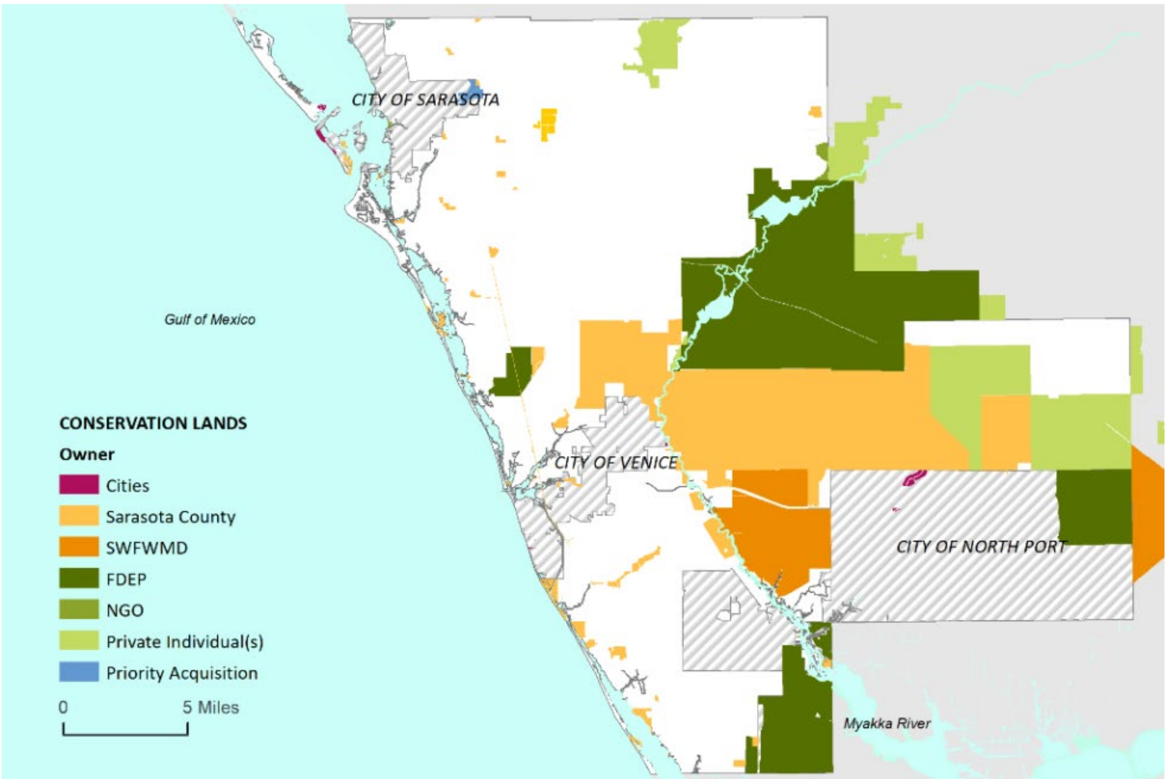

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Figure 16. Conservation lands in Sarasota County

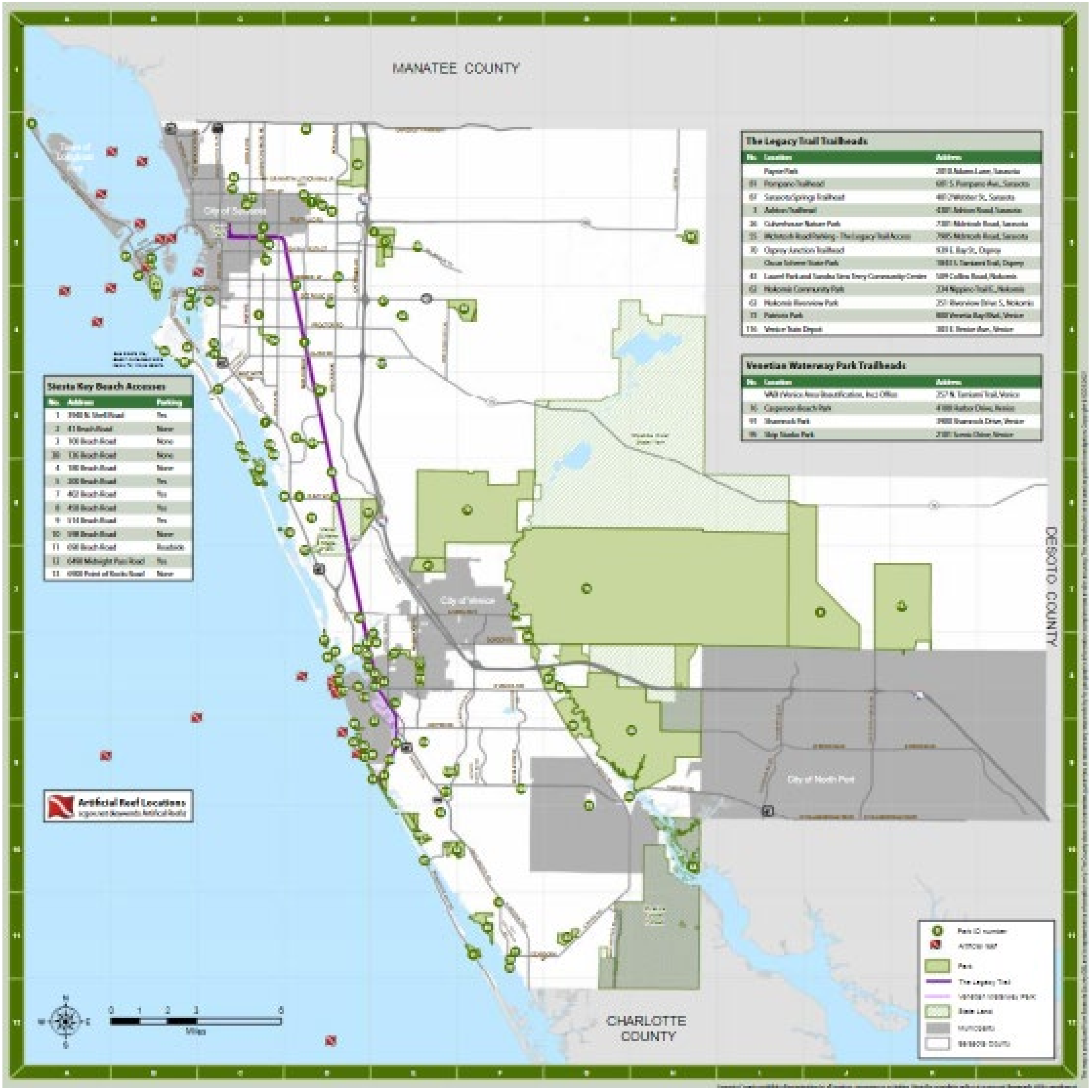


Figure 17. Parks And Wetlands in Sarasota County

1.1.5 Floodplains

Floodplain identification and mapping are important for reducing property/damage due to flood risk. Because floodplains will flood periodically, local governments are expected to develop regulations that either prohibit development in floodplains or permit development that follows standards that make the structures/properties more resilient to flooding - see County Codes Chapter 54, Article XVI and Chapter 124. https://library.municode.com/fl/sarasota_county/codes/code_of_ordinances, and Section 3.1.4.

Beyond the floodway is the flood fringe, which extends from the outer banks of the floodway to the bluff lines of a river valley. When a channel receives too much water, the excess flows over its banks and into the adjacent floodplain. Flooding that occurs along a channel is called riverine flooding. Overbank flooding occurs when downstream channels receive more than normal rain or snowmelt from their watershed. Excess water overloads the channels and flows out onto the floodplain. Overbank flooding varies with the watershed's size and terrain. One measure of a flood is the speed of its moving water (velocity). Depending on the size of the river and the terrain of its floodplain, flooding can last for days and cover wide areas. In urban areas, flash flooding can occur where impervious surfaces, gutters, and storm sewers increase the speed of runoff.

The City has developed such regulations. (see https://www.sarasotafl.gov/home/showpublisheddocument/10926/638016916013230000) The City of Sarasota's FEMA flood map is shown in Figure 18.

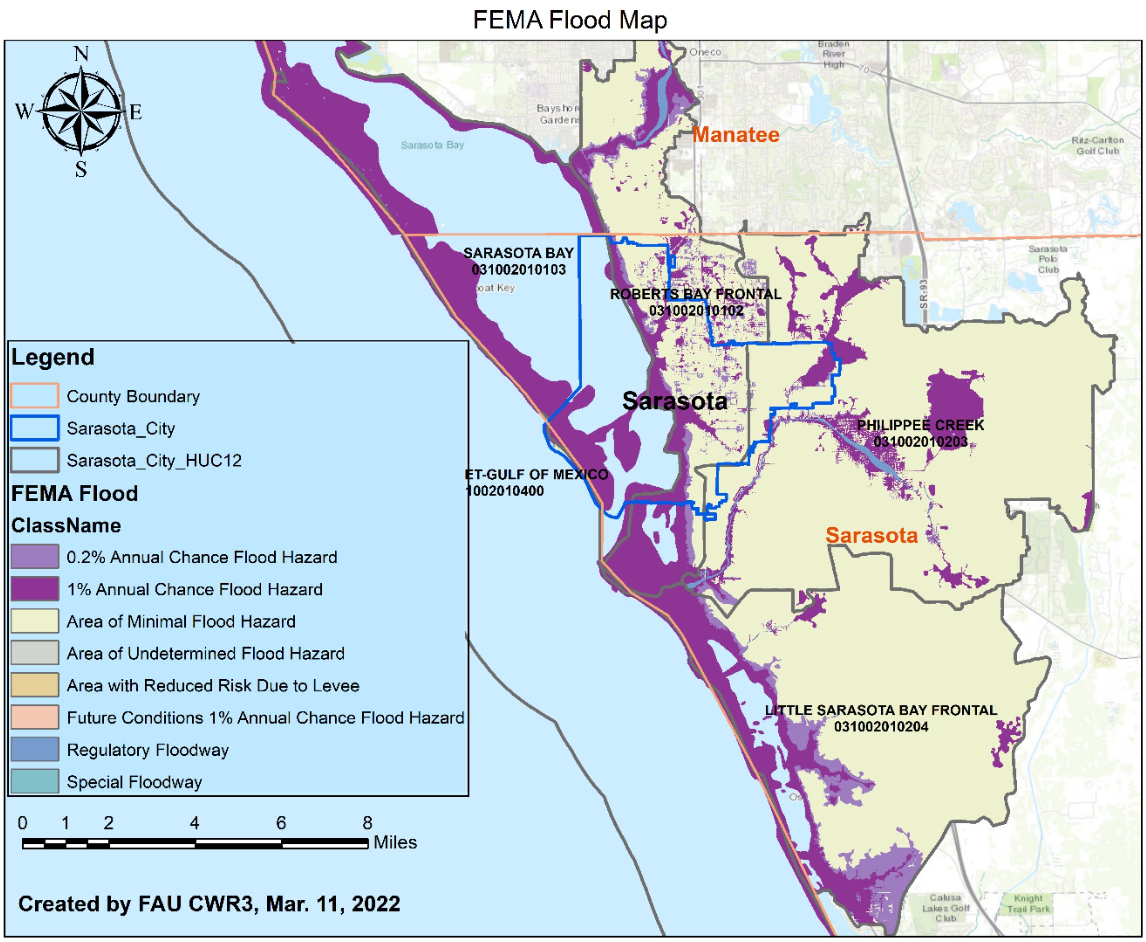


Figure 18. City of Sarasota flood insurance rate map, extending through all affected HUC 12's

1.1.6 Flow Paths and Natural Channels

ArcHydro is an available extension in ArcMap with a set of tools designed to draw the catchment drainage areas using a DEM as input. The ArcHydro function also permits the delineation of routing and sub-basins, which may need to be modeled separately. The results from the land cover, water bodies, flood routing, soil capacity, and topography are all inputs that will be used to generate flood maps. Figure 3 in Section 1.1.1 shows the flow channels for the watershed based on modeling conducted by Florida Atlantic University (FAU).

1.2 Planning Goals and Scope

To ensure that the watershed planning effort remains focused, the planning goals and scope of the effort must be clearly defined. Defining the scope and setting goals early in the planning process will make it easier to implement and monitor the plan. The primary purpose of a watershed management plan is to guide watershed coordinators, resource managers, policymakers, and community organizations to restore and protect the quality of lakes, rivers, streams, and wetlands in each watershed. The plan is intended to be a practical tool with specific recommendations on practices to improve and sustain water quality.

The specific goals for the City are to:

- Identify the characterize the physical and natural features of the watershed in the following categories:
  - Topographic data
  - Groundwater
  - Surface water/tides
  - Soils data
  - Land cover/land use identification including vacant land, wetlands, waterbodies, etc.
  - Precipitation records
  - Open space
  - Impervious areas
  - Waterbodies
  - Natural resources
  - Demographics
  - Locations of stormwater infrastructure
- Identify existing plans and policies such as:
  - Source water assessments
  - Water quality management reports (TMDL implementation plans, BMAPs, SWIM Plans)
  - Flood insurance studies
  - Floodplain management plans
  - Florida “Peril of Flood” Guidance

  - Comprehensive plans
  - Stormwater management policies
  - Local mitigation strategies
  - Unified land development regulations
  - Intergovernmental cooperative agreements
  - Special Watershed Restoration Plans
  - Stormwater pollution prevention plans
  - Post-disaster redevelopment plans
  - Climate adaptation action plans
- Identify
  - Flood prone areas
  - Current and proposed watershed projects
  - Local flood protection projects
  - Local regulatory constraints
  - Dedicated funding for projects

Table 2 shows the ultimate planning goals for the watershed per the City.

Table 2. Goals related to flood protection at the watershed level

Goal	**Indicator**	**Management/Project**
Define the level of service	Determine acceptable flood frequency	Master plans
Develop a plan to meet the LOS	Development of projects to meet LOS	Watershed plan Annual Maintenance budget Capital projects
Meet NDPES requirements	Violations of NDPES requirements in annual reports	Ongoing BMPs for NPDES program
Maintain Water quality	Increased wetland species	Improved management strategies for the river Restore water flow, increase regulatory protection,
Reduce flood frequency	Reduced repetitive loss claims Changes to flood maps	Improved management strategies for the river Locally, install stormwater treatment areas, and develop additional green strategies

1.3 Public Outreach

Community outreach is a major part of the watershed master planning process. The stakeholders for the basin include county governments, municipal governments, the water management district, agricultural, tourism interests, and environmental interests that may have more concerns associated with the timing of flood releases and water quality. Public works agencies and FDOT should also be included as a part of the process because roadways are major sources of conveyance (bridges and culverts).

The goal of the watershed master plan public outreach program is to reflect the steps required to solicit public and key stakeholder input and build awareness of the project. Public information on the plan must be straightforward, factual, and designed to be understood by a non-technical audience. The public outreach plan will engage the community are as follows:

- Create and implement a meaningful public involvement process, and evaluate the public involvement process on a regular basis to make sure that the various communities and key stakeholders are engaged
- Create measurable objectives tied to the milestones that are required for the successful conclusion of the project
- Create public forums and collateral materials that provide clear, concise, and easy-to-understand information designed to enable the public to make informed decisions about the project
- Develop a strong list of public and regional benefits that the project will generate
- Provide accurate, timely, and comprehensive documentation on the public involvement process
- Publish and distribute draft documents for review and also notify the public, elected officials, and other stakeholders of upcoming community meetings and public hearings
- Respond to public and stakeholder feedback in an accurate, consistent, and timely manner

To facilitate community participation, there is a need to develop a database of key stakeholders including, but not limited to, community groups, residents, local and regional business owners, labor, environmental organizations, employers, employees, academia, cultural and entertainment attractions, emergency responders, media, surface transportation industry, policy leaders, other institutions, etc. Then the outreach program should be applied to the stakeholders to:

- Develop corollary key messages that are consistent with the goals and objectives of the demonstration project
- Assess attitudes and perceptions among target audiences
- Identify barriers, advantages, and levels of support

The meetings must be public, and all input recorded. Each meeting should be developed with an agenda that includes:

- Community group meetings/workshop times
- Locations
- Meeting formats
- Speakers/presenters
- Content of presentation material

A website should be created to provide documentation for all meetings including:

- Agendas
- Notices/ads
- Meeting materials and summaries of key information
- Meeting minutes
- Public comment logs
- Draft plan documents

Many stakeholders cannot attend daytime meetings in person, options to provide input should include as many from the following list as necessary to reach the maximum audience:

- Comments on the webpage
- Virtual meetings
- Blogs
- Survey platforms
- Electronic news outlets
- Discussion boards

Such forums must be monitored to incorporate findings into the plan. All outreach efforts should incorporate a news media outlet – for this basin, the Sarasota Herald Tribune is the most widely read newspaper. A variety of County and municipality websites would be effective hosting alternatives as well:

- Sarasota County (https://www.scgov.net/)
- Manatee County (https://www.mymanatee.org/)
- City of Sarasota (https://www.sarasotafl.gov/)
- Town of Longboat Key (https://www.longboatkey.org/)

A list of potential stakeholders:

- SWFWMD
- Manatee County
- Sarasota County

- City of Sarasota
- Town of Longboat Key
- Southwest Regional Planning Council
- City of Bradenton (https://cityofbradenton.com/)
- SRQ airport
- Estuary
- FDOT
- The Bay

Within the community, prior FAU modeling reveals there are challenges on the barrier island portion of the City, bayfront, and along waterways within the community. Direct exposure to the Gulf of Mexico means that sea level rise, king tides, and storms will all affect the future condition.

1.4 Credit Criteria and Documentation

The credit criteria for Section 452.b is found in the 2017 *CRS Coordinator's Manual and Addendum to the 2017 CRS Coordinator's Manual.* There is no need to submit more than one copy of a watershed master plan or regulatory section if it can be used to document separate sub-elements. Instead, each section clearly indicates where to find the desired criteria.

1.4.1 Elements of the WMP

When submitting a plan for WMP credit, the plan must indicate which of the eight sub-elements the plan meets. Note that WMP1 credit must be received in order to receive credit for any of the additional sub-elements.

(A) WMP1 documentation

Attach a copy of each watershed plan that has analyzed the impact of sea level rise and/or fully developed watersheds on your community during a 100-year event. To be credited, the plan must have been adopted by your community and you must have a plan to control the impacts of the 10-year event and at least the 25-year event on your community. Credit for onsite control of the 10-year event and the 25-year event or the 100-year event is an acceptable method of controlling the impacts.

(B) WMP2 documentation

Explain how your plan and regulations manage a 100-year event and where those requirements/ regulations are found. Note the City has adopted the standard flood ordinance.

(C) WMP3 documentation

Explain how your plan manages not only future peak flows but also the volume of runoff from new development so that it does not increase over present values. A community must demonstrate that its watershed management plan and associated regulations prevent increases in peak flows at all points within its watershed(s) and downstream.

(D) WMP4 documentation

Explain how your plan manages the runoff from all storms up to and including the 5-day event and where to find that in the plan itself. Refer to specific regulations or standards.

(E) WMP5 documentation

Highlight the section of your plan that identifies existing wetlands or other natural open space areas to be preserved from development to provide natural attenuation, retention, or detention of runoff. Include the regulation that requires their preservation. For WMP5 credit, the plan must identify these areas and there must be regulations to preserve them, a map by itself is not creditable. Note the section/page number of the plan and regulation.

(F) WMP6 documentation

Highlight the section of your plan that recommends prohibiting the development, alteration, or modification of existing natural stream channels. Include the regulation that implements the prohibition. For WMP6 credit, the plan must identify these areas, and there must be regulations to preserve them. (These channels may be eligible for credit under element NSP—natural shoreline protection, under Activity 420.) Note the section/page number of the plan and regulation.

(G) WMP7 documentation

Highlight the section of your plan that recommends that channel improvement projects use only natural or "soft" approaches rather than gabions, rip rap, concrete, or other "hard" techniques. Include a copy of the regulation or the design standards that implement the regulation. For WMP7 credit, the plan must recommend these techniques and there must be regulations to require them. Note the section/page number of the plan and regulation.

(H) WMP8 documentation

Attach a copy of the ordinance establishing your source of dedicated funding to implement the watershed master plan and a copy of recent expenditures. (see Appendix A for the stormwater assessment information)

1.4.2 Conclusion on WMP Credits

The goal of this report is to support the City's efforts to gain up to 350 points toward a Class 4 CRS score.

2.0 WATERSHED CHARACTERIZATION

Despite historical water management conflicts and periodic disruptions, Southwest Florida will remain a desirable place to live, so the interconnectedness of water bodies will require a more integrated solution to resolve water quantity and quality issues. Making thoughtful, long-term decisions will be important because infrastructure and development typically have an expected life cycle of at least 50 years or more. It is important to create a planning framework to protect vulnerable infrastructure through a long-term plan. While uncertainties in the scale, timing, and location of climate change impacts can make decision-making difficult, response strategies can be effective if planning is initiated early. Because vulnerability can never be estimated with 100% accuracy, the conventional approach should be replaced or supplemented with one that recognizes the importance of building resiliency, which requires data. Among the datasets to be acquired for this WMP process are the following:

- Topographic data (LiDAR)
- Relevant waterway locations
- Groundwater levels
- Soil data
- Land uses, including vacant land, wetlands, etc.
- Basin delineations for flood routing

In addition, the FEMA flood maps must be obtained, and the storm of interest must be identified for screening purposes (3-day 25-year, 1-day 10-year, 1-day 5-year, and 1-day 100-year storm events to achieve class 4 in the CRS Manual). In developed areas many sources of data are already available – the key is putting the key datasets in a format that can be queried for screening to identify the priority areas of the watershed. Table 3 is a summary of datasets available at cwr3.fau.edu that were used to construct this plan.

Table 3. List of datasets collected by FAU as of List of datasets collected by FAU for the project

Data Category	Dataset Name	Original Source	Spatial Coverage/ Resolution	Temporal Coverage/ Resolution	Dataset size and Format	Native or FAU Processed dataset
Topography	USGS_NED	USGS	Part of Florida, raster image in 1 m	Created by USGS in 2016	3.28G bytes, raster images	Native
	USGS_NED	USGS	Part of Florida, raster image in 3m	Created by USGS	40.9G bytes, raster images	Native
	USGS_DEM	USGS	Florida, Raster data in 10m	Created by USGS	22.6 G bytes, raster images	Native
	DEM_3m_merged	USGS	3m in tiff		186G bytes, raster images	FAU Processed
	SRTM_30m	NASA	30m Raster		607M bytes, raster images	Native
Groundwater	USGS_3DEP	USGS	Sarasota County, raster image in 1 meter	2018-2020	53G bytes, raster images	Mosaiced by FAU
	FL_GW	Southwest FL Water Management District	Florida, Geodatabase	Daily, 1980-2020	27.9 G bytes, Geodatabase	Native

Data Category	Dataset Name	Original Source	Spatial Coverage/ Resolution	Temporal Coverage/ Resolution	Dataset size and Format	Native or FAU Processed dataset
Surface Water and Tides	FL_SW	Southwest Florida Water Management District	Southwest of Florida, site observations	Daily, since 2000	74.5M bytes, in excel and dbf	Native
Soil	FL_Soil	FY2019 USDA Soil SSURGO gSSURGO) Database https://sdmdataaccess.nrcs.usda.gov/	Florida, Raster data is in 10m	Released by USDA in 2019	107G bytes, both vector and raster	FAU Processed
Land Cover	USGS_LC	USGS	Conterminous United States, raster format, 30m derived from satellite	Created by USGS in 2016 (Most recent)	20G bytes, raster	Native
	Impervious Surface	USGS	Florida, 30m derived from satellite	Created by USGS in 2016 (Most recent)	24.6G Bytes, Raster Image	FAU Processed
	Open Space	USGS	Florida, 30m derived from satellite	Created by USGS in 2016 (Most recent)	21G bytes, raster	FAU Processed
Precipitation Records	FL_NOAA14_Precipitation	NOAA Atlas 14 Database	Florida, raster in 800m	Most recent release from NOAA	34 M bytes, raster images	FAU Processed, 3-day 25-year and 3-day 100-year

The data can be used to model the impacts of flood routing during the storm of interest. As a result, the modeling pieces (discussed in Chapter 4) will include the following:

- Flood response model results (Cascade 2001)
- Flood risk/hazard mapping
- Vulnerability assessments to identify areas of concern for future repetitive losses

Aside from the Myakka River, the northmost portion of the study area also has a number of water bodies, much of the watershed is classified as urbanized areas, agriculture, wetland areas, and coastal areas, which are nearly level lands with poorly drained soils. However, the northmost portion is nearly level to strongly sloping excessively drained thick sandy soils, where some with thin loamy sand bands in the subsoil. The coastal portion of this watershed is classified as an Undifferentiated Superficial Aquifer, which consists of sand and limestone. The inland portion of this watershed is a part of the Floridian aquifer system, which contains a sequence of Paleogene carbonate rock (mostly limestone and dolostone) and can be classified as Upper and Lower Floridan aquifers. The Floridian aquifer system is an important source of freshwater in this area, and the groundwater is mostly near the surface.

2.1 Surface Topography

Topography is a key parameter that influences many of the processes involved in flood risk. In a flood risk assessment, the ground surface elevation is an important consideration as low-lying land areas are often highly vulnerable to flooding. assessment, and thus, up-to-date, high-resolution, high-accuracy elevation data is required. In order to meet the requirements for FEMA Risk Mapping, Assessment, and Planning (RiskMAP), 1-meter (2015 to present) and 1/9 arc-second (~ 3-meter) (2010 -2015) LiDAR DEMs were acquired. The 3 m × 3 m LiDAR tiles were kriged to create a topographic map of the watershed. This accuracy meets the 3DEP Quality Level 2 vertical root mean square error accuracy threshold of ±10 cm for FEMA (Arundel et al., 2015). The LiDAR used for this basin was collected in 2016. The LiDAR DEM products used in this study have a horizontal resolution of three meters and a vertical accuracy between 22 centimeters and 30 centimeters. This dataset covers nearly all areas in the watershed. Further processing of the data involved mosaicking into a seamless ground elevation surface, projecting into the NAD 1983 UTM Zone 17N coordinate system, and converting vertical units from meters to feet.

Figure 19 is a topographic map of the City of Sarasota generated by FAU CWR3 (2016 flight). Note the LiDAR shows an area north of the basin that is relatively high, but it drains west toward the Gulf of Mexico.

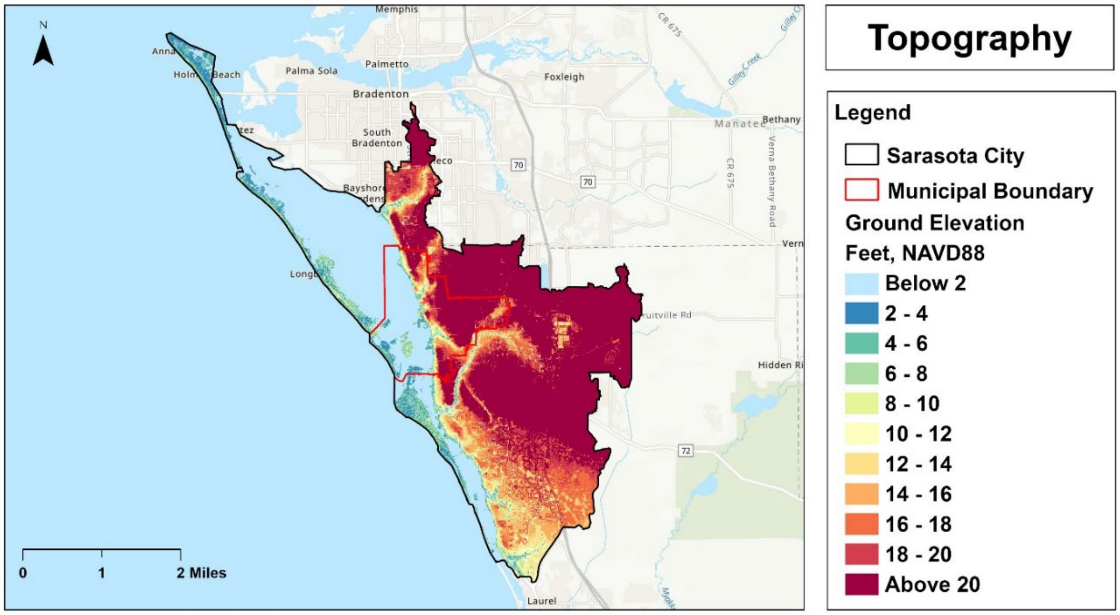


Figure 19. Topographic map of the City of Sarasota as generated by FAU CWR3 (2019 County flight). Note this represents areas outside the basin.

2.2 Surface Water/Tides

Historically, surface water and tides have been key factors in determining how much freshwater is delivered, how fast this water enters wetlands and estuaries, and the quality of that water. Evapotranspiration and rainfall do not coincide (Figure 20), which makes water supply planning difficult (Bloetscher, 1995).

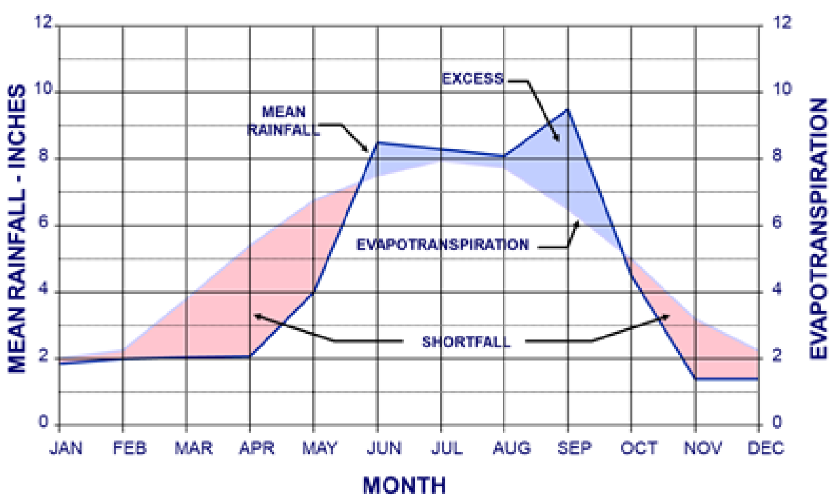


Figure 20. Comparison of rainfall and evapotranspiration for SW Florida (Bloetscher, 1995)

While the native soil (Section 2.4) and topography (Section 2.1) create an environment that is highly permeable and capable of infiltrating significant percolation of the water into the soil, changes in land use have resulted in water falling on impervious areas, where the water collects in pools or runs off rapidly, in direct contrast to the natural condition. This runoff flowing over impermeable regions can lead to large-scale flooding. Over the past few decades, Sarasota County has constructed many projects of various scales to attenuate flooding of structures and roadways.

In this region of Florida, there is a direct interaction between groundwater and surface water. In addition to low land elevations and topographic relief, the groundwater and surface water are controlled by $ 332,970

canals, rivers, and tides. Since there is a limited number of groundwater monitoring stations, the strong relationship between groundwater and surface water was leveraged to develop a 99th percentile surface of the groundwater table elevation for mapping purposes. To set a boundary for the coastal areas, the high tide on the common date of 09/27/2013 was developed based on a review of all wells across the region. Many stations are located along canals and rivers, which assists in determining the water levels across open and connected surface water bodies. See Figure 21 for the stations used in the modeling.

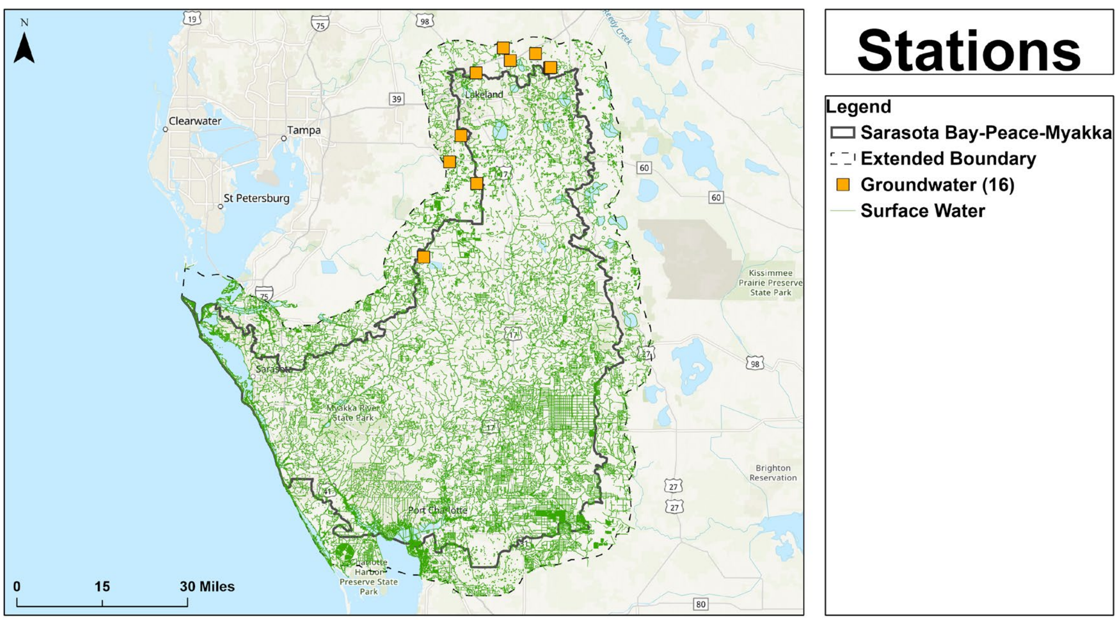


Figure 21. Control and surface water stations maintained in the City of Sarasota as generated by FAU CWR3

Tidal data can be gathered from NOAA tidal gages and other gages monitored by local governments. The location of tide gages is important to ensure they accurately depict tides, as opposed to inland waters. To set a boundary for the coastal areas, the high tide on the common date of 09/27/2013 was chosen. Figure 22 shows the tide gages in Florida. The Fort Myers tide station was used for this exercise.

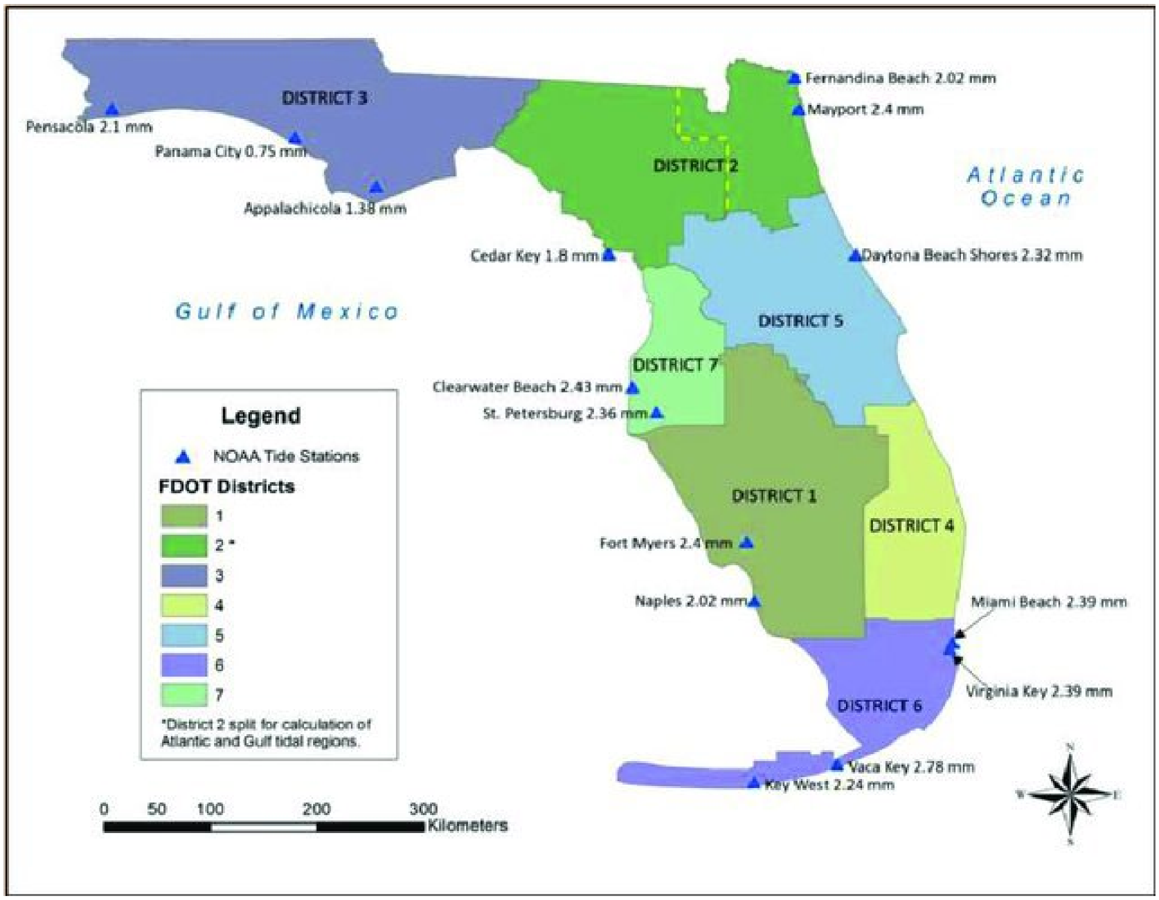


Figure 22. Locations of Florida tidal stations maintained by NOAA in FDOT Districts

2.3 Groundwater

The surficial aquifer system is contained within near-surface deposits that mainly consist of undifferentiated sands, clayey sand, silt, shell, and marl of Quaternary age. The aquifer produces relatively small quantities of water, which are generally used for low-volume irrigation or domestic water supply. Surficial deposits range in thickness from 10 feet in coastal areas to greater than 100 feet further inland (SWFWMD, 1993). The thickness of sand layers is variable in the area but averages approximately 40 feet. This geological formation is termed the surficial aquifer system (SAS) and is the water supply for most potable and irrigation users. The SAS and its associated wetlands depend on rainfall for aquifer recharge. During dry conditions, recharge diminishes, drainage persists, and irrigation and other demands increase, compounding stress on the SAS and wetland systems.

Underlying the surficial aquifer system is the confined intermediate aquifer system (IAS) with its associated confining units. This aquifer consists predominantly of discontinuous sand, gravel, shell, limestone, and dolomite beds of the Hawthorn Group and contains up to three confined or semi-confined production zones throughout much of the planning region (Wolansky, 1983). The production zones are separated by low-permeability sandy clays, clays, and marls. These confining beds restrict the vertical movement of groundwater between individual water-bearing zones in the intermediate aquifers and the overlying surficial and underlying Upper Floridan Aquifer (UFA). In general, the thickness of the intermediate aquifer system increases from north to south. The intermediate aquifers are utilized extensively for public supply, agricultural irrigation, and recreational, domestic, and industrial water uses, especially in the southern coastal portions of the planning region where its water quality is better than the UFA. Typically, the IAS is recharged by seepage from above or laterally. The IAS is also limited, as it has become the major potable supply source for the region.

The UFA, by far the most important source of groundwater in the planning region, is composed of a thick, stratified sequence of limestone and dolomite units that include (in order of increasing geologic age and depth) the Suwannee Limestone, Ocala Limestone and Avon Park Formation. The aquifer is confined throughout the planning region by the low-permeability sediments of the overlying intermediate aquifer system. The UFA can be separated into upper and lower flow zones. The Suwannee Limestone forms the upper flow zone and the lower zone is composed of the highly transmissive portion of the Avon Park Formation. The two zones are separated by the lower permeability of Ocala Limestone. The two flow zones are locally connected, through the Ocala, by diffuse leakage, vertical solution openings along fractures, or other zones of preferential flow (Menke et al., 1961). The Middle Confining Unit 2 (MCU II) of the Floridan Aquifer lies near the base of the Avon Park Formation (Miller, 1986). It is composed of evaporated minerals such as gypsum and anhydrite, which occur as thin beds or as nodules within dolomitic limestone that overall have extremely low permeability. MCU II is generally considered to be the base of the freshwater production zone of the aquifer, except in coastal areas of Manatee and Sarasota counties, southern DeSoto, and Charlotte counties. In this area, water quality within the Avon Park Formation is mineralized or saline with sulfate or chloride concentrations exceeding 1,000 mg/L. Figure 23 shows a schematic of the aquifer system.

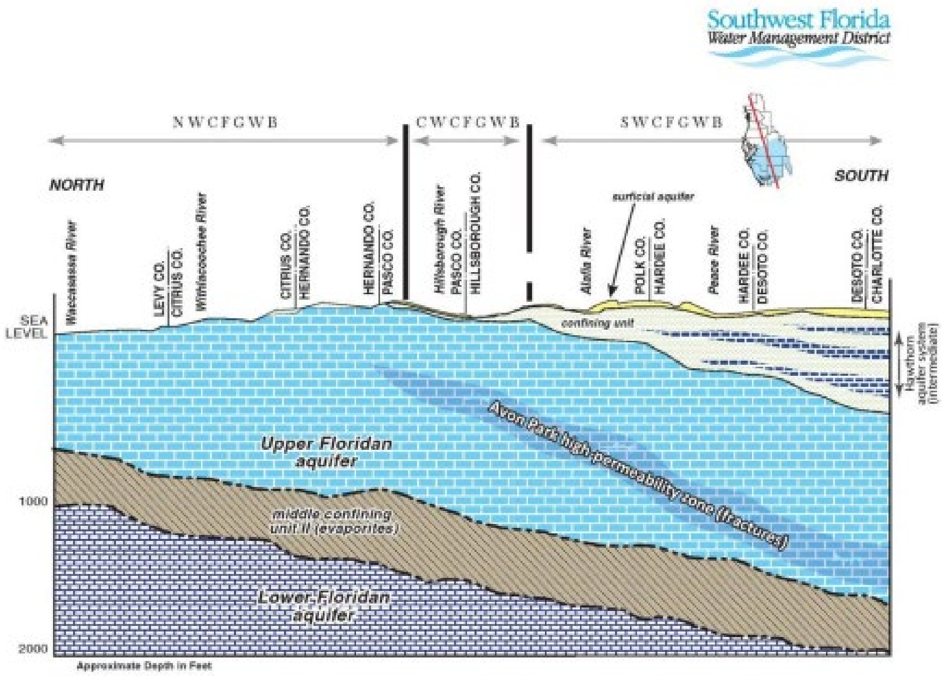


Figure 23. Geological Profile of Aquifers under Sarasota County

The southern Florida coastal condition is characterized by direct interaction between groundwater and surface water near the coast. The land has relatively flat terrain and coastal groundwater elevation is controlled by canals and tides. Resolving the situation is straightforward. Bloetscher et al. (2012) found that the groundwater table elevation would seek high tides as opposed to average tides for a boundary condition.

Once a common time period was determined across the majority of wells, canal data can be gathered for that common date (and two days prior in the event the canals were deliberately lowered). Data was obtained from the SWFWMD DBHYDRO site for surface waters (https://www.swfwmd.state.fl.us/resources/data-maps/hydrologic-data) and generated by FAU CWR3 at cwr3.fau.edu. Between stations, an ArcGIS tool permits a line to be drawn to replicate the canals and establish points in a gradient between stations. The same is true for the ocean, but it is a constant head boundary. The canals form boundary conditions for the screening tool on the edges of the basin and affect localized groundwater. Using water levels in the groundwater and canals, the only remaining boundary was the Gulf of Mexico. The tide issue is resolved by using the common date for high tide. Based on the tides, surface waters, and groundwater, a surface for groundwater was created in GIS based on the common date (see Figure 24).

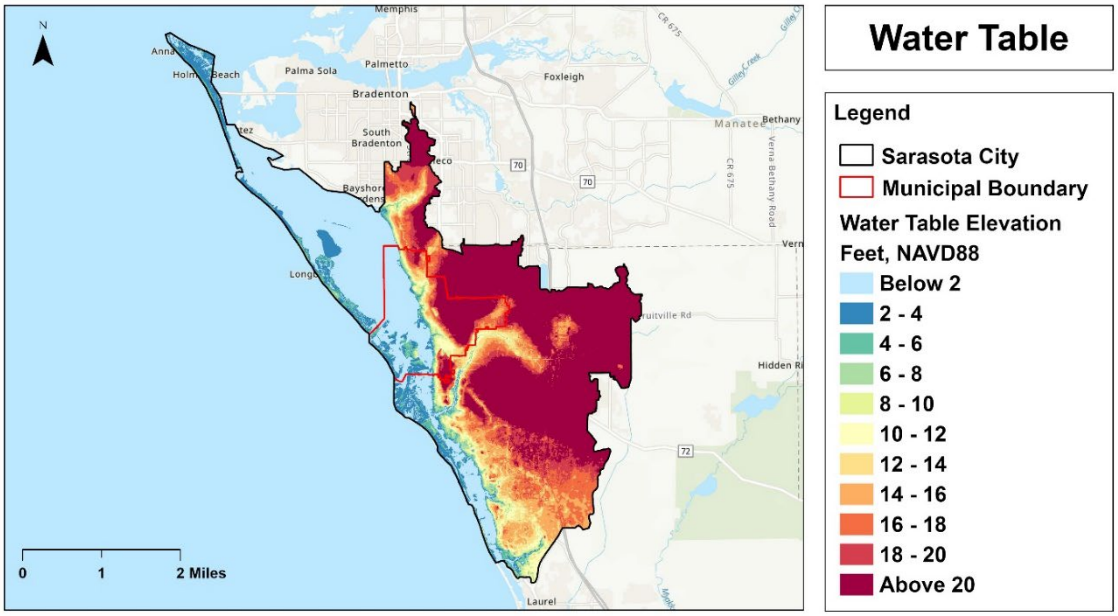


Figure 24. Elevation of the top of the surficial groundwater layer for the City of Sarasota created by kriging – elevation NAVD88, as generated by FAU CWR3

2.4 Soils

While low land elevations and high groundwater table elevations influence flooding, the soil storage capacity will also greatly influence the watershed’s vulnerability to flooding. Open surface water bodies and frequently inundated land will be unable to store additional water during a rainfall event. Hence, when mapping the soil storage capacity across the watershed, these areas were set to zero as there is no capacity for these areas to store additional water (note of a 10 x10 ft grid, the canal banks will show the elevation change, but drilldowns are needed to see this). These areas were delineated from statewide land use and land cover datasets and were used in the calculation of soil storage capacity. Flooding is likely to occur near open surface water bodies and areas such as wetlands, swamps, and marshes.

Soil can store water if there is adequate distance between the topographic surface and the groundwater, and the soil is capable of absorbing the water. Soil storage capacity is the volume of soil pores in the unsaturated zone that is available to store infiltrated stormwater (Gregory, 1999). Throughout Florida, it is common to have large-volume storm events that fill the voids in the unsaturated zone as shown in Figure 25.

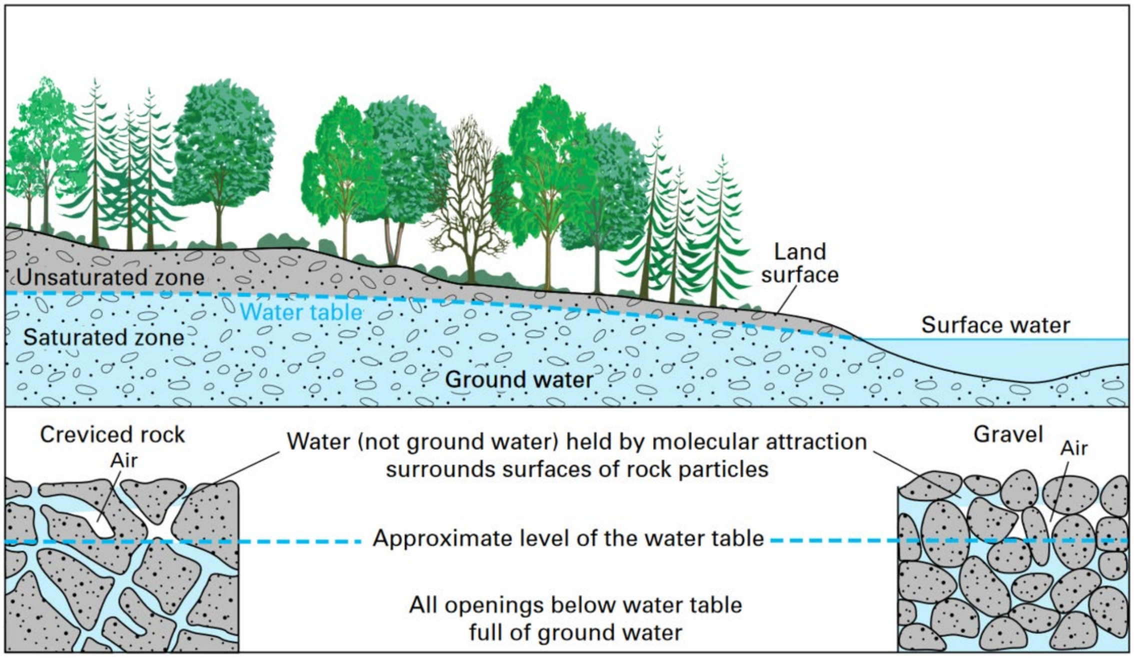


Figure 25. Zones where underground water exists (USGS, 2020)

The unsaturated zone is the portion of the subsurface above the groundwater table that contains soil and rock, with air and water in its pores, as depicted in Figure 26. This zone affects the rate at which the aquifer gets recharged by controlling water movement from the surface of the land downward toward the aquifer. During rain events, the soil voids fill up quickly resulting in the ground water table rising to the surface and the surplus rainfall becomes runoff.

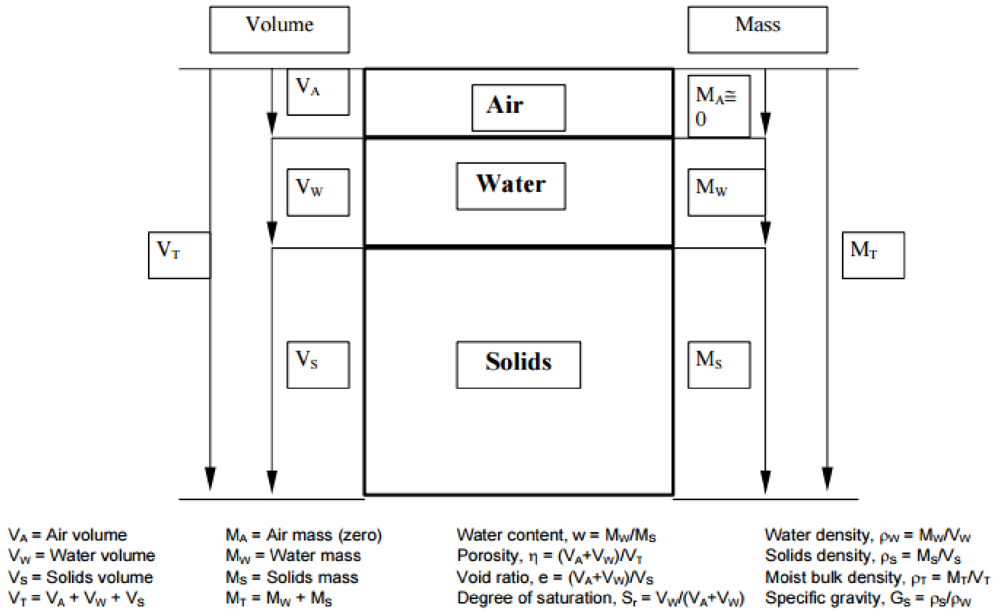


Figure 26. Saturated zone soil phase diagram and definitions (Gregory et al., 1998)

Soil data available from the United States Department of Agriculture (USDA) or other agencies is available in the form of maps that can be incorporated as a GIS layer. FAU chose to use the Gridded SSURGO (gSSURGO) dataset from USDA, which is similar to the standard product from the USDA Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database but is in the Environmental Systems Research Institute, Inc. (ESRI®) file geodatabase format. A file geodatabase allows for statewide or even Conterminous United States (CONUS) tiling of data. The gSSURGO dataset contains all the original soil attribute tables in SSURGO. All spatial data are stored within the geodatabase instead of externally as separate shape files. Both SSURGO and gSSURGO are considered products of the National Cooperative Soil Survey (NCSS). Figure 27 shows the soil storage values found by the difference between the groundwater elevation layer and surface topography.

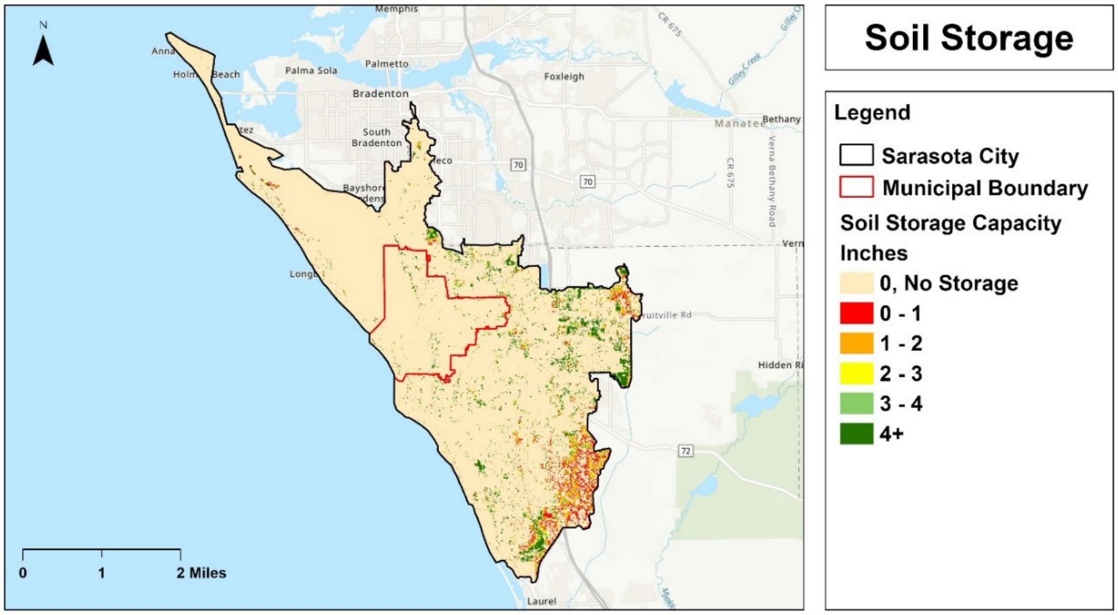


Figure 27. Unsaturated zone map for Sarasota County as generated by FAU CWR3

The available water storage from USDA derived for the soil layer (0-150 cm) statewide is shown in Figure 28, which covers most of Florida with a spatial resolution of 10 m. The unit is in cm. The “no data area” is mainly due to a land covered by a water body or wetland. As a result of applying this layer (Figure 29), the estimated soil storage capacity can be illustrated. Much of the study area has limited soil storage capacity.

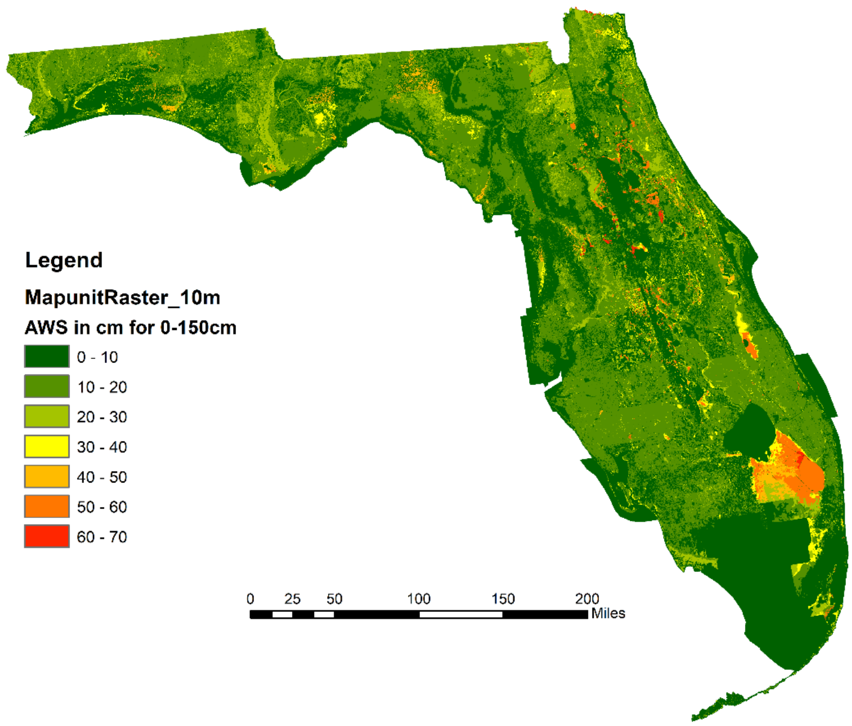


Figure 28. Available water storage derived from the gSSURGO soil database for all of Florida, as generated by FAU CWR3

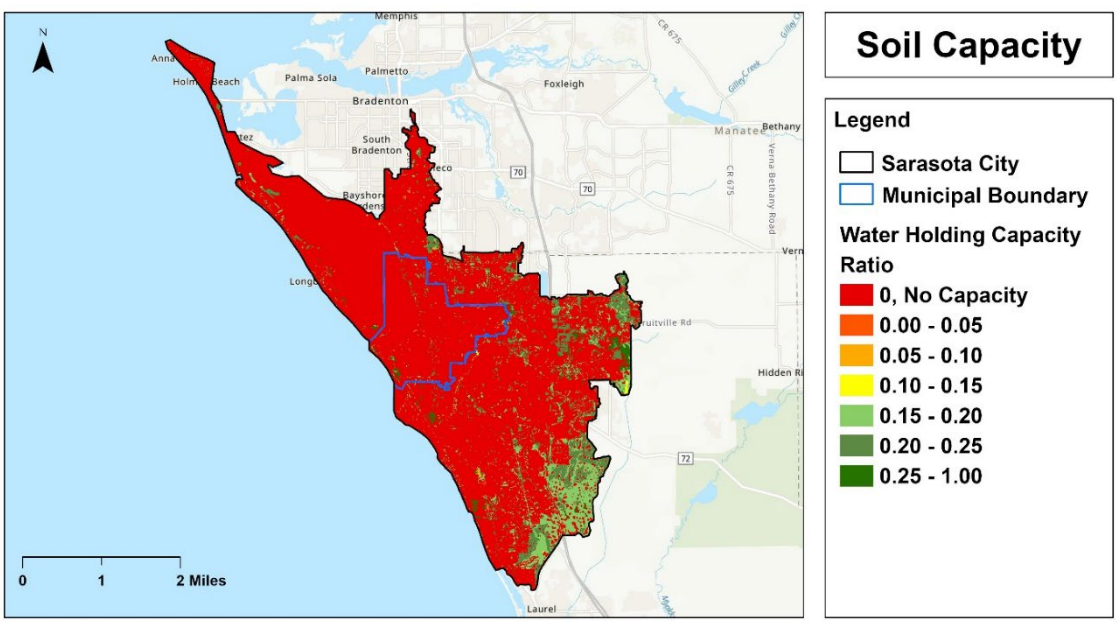


Figure 29. Soil Capacity for the City of Sarasota (holding capacity in inches), as generated by FAU CWR3

2.5 Land Cover

The U.S. Geological Survey (USGS) produces the NLCD of nationwide data on land cover at a 30 m resolution with a 16-class legend based on a modified Anderson Level II classification system. NLCD is coordinated through the 10-member Multi-Resolution Land Characteristics Consortium (MRLC) to provide digital land cover information nationwide. For the conterminous United States, NLCD 2016 contains 28 different land cover products characterizing land cover and land cover change across 7 epochs from 2001-2016, urban imperviousness and urban imperviousness change across 4 epochs from 2001-2016, tree canopy and tree canopy change across 2 epochs from 2011-2016 and western U.S. shrub and grassland areas for 2016. This map was used for the land cover.

2.6 Precipitation

Rainfall used in the screening tool is based on the any rainfall event using the accumulated rainfall table obtained from NOAA Atlas 14 Point Precipitation Frequency Estimates obtained from https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html. Figure 30 shows the 3-day 25-year rainfall map based on the NOAA Atlas 14 dataset for the whole state. Figure 31 shows the rainfall distribution across the basin for 1-day 100-year storm. Figure 32 shows the rainfall distribution across the basin for 1-day 10-year storm. Figure 33 shows the rainfall distribution across the basin for 1-day 5-year storm. Figure 34 shows the rainfall in the City since 1915.

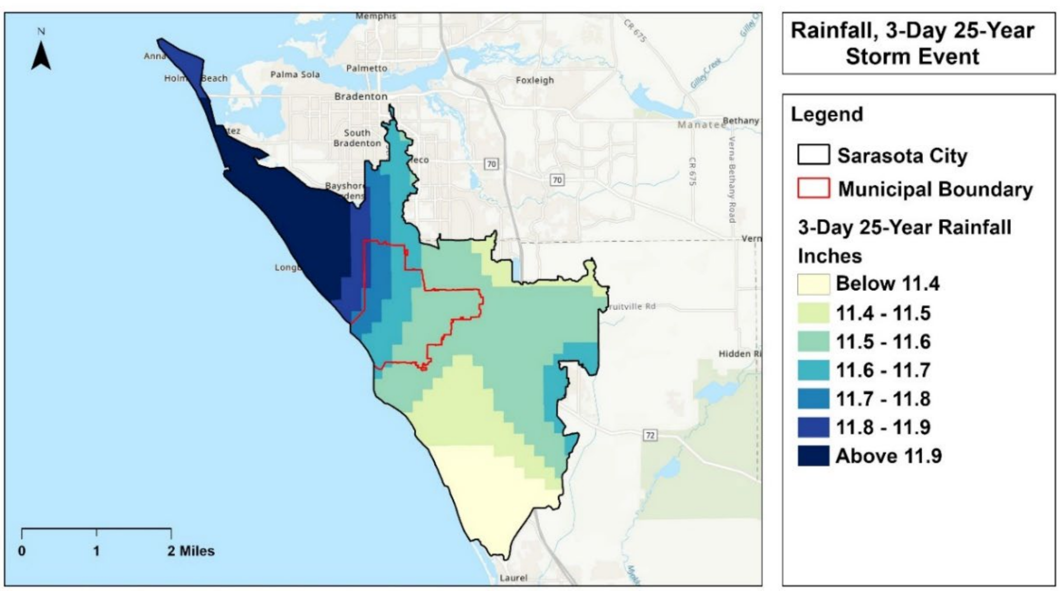


Figure 30. Rainfall distribution across the basin for 3-day 25-year storm, as generated by FAU CWR3

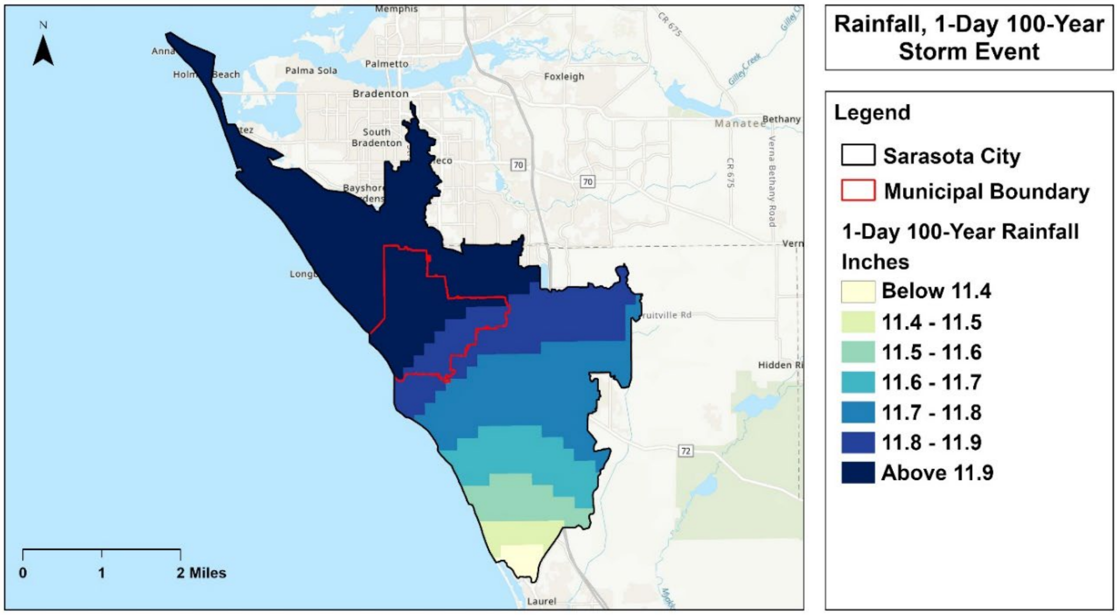


Figure 31. Rainfall distribution across the basin for 1-day 100-year storm, as generated by FAU CWR3

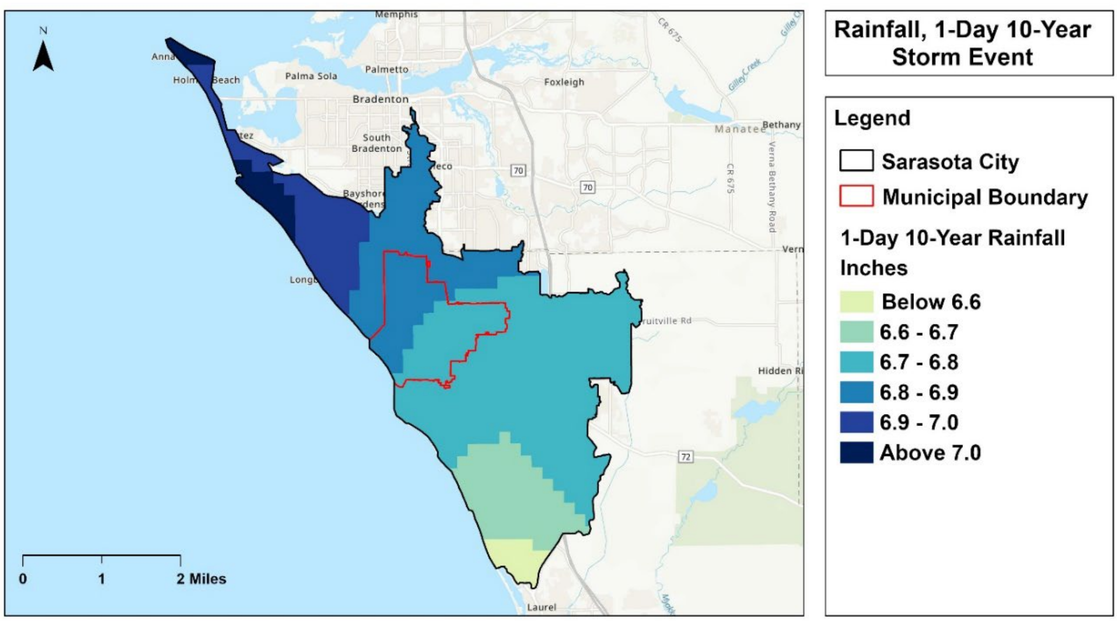


Figure 32. Rainfall distribution across the basin for 1-day 10-year storm, as generated by FAU CWR3

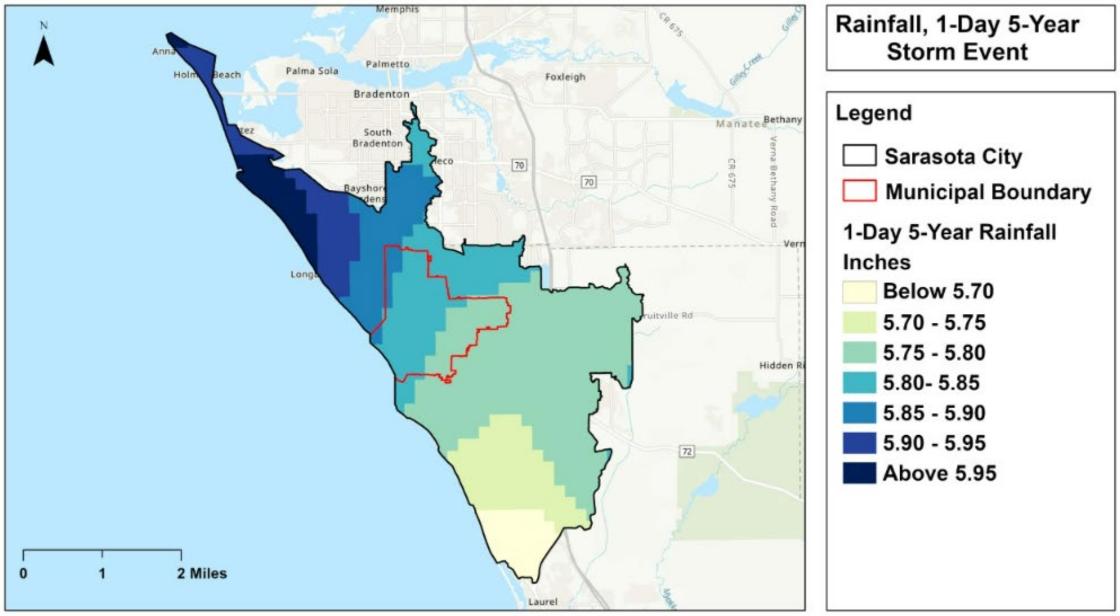


Figure 33. Rainfall distribution across the basin for 1-day 5-year storm, as generated by FAU CWR3

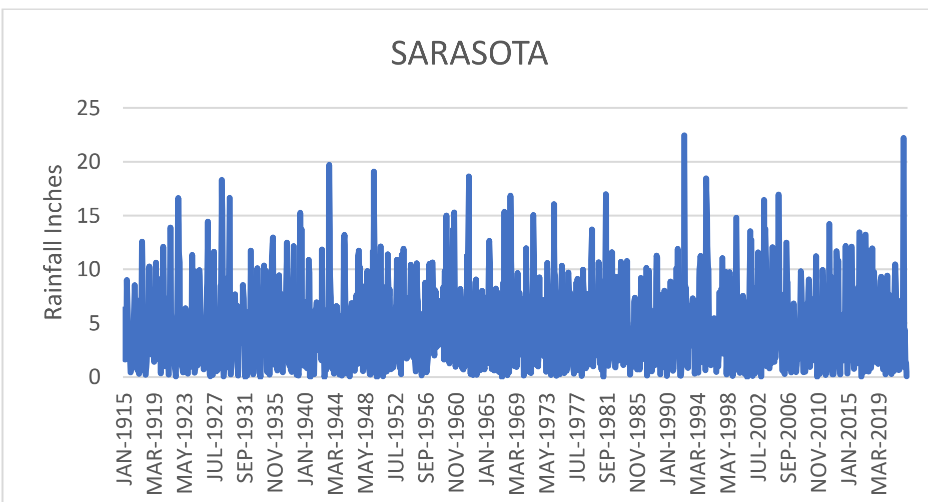


Figure 34. Variation of monthly rainfall in the County.

2.7 Open Space

Open space is defined as areas that are exempted from development. Generally, it means one or more of the following qualifiers exist:

1. Land that is valuable for recreation, forestry, fishing, or conservation of wildlife or natural resources
2. Land that is a prime natural feature of the state's landscape, such as a shoreline or ridgeline
3. Land that is a habitat for native plant or animal species listed as threatened, endangered, or of special concern
4. Land that is a relatively undisturbed example or an uncommon native ecological community
5. Land that is important for enhancing and conserving the water quality of lakes, rivers, springs, and coastal water
6. Land that is valuable for preserving local agricultural heritage
7. Proximity to urban areas or areas with open space deficiencies and underserved populations
8. Vulnerability of land to development
9. Stewardship needs and management constraints
10. Preservation of forest land and bodies of water that naturally absorb significant amounts of carbon dioxide

Permanent protection of sensitive areas can provide critical water quality protection and can be achieved through partnerships with landowners, municipalities, land trusts, and state agencies. There is land throughout the watershed that has been protected via acquisition by federal, state, or local agencies, has conservation easements, or is designated as wetlands or areas of critical concern. These are primarily shown on the conservation maps noted in Section 1.1.4. Agricultural land and other land cover will come from the land cover map. Added to this will be the waterbodies discussed in Section 2.9, which serve a related condition to open space.

2.8 Impervious Areas

Impervious areas do not permit the infiltration of rainfall to groundwater, and because the water cannot infiltrate the ground, it runs off faster. Faster runoff means that peak flows to water bodies and storm sewers occur faster and with a higher peak. The result is a disruption of the natural and potentially the planned hydrology. Impervious areas include pavement, buildings, and other hard surfaces that reduce runoff capacity. In other words, developed areas have much higher imperviousness than areas that are natural or agricultural.

The NLCD provides nationwide data on land cover and land cover change at a 30 m resolution with a 16-class legend based on a modified Anderson Level II classification system. The database is designed to provide cyclical updates on United States land cover and associated changes. Systematically aligned over time, the database offers the ability to understand both current and historical land cover and land cover change and enables monitoring and trend assessments. Using the NLCD 2016 dataset, a layer was created by using only three categories out of the 13 to identify impervious areas such as primary roads in urban areas, secondary roads in urban areas, and tertiary roads in urban areas. The new layer was then converted to match the 3-meter spatial resolution from the DEM and the standard State Plane Coordinate system. Figure 35 shows the impervious areas derived from the NLCD2016.

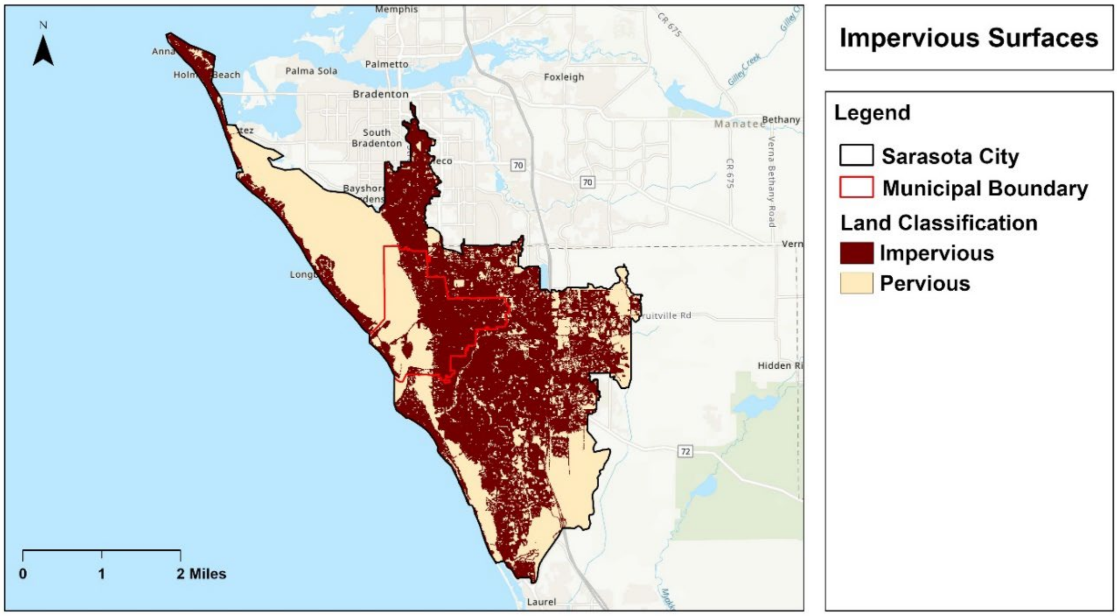


Figure 35. Impervious area map for Sarasota as generated by FAU CWR3

2.9 Water Bodies

Waterbodies were set to have a soil water holding capacity of zero in model simulations as do impervious areas (Figure 36). Note that tiny waterbodies may be missing from the maps. Soils were discussed previously in Section 2.4.

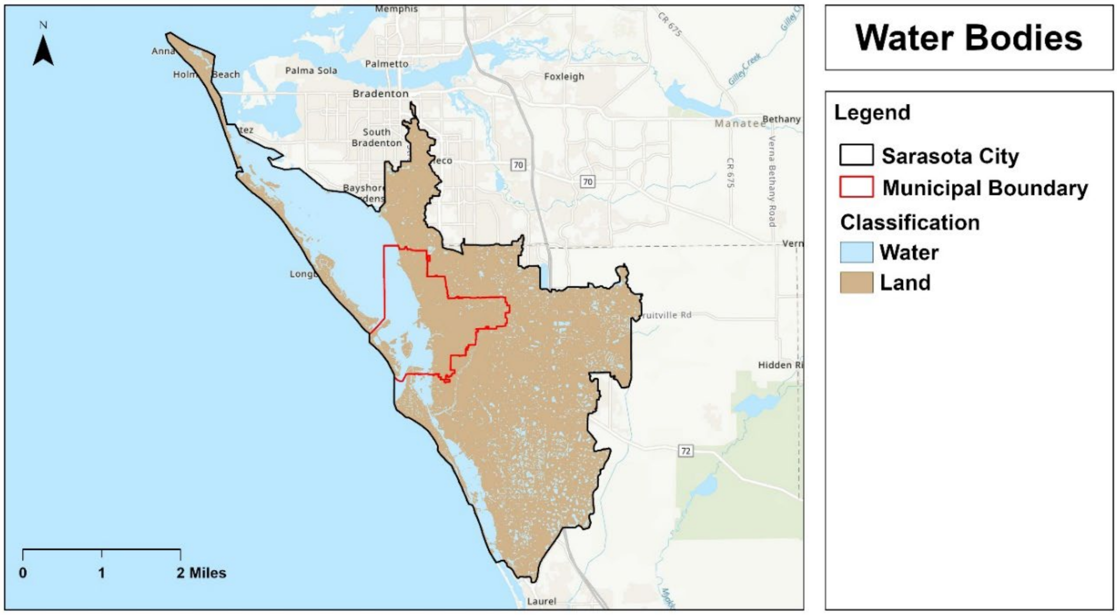


Figure 36. Waterbodies map for Sarasota as generated by FAU CWR3

2.10. Natural Resources

One possible goal of watershed master planning is to protect terrestrial wildlife, aquatic habitats, and buffer zones. Understanding the watershed's natural resources is critical to identifying potential sources of water quality degradation and areas to designate for conservation, protection, and restoration.

USGS maintains important sources of information on physical and geographical features as well as soil and mineral resources, surface and ground water resources, topographic maps, and water quality monitoring data. The USDA's Natural Resources Inventory (NRI) a survey of information on natural resources on non-federal land in the United States that captures data on land cover and land use, soil erosion, prime farmland soils, wetlands, habitat diversity, erosion, conservation practices, and related items. Since 2001, the NRI has been updated continually with annual releases of NRI data from all 50 states. The information provided can be used for addressing agricultural and environmental issues down to the county or cataloging unit level. Therefore, at the watershed level, this data can be used to determine erosion and site-specific soil characteristics for certain land uses such as croplands, pasturelands, forestlands, etc., but the data is typically provided as inventories, not GIS layers. Much of this information is primarily covered in Section 1.1 and earlier parts of this chapter and will not be repeated here.

2.11 Demographics

Demographic data is important for determining several key indicators for watershed-level master planning such as the ability to pay for improvements, social justice issues, land acquisition costs, property/land use, and communication strategies. The US Census has databases at the census tract level. Based on the census data for the watershed, Table 4 outlines population and racial composition demographics by County.

Table 4. Demographics and Housing Characteristics of the Watershed by County (US Census 2020)

Demographic Parameter	**Manatee County**	**Sarasota County (2020 Census)**
Area	893 mi^2	725 mi^2
Population	399,710	434,066
No. of Households	150,345	189,228
Med. Household Income	$59,963	$64,644
White	68.32%	80.6%
Black, African American	7.79%	3.7%
American Indian, Native	0.2%	0.2%
Asian	1.6%	2.0%
Other Race	0.2%	0.4%
Two or More Races	1.3%	3.2%
Hispanic or Latino (Regardless of Race)	14.9%	10.0%

2.12 Stormwater Infrastructure Inventory

Local community stormwater systems consist of drainage ditches, storm sewers, retention ponds, and other facilities constructed to store runoff or carry it to a receiving stream, lake, or ocean. Other manmade features include yards and swales that collect runoff and direct it to the sewers and ditches. When most of these systems were built, they were typically designed to manage the amount of water expected during a 10-year storm. Larger storms overload them, and the resulting backed-up sewers and overloaded ditches produce shallow flooding. Figure 37 shows the City's infrastructure.

Another challenge with stormwater infrastructure is related to recordkeeping. It is not uncommon for stormwater data to be incomplete in most jurisdictions and may be completely lacking in others. Quality of data differs from jurisdiction to jurisdiction; some are located on GIS formats, while others are paper maps or as-builts that represent the infrastructure at a macroscale level. The condition of the assets may be lacking and the maintenance history may not be available either. Stormwater assets may have been installed with no records, especially in rural areas, farm fields, and private property.

2.13 Data Gaps

There is only one data gap for the watershed – existing stormwater infrastructure records are incomplete. However, for the purposes of this plan, this data gap does not limit the findings as there are two scales: 1) the watershed level and 2) community hotspots. The regional infrastructure overwhelms the impacts of local infrastructure at the watershed analysis level. A neighborhood-level vulnerability assessment will require the local infrastructure inventory.

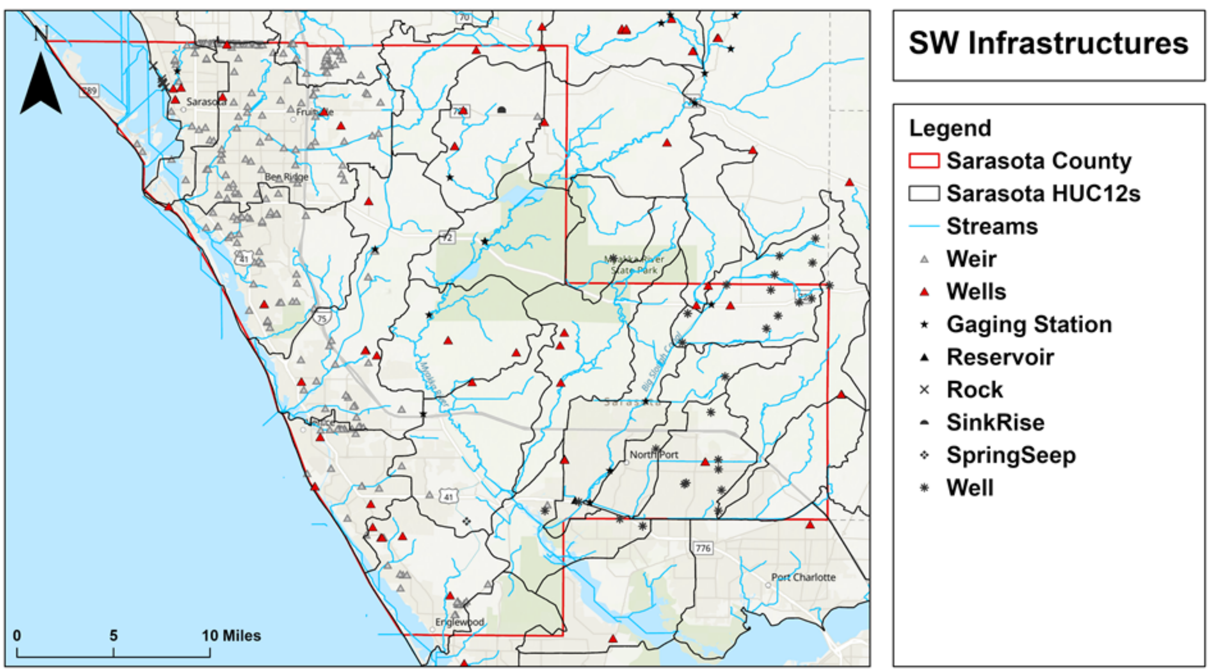


Figure 37. Location of major watershed-level stormwater infrastructure in Sarasota County

3.0 POLICY FRAMEWORK

A Watershed Master Plan should be cognizant of all applicable policy guidelines, ordinances, and public policies that relate to water management within the study area. In this section, the planning documents available for the HUC 12 subwatersheds that affect the City are discussed as they relate to watershed master planning purposes and CRS credits. Ultimately the goal Is that there is harmony among the plans, regulations, and implementation of flood reduction efforts in adjoining jurisdictions.

3.1 Existing Regulations

It is important that the watershed master plan identify the control actions, management practices, and regulations as well as the agencies that have authority and jurisdiction, as applicable to the study area. The universe of existing regulations includes federal, state, tribal, regional, and local rules. The following section summarizes them. These will include regulatory standards for new development such that peak flows and volumes are sufficiently controlled and regulations that prohibit the development, alteration, and modification of existing natural channels. In Southwest Florida, the rules are created by the Southwest Florida Water Management District, depending on location.

3.1.1 Federal Regulations

The federal and state rules have been interconnected since the 1980s with the delegation of enforcement and administration of the major environmental protection rules to the states. In response to increased flood damage, the escalating costs of disaster relief for taxpayers, and the lack of affordable flood insurance, Congress enacted the National Flood Insurance Act (NFIA) in 1968 (Public Law Number 90-448, 82 Stat. 572 (August 1, 1968). Codified, as amended, at 42 U.S.C. §4001), which established the National Flood Insurance Program (NFIP). Property located in a flood area where the community participates in the NFIP is subject to the NFIP's requirements.

Flood insurance compliance requirements for federally regulated financial institutions began in 1973 when Congress enacted the Flood Disaster Protection Act of 1973 (FDPA - Public Law Number 93-234, 87 Stat. 975.). Section 102(b) of the FDPA amended the NFIA to require the Board of Governors of the Federal Reserve System (Board), the Federal Deposit Insurance Corporation (FDIC), the Office of the Comptroller of the Currency (OCC), and the National Credit Union Administration (NCUA) to issue regulations directing lending institutions under their supervision not to make, increase, extend, or renew any loan secured by improved real estate or mobile homes located, or to be located, in a SFHA where flood insurance is available under the NFIP unless the building or mobile home and any personal property securing the loan are covered by flood insurance for the term of the loan.

Congress subsequently enacted the National Flood Insurance Reform Act of 1994 (Reform Act - Title V of the Riegle Community Development and Regulatory Improvement Act of 1994, Public Law Number 103-325 (September 23, 1994), which made comprehensive changes to the NFIA and FDPA. The changes include obligating lenders to escrow all premiums and fees for flood insurance required under the NFIA. In part, because the NFIP incurred large deficits from paying claims for major floods, Congress enacted the Biggert-Waters Flood Insurance Reform Act of 2012 (BWA) to ensure the NFIP's fiscal stability and for other purposes. To make the program self-sustaining, the BWA phased out both subsidized rates, which apply to approximately 20% of policyholders (Pub. L. No. 112-141, 126 Stat. 916 (2012). The BWA also directed FEMA to implement full-risk pricing for all policies.

Discharging into surface waters is one of the oldest methods of disposal from the point of generation. Given sufficient treatment prior to discharge, dilution, and natural degradation processes work to limit the impacts downstream of disposal. Failure to treat adequately will overload the natural attenuation capacity of the receiving water, resulting in noticeable pollution. As a result of major issues with water pollution in the 1960s, Congress passed the Clean Water Act (CWA). The preamble for the CWA is as follows:

> *"The objective of this act is to restore and maintain the chemical physical and biological integrity of the Nation's waters…"*

Congress further stated that the discharge of pollutants in toxic amounts must be prohibited. As a result, the Clean Water Act regulates surface discharges to fresh waters, ocean discharges by wastewater plants, disposal of concentrated process waters from water plants (such as concentrate from membrane facilities), and disposal of residuals (sludge).

Legislation was first directed to wastewater because discharging to a stream or surface waterbody made it the source water for downstream communities. Hence, if wastewater could be treated before it was discharged into the rivers, this might reduce the amount of treatment necessary for drinking water. Thus, the focus was primarily on wastewater treatment plants. At the same time, there were a variety of other issues that were addressed such as the attempt to reuse wastewater for beneficial uses like irrigation, to deal with industrial pretreatment so that metals and other contaminants that would disrupt the wastewater treatment process would not be discharged to the sewer system as well as the idea that stormwater might contribute to overflows.). Implicit is that stormwater and agricultural runoff issues may affect potable water supplies and are potentially subject to regulation.

Since 1990, the focus has shifted from wastewater (mostly addressed) to agricultural and urban nonpoint source stormwater runoff (nutrients) which account for about half the pollutant loadings that originally existed in federal waterways. Because agriculture is so expansive and difficult to regulate, USEPA developed MS4 and other permitting systems to address runoff. Runoff continues to be a regulatory challenge at the federal level, so much of the enforcement has been delegated to the states and regional/local governments. In Florida, the state has delegated much of this effort to FDEP and the water management districts.

3.1.2. Dredge, Fill, and Changes to Channels – State, Local, and Federal Jurisdiction

USACOE has rules associated with federal works that apply to dredging, and other activities on navigable waters or wetlands. Such changes require permits from the Corps unless delegated to the states. In Florida, dredging and filling in the surface waters has been regulated since the early 1970s. This program was established under Chapter 403, F.S., to protect our surface waters from degradation caused by the loss of wetlands and from pollution caused by construction activities.

Any activity on or over wetlands and other surface waters (dredging and filling) is regulated by the FDEP and the five water management districts (Northwest Florida, Suwannee River, St. Johns River, Southwest Florida, and South Florida) through the Environmental Resources Permitting program. The ERP program replaced the older dredge and fill permit program by combining it with the management and storage of surface water (MSSW) permit program of the districts, creating a new environmental resource permit (ERP) program under Part IV of Chapter 373 of the Florida Statutes. The ERP program regulates dredging and filling in all wetlands and other surface waters and also regulates the aspects of the MSSW program such as water quantity (flooding) and water quality (stormwater) in both wetlands and uplands.

Dredging and filling also is regulated by the federal government under a separate program administered by USACOE. The process is initiated by submitting a joint (interagency) application to FDEP or the appropriate water management district. Processing such permits involves evaluation of individual, project-specific applications in what can be considered three steps:

1. pre-application consultation (for major projects)
2. project review
3. decision-making

Pre-application consultation is suggested to provide for informal discussions about a proposed activity. This invaluable feedback gives the applicant insight into the viability of alternatives available to accomplish the project goals and provides opportunities to discuss measures for

reducing impacts and to inform the applicant of the factors USACOE must consider in its decision-making process.
The following general criteria are considered in evaluating all applications (https://www.lrl.usace.army.mil/Portals/64/docs/regulatory/Permitting/PermittingProcessInformation.pdf):

1. The relevant extent of public and private need for the proposed work
2. Where unresolved conflicts of resource use exist, the practicability of using reasonable alternative locations and methods to accomplish the objective of the proposed structure or work
3. The extent and permanence of the beneficial and/or detrimental effects the proposed structure or work is likely to have on public and private uses to which the area is suited

The public interest review involves an analysis of the foreseeable impacts the proposed work would have on public interest factors, such as navigation, general environmental concerns, wetlands, economics, fish and wildlife values, land use, floodplain values, and the needs and welfare of the people. The permit decision document includes a discussion of the environmental impacts of the project, the findings of the public interest review process, and any special evaluation required by the type of activity, such as determining compliance with Section 404(b)(1) guidelines. Because every project is subject to regulations and permitting requirements, preparing a comprehensive up-to-date list may be problematic. Therefore, it is recommended to conduct pre-application meetings with the pertinent regulatory agencies (USACE, FDEP, WMDs, and the counties) to identify the appropriate permits and guidelines for regulatory compliance.

3.1.3 State Regulations

In addition to the dredge and fill/MSSW program described in the prior section, the Florida Legislature enacted the Florida Watershed Restoration Act (FWRA) in 1999 to protect Florida's water resources from excessive pollution loading. It focuses on the Total Maximum Daily Load (TMDL) program that is required by the federal Clean Water Act and discusses specifics of how this program should be implemented in Florida. It does not address water quantity directly. TMDLs will be discussed in Section 3.5.

3.1.3.1 Water Quality Management Reports (TMDL/BMAP/SWIM Plans)

A TMDL is the total amount of pollutant discharge from all sources that a water body can assimilate and still meet water quality standards. This value is typically represented in lb/year allocations. For more information on water quality standards, consult Surface Water Quality Standards - Chapter 62-302. The TMDL program protects state waters by coordinating the control of pollution from point sources (i.e., sources discharging through a discrete conveyance, such as a pipe, as well as urban stormwater conveyance outfalls) and nonpoint sources (i.e., sources contributing to pollution caused by rainfall moving over and through the ground).

Water bodies that do not meet water quality standards are identified as “impaired,” and implementation plans must be developed describing how the point and nonpoint sources of pollution will meet their discharge allocations. This implementation plan is referred to as Basin Management Action Plan (BMAP). FDEP identified the following basic steps for the TMDL program (the bulleted list that follows is a direct quotation from the website at http://www.dep.state.fl.us/water/tmdl/):

- Access the quality of surface waters − Are water quality standards being met?
- Determine which waters are impaired or are not meeting water quality standards for particular pollutants
- Establish and adopt, by rule, a TMDL for each impaired water for the pollutants of concern
- Develop, with extensive local stakeholder input, and implement the strategies and actions of Basin Management Action Plans (BMAPs)
- Measure the effectiveness of BMAPs, both continuously at the local level and through a formal re-evaluation every five years
- Adapt BMAPs to local conditions by changing the plan and changing the actions if things are not working
- Reassess the quality of surface waters continuously

FDEP is the lead agency in establishing TMDLs and for enforcing the FWRA when addressing point source and nonagricultural nonpoint source pollution, while the Florida Department of Agriculture and Consumer Affairs (FDACS) is the lead agency for enforcing the FWRA when it comes to agricultural nonpoint source pollution. FDEP is required to coordinate with the water management districts, FDACS, soil and water conservation districts, environmental groups, regulated parties, and local stakeholders during all phases of the TMDL process, which includes:

- Development of a TMDL assessment. The assessment methodology for determining those waters that are impaired should be adopted by the FDEP by rule. The methodology should include the determination of what information is required for the TMDL assessment, the acceptable methods of data collection, and analysis and quality control requirements. Recall that impaired waters are those that fail to meet the water quality standards assigned to them based on designated uses. If water bodies are determined to be impaired, the FDEP must establish a TMDL.
- Development of an approved list of water bodies or segments for which TMDLs will be applied, including a priority ranking and schedule for analyzing such waters.

- Calculation and implementation of TMDLs, accounting for seasonal variations and including a margin of safety to reflect uncertainties about pollution loading effects on water quality. A TMDL should be allocated among pollution sources in a reasonable and equitable manner (accounting for the availability of treatment technologies, existing treatment levels, and the costs/benefits of achieving allocation).

FDEP in coordination with the water management districts may develop a BMAP to achieve the TMDL. BMAPs can include such strategies as the construction of regional treatment systems or voluntary trading of water quality credits. BMAPs should include water quality improvement milestones, and the progress toward achieving these milestones should be evaluated every five years. FDEP can implement TMDLs under existing water quality protection programs, such as:

- Permitting and other existing regulatory programs, such as water-quality-based effluent limitations
- Non-regulatory and incentive-based programs, such as cost-share, best management practices, and public education
- Trading of water quality credits or other agreements
- Public works, including capital facilities
- Land acquisition

Section 303(d) of the Clean Water Act allows USEPA to assist states, territories, and authorized tribes in the process of listing out any and all impaired waters and developing each of their respective TMDLs. FDEP monitors the water quality in watersheds across the State of Florida and determines if the water bodies meet acceptable or published standards. A TMDL is the restoration goal of a specific watershed. If the TMDL goal Is not met, FDEP will designate a BMAP and set the total maximum daily loads (TMDLs) for pollutants. The TMDL is set to facilitate the restoration of the watershed. Figure 38 shows there BMAPs and TMDLs are set in Florida. Charlotte Harbor/Alligator Creek area has a TMDL goal for fecal coliforms. Coral Creek has a DO and Nutrient TMDL regulation. There are no areas in Sarasota County as shown in Figure 39.

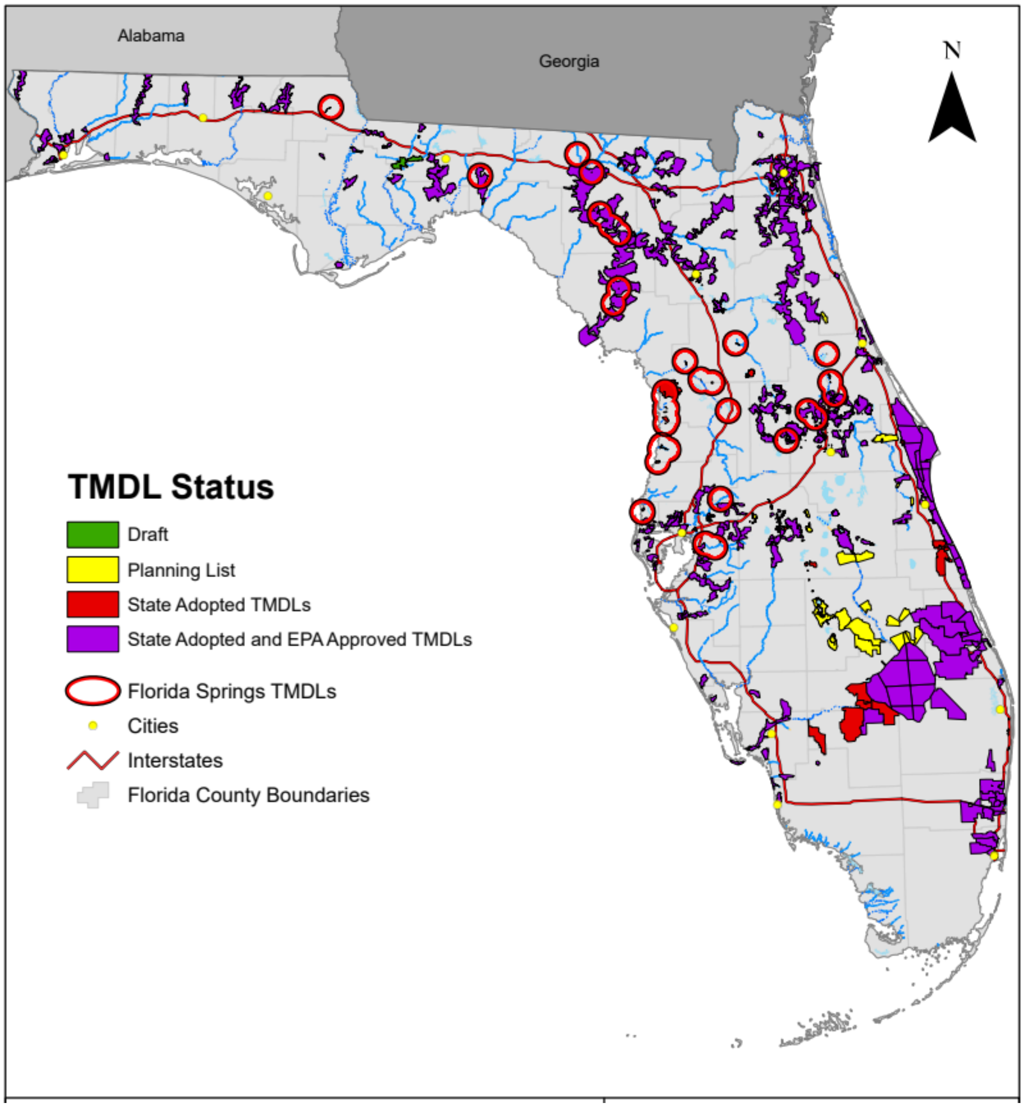


Figure 38. TMDLs across the state of Florida
(https://www.cwp.org/wp-content/uploads/2019/05/Caloosa-Presentation.pdf)

Figure 39. TMDL regions in Sarasota County

3.1.2.2 National Pollutant Discharge Elimination System (NPDES)

The Environmental Protection Agency's (EPA) National Pollutant Discharge Elimination System (NPDES) is the means by which discharges to waters of the state or nation are regulated. NPDES permits are issued and the results are monitored to prevent degradation of water bodies.

After converting wastewater discharges to NPDES permits, about 50% of the pollutant loading remained unaccounted for. This portion is largely related to stormwater and nonpoint runoff contributions. As a result, the focus turned to stormwater. The NPDES Stormwater Program regulates point source discharges from three potential sources: 1) Municipal Separate Storm Sewer Systems (MS4s), 2) construction activities, and 3) industrial activities. The NPDES Stormwater Program in Tallahassee is responsible for the development, administration, and compliance of rules and policy to minimize and prevent pollutants in stormwater discharges in the state of Florida. In turn, local governments are tasked with implementation to control stormwater pollution to the maximum extent practicable.

A municipal separate storm sewer system (MS4) is a publicly-owned conveyance or system of conveyances (i.e., ditches, curbs, catch basins, underground pipes, etc.) designed or used for collecting and transporting stormwater that discharges to surface waters of the state. Examples of

MS4 operators include, but are not limited to, municipalities, counties, community development districts, universities, military bases, or federal correctional facilities. Operators of large, medium, and regulated small MS4s are required to obtain NPDES permit coverage to discharge to waters of the state. As implemented by Chapter 62-624, F.A.C., Phase I addresses discharges of stormwater runoff from "medium" and "large" MS4s (i.e., those MS4s located in areas with populations of 100,000 or greater).

3.1.3 Regional Regulations

The stormwater rule is a technology-based rule that relies upon four key components:

1. A performance standard or goal for the minimum level of treatment.
2. Design criteria for best management practices (BMPs) that will achieve the performance standard.
3. A rebuttable presumption that discharges from a stormwater management system designed in accordance with the BMP design criteria will not cause harm to water resources.
4. Periodic review and updating of BMP design criteria as more information becomes available to increase their effectiveness in removing pollutants.

Florida's stormwater rules were developed to meet a performance standard of reducing the average annual post-development stormwater pollutant loading of Total Suspended Solids (TSS) by 80% or by 95% for stormwater discharges directly into Outstanding Florida Waters. This level of treatment was selected for two reasons:

1. To establish equitability in treatment requirements between point and nonpoint sources of pollution. The minimum level of treatment for domestic wastewater point sources was "secondary treatment" which equated to an 80% reduction in TSS.
2. The costs of stormwater treatment greatly increased as the level of treatment rose above 80%.

In 1990, in response to legislation, the department developed and implemented the State Water Resource Implementation Rule (originally known as the State Water Policy Rule). This rule sets forth the broad guidelines for the implementation of Florida's stormwater program and describes the roles of DEP, the water management districts, and local governments.

The rule provides that one of the primary goals of the program is to maintain, to the degree possible, during and after construction and development, the predevelopment stormwater characteristics of a site. The rule also provides a specific minimum performance standard for stormwater treatment systems: to remove 80% of the post-development average annual stormwater pollutant loading of pollutants "that cause or contribute to violations of water quality standards."

Volume I applies to facilities that are designed and constructed or implemented to control discharges which are necessitated by rainfall events, incorporating methods to collect, convey, store, absorb, inhibit, treat, use, or reuse water to prevent or reduce flooding, over drainage, environmental degradation, and water pollution or otherwise affect the quantity and quality of discharges from the system. **Volume II** generally is not applicable to projects that generate no more than an incidental amount of stormwater runoff, such as:

- Dredging and filling to construct such things as most "stand-alone" seawalls, docks, and "in water" types of activities, such as channel dredging. This would not include dredging and filling in wetlands or other surface waters to construct such things as bridges or culverted road crossings, parking areas, building sites, or landfills which may or may not contain structures;
- Pervious (e.g., slatted decking) piers that do not convey vehicular traffic.
- An overwater pier, dock, or a similar structure located in a deepwater port subject to subsection 373.406(12), F.S. This would not include activities landside of a wharf bulkhead at a port facility;
- Construction of an individual, single-family residence, duplex, triplex, or quadruplex dwelling unit that is not part of a larger plan of development;
- "Stand-alone" dredging, including maintenance dredging; or
- Activities that do not add new impervious surfaces, such as the installation of overland and buried electric and communication transmission and distribution lines.

In order to obtain an Environmental Resource Permit to construct an individual, private single-family home involving some impacts to wetlands, an applicant must provide reasonable assurance that the project: 1. eliminates and reduces impacts to wetlands as much as possible 2. won't cause or contribute to flooding (water quantity), 3. will maintain pre-development drainage flows as much as possible, AND 4. won't contribute to water pollution (water quality). Efforts to minimize and redirect stormwater runoff to grassed or landscaped areas should be shown on the plans to the extent possible.

As a result, stormwater management systems in the County are regulated by SWFWMD and the Florida Department of Environmental Protection via *the Environmental Resource Permit Applicant's Handbook Volume II (Design and Performance Standards Including Basin Design And Criteria) For Use Within The Geographic Limits Of The Southwest Florida Water Management District*. The volume was created to assist persons in understanding and applying the rules, procedures, standards, and criteria for implementing the environmental resource permit (ERP) program under Part IV of Chapter 373 of the Florida Statutes (F.S.). More specifically, it provides specific, detailed design and performance methodologies designed to meet the water quality and quantity requirements of stormwater management systems. It also will assist persons who are designing activities to comply with the general permit in Section 403.814(12), F.S. District-specific appendices for regionally-specific criteria applicable to such things as Sensitive Karst areas are included as well.

With respect to wetlands, impacts are to be minimized. Discussion about encroachment into the floodplain is not discussed in the volume. Treatment is required for offsite discharge to many categories of water. Treatment that is part of retention/detention must provide for: 1) the first inch of runoff from the developed project, or the total runoff of 2.5 inches times the percentage of imperviousness, whichever is greater; or 2) dry detention volume must be provided as 75% of the above amounts computed for wet detention; or 3) retention volume shall be provided as 50% of the above amounts computed for wet detention. Projects having greater than 40% impervious area and which discharge directly into receiving waters are required to provide at least one-half inch of dry detention or retention pretreatment as part of the required retention/detention. The major point is that added volumetric loadings are not permitted in most circumstances.

3.1.4 Local Regulations/Comprehensive Plans

In 1985, the Florida legislature approved the Growth Management Act, which guided community development in the state until 2010. However, many communities still conduct planning activities as if the Growth Management Act was still in place. As a result, comprehensive plans are still available in most communities. Comprehensive plans are official public documents that have been adopted by a local government as a policy to guide decisions regarding development in the community. These plans are generally how local leaders communicate their views of growing their communities over the next 20-30 years. Many communities still update these plans. While the modeling of future floodway conditions will largely depend on the analytical approaches used (see Section 4.0), projected future land use and land cover will have a direct relationship to future runoff. All plans have a stormwater element.

In addition, some communities have watershed or stormwater master plans. The following communities have stormwater or watershed plans:

- Sarasota County

A variety of basin studies may exist.

The following communities have a comprehensive plan with associated land development regulations:

- Sarasota County (https://www.scgov.net/home/showpublisheddocument/60418/638203539838600000)
- City of Sarasota (https://www.sarasotafl.gov/government/planning)
- Manatee County (https://www.mymanatee.org/departments/building___development_services/planning___development/comprehensive_planning/comprehensive_plan)

3.1.4.1 City of Sarasota

The City's comprehensive plan (https://www.sarasotafl.gov/government/planning) outlines the City's goals with respect to growth and stormwater.

In 1989, the City joined with Sarasota County through an interlocal agreement to form the Sarasota County Stormwater Environmental Utility to perform stormwater management. The Utility's responsibilities include administration, basin planning, operations, maintenance, repair, and capital improvements. The City of Sarasota's stormwater drainage facilities consist of a system of natural and manmade conveyance and retention/treatment systems. Upstream facilities are predominantly paved streets and gutters. These drainage features receive overland flow that generally serves as tributaries to intermediate facilities such as storm sewers, culverts, and ditches. These intermediate facilities in turn serve as tributaries for larger natural drainage features such as Whitaker and Hudson Bayous, Phillippi Creek, and Sarasota Bay. The City-Wide Drainage Master Plan was completed in 1987 and provides an analysis of the drainage facilities for the mainland basins of the City. In January 1989 the City adopted the Engineering Design Criteria Manual (EDCM) which provides storm drain design criteria including design storm requirements. There are 12 drainage basins as seen in Figure 40.

The level of service for stormwater management is established using storm design criteria in accordance with the Engineering Design Criteria Manual. The following levels of service are general in nature and will be applied using a 25-year/24-hour storm event.

LOS A: Gutter flow only
LOS B: Street flow only
LOS C: Street and yard flooding
LOS D: Street, yard and structure flooding

The City has adopted level-of-service C, street, and yard flooding, as the level-of-service to which all external drainage facilities will be designed. On-site attenuation of stormwater is required so that any development or grading will not shed stormwater at a higher rate onto adjacent right-of-way or property than was discharged from the site in its pre-development or pre-redevelopment state.

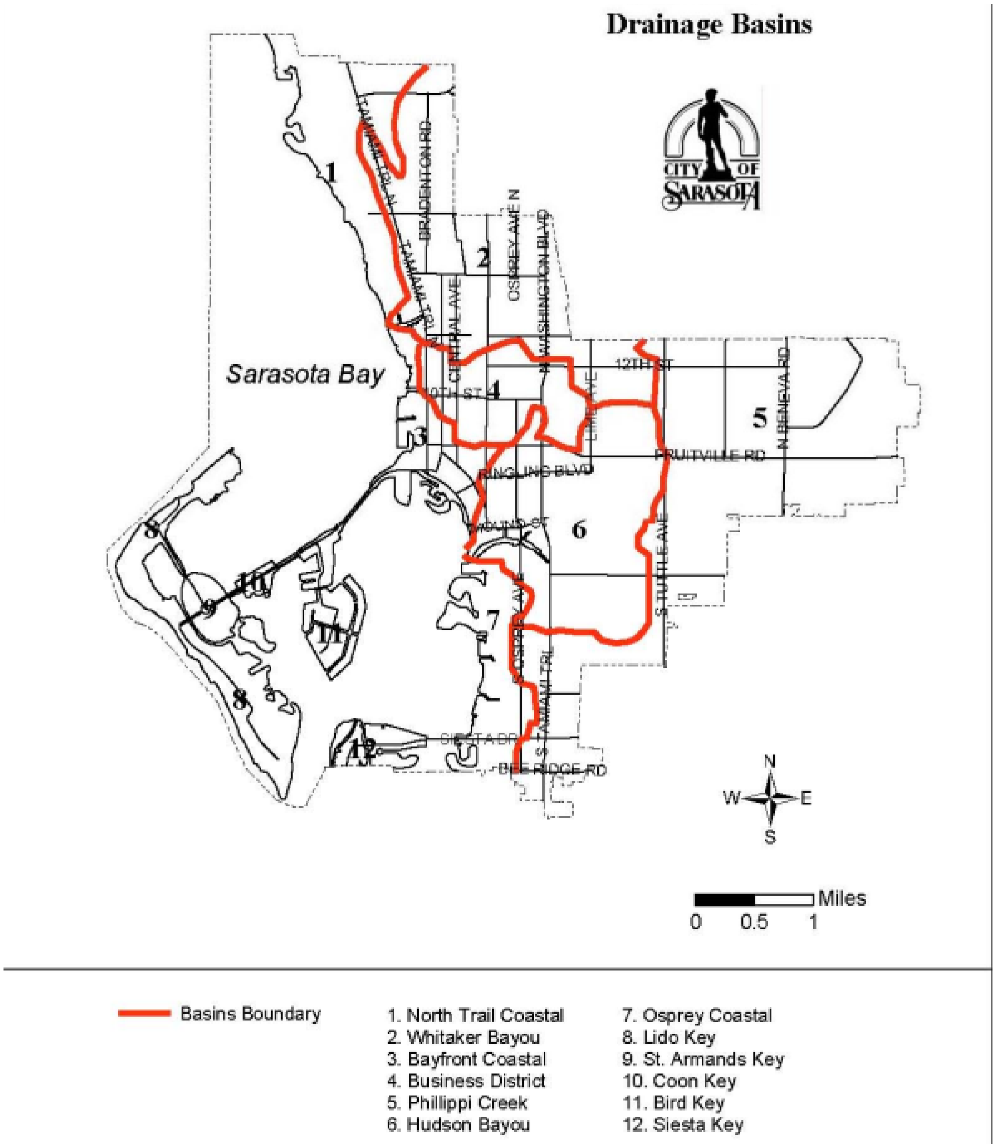


Figure 40. Drainage Basins in the City of Sarasota

The City's comprehensive plan also includes the following components relative to stormwater management.

Utilities Plan

Action Strategy 1.7, Stormwater Drainage: The City shall require development to provide facilities for stormwater drainage in accordance with the Engineering Design Criteria Manual and in accordance with the requirements of Florida Administrative Code, Chapter 62-25.

Action Strategy 1.8, Stormwater Drainage Level-of-Service: The stormwater drainage system shall provide adequate capacity to maintain a minimum level-of-service C (Street and Yard Flooding only) using a 25-year/24-hour design storm.

Action Strategy2.2, Environmental Protection from Stormwater Runoff: The quality and quantity of stormwater runoff shall be regulated in accordance with:

- Chapter 17-25 Florida Administrative Code;
- Environmental Resource Permitting of Surface Water Management Systems, administered by the Southwest Florida Water Management District, (Chapters 40D-4, 40D-40, 40D-45 and 40D-400, Florida Administrative Code);
- National Pollutant Discharge Elimination Permit No. FLS000004; and
- The City's Engineering Design Criteria Manual (EDCM), Chapter 29.5, Ordinance 89-3278, in order to protect the quality of receiving water bodies. The EDCM will continue to require that any new development not be allowed to shed stormwater at a higher rate onto adjacent right-of-way or property than was discharged from the site in its prior existing state.

Environmental Protection and Coastal Islands Plan

Action Strategy 4.3, Federal Emergency Management Act (FEMA): The City will continue to participate in the Federal Emergency Management Act Community Rating Systems (CRS) Program, which involves meeting higher than minimum FEMA standards. The CRS program includes but is not limited to: the City's adopted flood plain management program which deals with strategies to lessen flooding and respond to emergencies; and annual reports to the CRS Program on the City's progress and effects of any storms.

Action Strategy 4.15, Flood Resistant Construction: To assure appropriate and safe development in coastal areas, the City shall enforce the most recent adopted standards of the Florida Building Code, including flood- and wind-resistant construction requirements, and applicable flood plain management regulations set forth in 44 C.F.R. part 60.

Action Strategy 4.19, Enhanced Stormwater Facilities: The City shall work with Sarasota County to identify improvements that will enhance the stormwater management system in flood prone areas.

Action Strategy 4.21, Construction in Special Flood Hazard Areas: Within Special Flood Hazard Areas, new construction and construction that is deemed a substantial improvement shall meet or exceed the requirements under the Florida Building Code that is in effect at the time of building permit application. Requirements in the Florida Building Code vary by location and type of structure. Examples of these requirements include, but are not limited to, elevation of the lowest habitable floor of structures and mechanical, electrical, and plumbing equipment to or above base flood elevation; floodproofing of non-residential structures; or construction of structures on pilings or columns with break-away walls and stairs.

Action Strategy 4.22, Best Management Practices in Flood Prone Areas: The City shall allow for best management practices to manage stormwater in flood prone areas by including design strategies in the Engineering and Design Criteria Manual and Zoning Code such as: shared parking, the use of pervious surface materials, bio swales and other Light Imprint Design techniques.

Action Strategy 4.24, Criteria to Assess Development in Flood Zones: The City's land development regulations shall include criteria to assess how proposed development and redevelopment project features including location, site design, land use types, density and intensity of uses, landscaping, and building design, will help to mitigate flood zone impacts or that may exacerbate flood zone related hazards.

Action Strategy 4.25, Transportation Adaptation and Mitigation Strategies: The City shall identify vulnerable roadways coordinate with transportation agencies that are developing transportation plans within the City to take into consideration adaptation and mitigation strategies through project review, design, and funding for future transportation projects. Transportation agencies should consider extending their planning horizons appropriately to address sea level rise.

3.1.4.2. Sarasota County

The County's comprehensive plan says that (https://www.scgov.net/home/showpublisheddocument/60418/638203539838600000): "Sarasota County Surface Water Management & Flood Protection vision is a collection of adopted principles and policies used to protect, conserve, and enhance the health of our watersheds and natural systems, address flooding concerns, manage risk, minimize flood loss, and protect the natural and beneficial functions of the county's floodplain. Core stormwater objectives are to operate, repair and maintain drainage facilities, regulate the construction of new improvements or buildings to safeguard people and property from the impact of flooding and develop ways to reduce pollutants, sediment, and nutrient levels in stormwater runoff prior to discharge to our creeks, bays, estuaries, or the Gulf of Mexico." As a part of the plan, water policy 1.1.4 says that "as part of the basin master planning program, the county shall identify: 1) the extent of the existing 100-year floodplain; 2) all drainage facilities which fall below-adopted level of service standards; 3) costs associated with improving such facilities to meet minimum drainage level of service standards; and 3) funding sources for those improvements." The following LOS was approved:

STORMWATER QUANTITY LEVEL OF SERVICE AND DESIGN CRITERIA

Florida Reference (buildings, roads and sites)	Level of Service (flood intervals in years)
I. BUILDINGS	
A. Emergency shelters and essential services	>100
B. Habitable	100
C. Employment/Service Centers	100
II. ROAD ACCESS: roads shall be passable during flooding. Roadway flooding <6" depth at the outside edge of pavement is considered passable.	
A. Evacuation	>100
B. Arterials	100
C. Collectors	25
D. Neighborhood	10
III. SITES: flooding refers to standing water in agricultural land, developed open or green space (yards and parking lots etc.) and undeveloped lands designated for future development. This does not include areas incorporated into the stormwater or Basin Master Plan as flow ways, floodplain, or flood storage areas.	
A. Urban (>1 unit/acre)	5
B. Rural	2

Maintenance of canals, lakes and drainage systems form a large part of the Stormwater Environmental Utility's activities. The Stormwater Environmental Utility provides stable and dedicated funding for:

- Long-range planning.
- Capital improvements to address existing as well as future concerns.
- Control water quantity.
- Enhance water quality.
- Effectively manage stormwater

There are approximately 600 miles of canals in Sarasota County. The Utility maintains those canals where appropriate easements or rights of way exist. Canal cleaning is done on schedules ranging from annually to once every three years. In addition, canal banks are mowed and periodic herbicide application keeps canals draining properly.

The Development Review section is responsible for reviewing proposed development plans to ensure that the plans meet the county's infrastructure construction standards that are outlined in the county land development ordinance.

The County currently requires all new developments to meet the 100-year storm event criteria and ensure that the runoff rate from new developments is less than or equal to the pre-development rate.

Some areas of the county are known to be problematic during storms and the Development Review section applies more stringent standards to those areas until capital improvement and maintenance projects are completed to rectify those situations.

The County established a stormwater utility over 20 years ago to fund improvements. The County has an interlocal with the City of Sarasota to maintain their stormwater system. The Joint Planning Agreement between the City of Venice and Sarasota County was made for matters of mutual interest.

3.1.4.3. Manatee County

Manatee County maintains 503 miles of pipe, 655 miles of ditches, 181 miles of canals and over 14,000 storm inlets with a frequency between 15 and 20 years (see Figure 41). In addition, there are other tasks associated with maintaining a productive stormwater system which includes canal cleaning, ditch cleaning, pond spraying, pipe cleaning, inlet cleaning, and street sweeping.

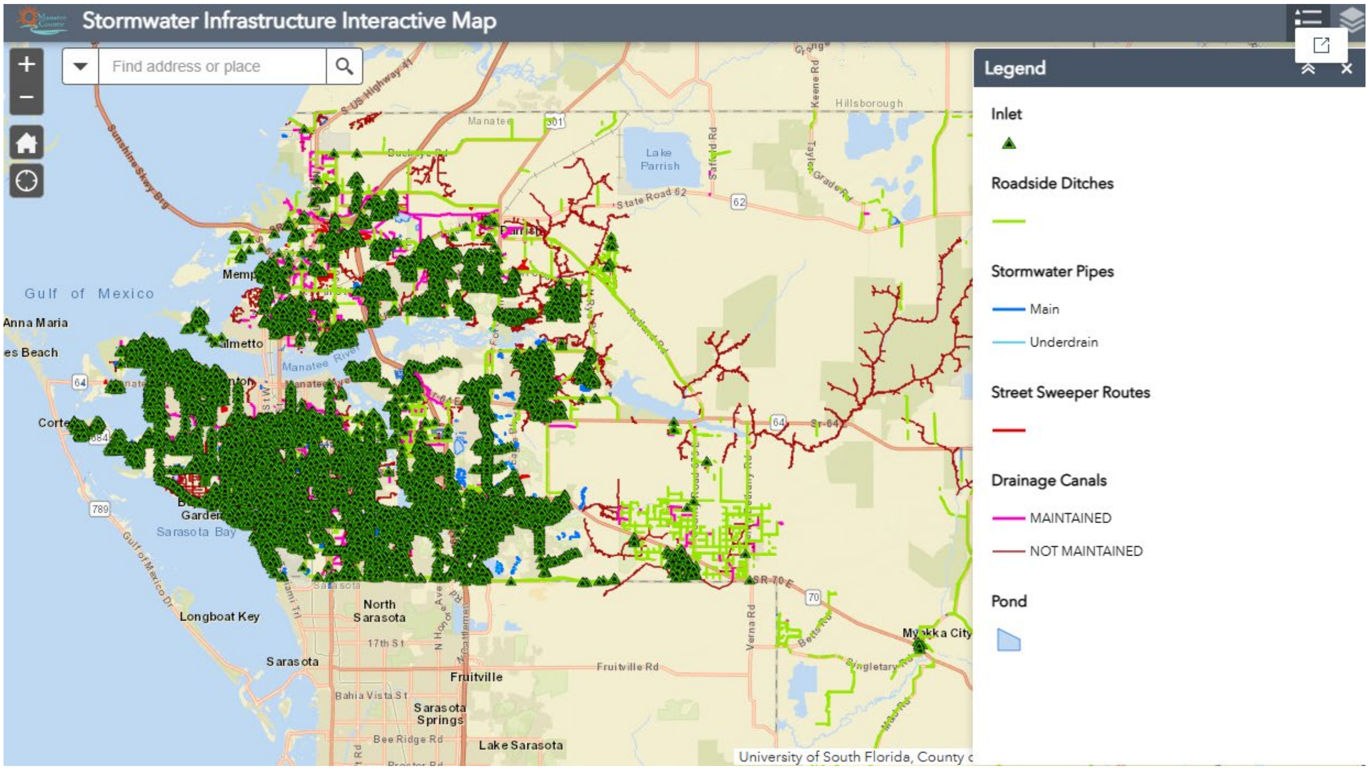


Figure 41 Stormwater infrastructure for Manatee County

Manatee County adopted its Comprehensive Plan on May 11, 1989 (Ordinance 89-01) which became effective on May 15, 1989. A major revision was adopted on December 16, 1997, renaming it the 2020 Manatee County Comprehensive Plan (Ordinances 97-02 thru 97-06), which became effective on March 9, 1998. Through our Evaluation and Appraisal Report (EAR) process, per PA-06-13/ORD-06-13, the Comprehensive Plan was renamed to the "Manatee County Comprehensive Plan". Numerous amendments have occurred since the effective date, including text, small- and large-scale Future Land Use Map Amendments.

The Comprehensive Plan for Unincorporated Manatee County, though developed in response to the state law, is based on and responds to the unique past, present, and preferred future characteristics of the unincorporated area of Manatee County, and of adjacent local governments.

Other than the purposes expressly defined in Chapter 163, F.S., this Comprehensive Plan has other specific targeted functions, as enumerated in the goals of the various plan elements.

These goals are developed to:

- Improve the physical environment of the community as a setting for human and natural resource activities;
- Protect the public health, safety, and welfare;
- Ensure that long-range considerations are included in the determination of short-range actions;

- Provide for fair and equitable consideration of private property rights while ensuring appropriate protection of the (more broadly defined) public interest as determined by the Board of County Commissioners of Manatee County;
- Effect political cooperation and technical coordination by bringing professional and technical knowledge to bear on governmental decisions concerning the physical development of the community; and
- To promote a healthy, stable, and vigorous local economy that can satisfy the goods and service needs of the local community, can provide opportunities for economic activity exporting goods and services outside Manatee County, and offer the community an ample range of employment opportunities.

The plan has no specific section on drainage. However, the code of Ordinances for Manatee County has the following:

Sec. 2-10-21. - Administration.

(a) *General.*

(1) *Title.* These regulations shall be known as the Floodplain Management Ordinance of Unincorporated Manatee County.

(2) *Scope.* The provisions of this article shall apply to all development that is wholly within or partially within any flood hazard area, including but not limited to the subdivision of land; filling, grading, and other site improvements and utility installations; construction, alteration, remodeling, enlargement, improvement, replacement, repair, relocation or demolition of buildings, structures, and facilities that are exempt from the Florida Building Code; placement, installation, or replacement of manufactured homes and manufactured buildings; installation or replacement of tanks; placement of recreational vehicles; installation of swimming pools; and any other development.

(3) *Intent.* The purposes of this article and the flood load and flood-resistant construction requirements of the Florida Building Code are to establish minimum requirements to safeguard the public health, safety, and general welfare and to minimize public and private losses due to flooding through regulation of development in flood hazard areas to:

A. Minimize unnecessary disruption of commerce, access, and public service during times of flooding;
B. Require the use of appropriate construction practices in order to prevent or minimize future flood damage;
C. Manage filling, grading, dredging, mining, paving, excavation, drilling operations, storage of equipment or materials, and other development which may increase flood damage or erosion potential;

D. Manage the alteration of flood hazard areas, watercourses, and shorelines to minimize the impact of development on the natural and beneficial functions of the floodplain;
E. Minimize damage to public and private facilities and utilities;
F. Help maintain a stable tax base by providing for the sound use and development of flood hazard areas;
G. Minimize the need for future expenditure of public funds for flood control projects and response to and recovery from flood events; and
H. Meet the requirements of the National Flood Insurance Program for community participation as set forth in the Title 44 Code of Federal Regulations, Section 59.22.

(4) *Coordination with the Florida Building Code.* This article is intended to be administered and enforced in conjunction with the Florida Building Code. Where cited, "ASCE-24" refers to the edition of this standard regarding the design and construction of buildings and structures located in flood hazard areas as referenced by the Florida Building Code.

A stormwater enterprise fund was created by Sec 2-10-77 of Manatee County Code of Ordinances.

3.2 10-year, 25-year, 100-yr, and 5-day events

Figure 30 shows the 3-day 25-year storm event, and Figure 31 shows the 1-day 100-year events to comply with. While the 5-day 10-year events are not part of the District's guidance, Figure 32 and Figure 33 show these events. They will all be modeled as a part of the project.

3.3 Peak Flows and Volumes

Section 1.1.3 includes the flow volumes for the rivers affecting the City.

3.4 Minimum Flows and Levels (MFLs)

The SWFWMD's purpose in establishing MFLs is to create hydrologic and ecologic standards against which permitting or planning decisions can be made regarding water withdrawals, either surface or groundwater. The SWFWMD analysis indicated MFLs for the upper region of the Peach River as follows:

- An annual 95% Exceedance Flow of 17 cfs as measured at the USGS Bartow Gage
- An annual 95% Exceedance Flow of 27 cfs as measured at the USGS Ft. Meade Gage
- An annual 95% Exceedance Flow of 45 cfs as measured at the USGS Zolfo Springs Gage

As a frame of reference, the mean annual 95% exceedance flow at the Bartow Gage for the period of record, 1940 to 2000, averaged 31 cfs.

3.5 Available Policy Documents

Note that watershed master plans are distinctly different than a variety of other plans developed for different purposes including: water quality and TMDL plans, local mitigation strategy plans, flood insurance studies, floodplain management plans, stormwater master plans, local ordinances, and CRS plans. For example, a County's Local Mitigation Strategy (LMS) details all of the possible hazards that the incorporated and unincorporated areas need to be concerned about. These possible hazards are identified and rated on the potential for damage based on previous hazards of similar type. LMS follows the FEMA hazard mitigation definitions in an attempt to address issues that will reduce or eliminate exposure to hazard impacts.

While the flood hazard event section of the County's LMS relates directly to CRS activity 510, there are still more aspects of the LMS that can be used for WMPs. These reports are only produced at the County level but are adopted through resolutions in a municipal ordinance. Section 322 of the Disaster Mitigation Act of 2000 specifically addresses mitigation planning and requires state and local governments to prepare multi-hazard mitigation plans (and their resubmission every five years to stay eligible) as a precondition for receiving FEMA mitigation project grants and non-emergency assistance.

3.5.1 Flood Insurance Study

"A Flood Insurance Study (FIS) is a compilation and presentation of flood risk data for specific watercourses, lakes, and coastal flood hazard areas within a community. The FIS report contains detailed flood elevation data in flood profiles and data tables" (FEMA, 2020). FIS is encouraged by FEMA and is commonly used to present flood risk data for specific waterbodies, lakes, and coastal flood hazard areas within a community.

All counties that take part in the NFIP should have access to a FIS for their respective county. FIS is valuable in understanding what the analysis and data expected of a WMP may look like. It is important to remember that flood elevations shown on the FIRMs are primarily intended for flood insurance rating purposes, developed from historical data. WMPs seek to bridge historical data with future projections (NFIP, 2017).

FEMA and Sarasota County initiated a physical map revision based on scientific and technical data that is more accurate than the material used to create the outgoing maps, some of which are based on studies completed prior to 1992. This has led to changes to Base Flood Elevations (BFEs) and floodplain boundaries based on new coastal and stormwater flood studies. Their Flood Insurance Rate Map (FIRM) is the official map of a community created by FEMA. The FIRM shows both the Special Flood Hazard Areas (SFHA) and the insurance risk premium zones applicable to the community. Color-coded preliminary flood maps can be accessed at ags3.scgov.net/sarcoflood.

The SFHA is a high-risk area defined as land with a 1 percent chance of flooding in any given year. Land in the SFHA is identified by zones that start with A and V. Land outside the SFHA is identified by zones that start with X.

Development in the SFHA must comply with the City's floodplain management ordinance. Flood insurance is required for residential and commercial buildings in the SFHA with federally backed mortgages. The City has adopted the standard ordinance language to address the flood requirements in the NFIP program.

3.5.2 Floodplain Management Plan

Floodplain Management Plans (FMPs) are found at both the municipal and county level, making them varied in format and content. These plans have varied objectives beyond what is discussed above, but many at the bare minimum will cover similar aspects to a local mitigation strategy.

3.5.3 Florida "Peril of Flood" Guidance

The 1000 Friends of Florida has a website for coastal resiliency (https://1000fof.org/) mainly focused on Tampa Bay. Charlotte County has not been included in the effort.

3.5.4 Comprehensive Plans

Refer to Section 3.1.4.

3.5.5 Unified Land Development Regulations (ULDRs)

Land development codes/comprehensive planning were discussed in Section 3.1.4, which is tied directly to the land development codes.

3.5.6 Stormwater Management Policies

The City has an interlocal agreement with the County to address overall stormwater planning.

3.5.7 Local Mitigation Strategies (LMS)

A county's Local Mitigation Strategy (LMS) identifies potential hazards (including floods) and ranks them on a scale of potential for damage based on previous hazards of similar type. There is also a plan of action for responding to each potential event. FEMA requires these LMS and their resubmission every five years to stay eligible for funding (Section 322 of the Disaster Mitigation Act of 2000), which means that they are widely available. LMS follows FEMA hazard mitigation definitions in an attempt to address issues that will reduce or eliminate exposure to hazard impacts. While the flood hazard event section of LMS relates directly to CRS activity 510, there are still more aspects of LMS that can be used for WMPs. These reports are only produced at the county level but are adopted through resolutions in a municipal ordinance.

The specific jurisdictions represented by The Sarasota County Unified Local Mitigation Strategy 2021 plan https://www.scgov.net/home/showpublisheddocument/60934/638206106205870000 are:

City of North Port
City of Sarasota
City of Venice
Sarasota County
Sarasota County Schools
Sarasota Memorial Hospital
Town of Longboat Key

The Sarasota County Local Mitigation Strategy Working Group prepared the 2021 LMS update by working collaboratively utilizing the Smartsheet application. The LMS identifies the community as vulnerable to many types of natural hazards (i.e., hurricanes, flooding, wildfire). Residents and visitors are aware of the County's location within the "Hurricane Belt." As a result, the Sub-recipient community has serious challenges regarding:

- Coastal erosion - Coastal erosion is the removal of land or beach or dune sediments by wave action, tidal currents, wave currents, or drainage. Waves generated by coastal storms or hurricanes cause coastal erosion, which may take the form of long-term losses of sediment and rocks, or merely the temporary redistribution of coastal sediments. Erosion in one location may result in accretion elsewhere. Vulnerability can impact the quality of life through damage to buildings, roads/bridges, and infrastructure (lifeline systems). Over wash occurs when waves and storm surge overtop dunes and transport sand landward. Over wash is likely at these locations because of increased water levels at the shoreline. During category-1 hurricane events on the Gulf Coast, wave height and storm surge combine to increase water levels at the shoreline by 14.5 feet higher than their normal levels.
- Flooding - Flooding has been the most frequent occurrence in Sarasota County over the past 100 years. Sarasota County residents can experience flooding from two sources, and they can occur at the same time:

    - Coastal flooding and erosion triggered by tropical storms and hurricanes.
    - Riverine flooding is intense and abundant rainfall in our rivers, streams, channels, and numerous low-lying areas. The extent of a flood is generally measured in water levels and the amount of damage done. Sarasota County is highly subject to riverine flooding due to heavy rains.

- Coastal storms are typically associated with hurricanes or other tropical depressions and storms that may impact Sarasota County. The difference between the vulnerabilities and impacts of coastal storms and hurricanes is separated by the severity of the event are extensive risks.
- Hurricanes are large cyclonic storms with counter-clockwise winds of 74 mph or greater based upon the Saffir-Simpson Hurricane Wind Scale. Coastal areas that receive the full force of hurricane winds and storm surges sustain the most damage. Since hurricanes

dissipate quite rapidly to less than hurricane strength after they make landfall, inland areas typically receive less catastrophic damage. Inland damage is usually in the form of flooding associated with the exceptionally heavy rains commonly associated with the remaining storm system. Hurricanes would cause the greatest impact on the jurisdictions of Sarasota County; thus, mitigation efforts are focused on hurricanes and include the mitigation efforts associated with coastal storms and wind events.

Among the major concerns for the City will be the bay, barrier island, and Phillippi Creek. Significant risk appears to occur at the southern end of the County around North Port. The proposed watershed master planning effort to be conducted under this grant will include prior efforts by the Subrecipient and build on prior modeling by FAU in the community as it relates to the combination of king tides, storm events, and rainfall, with respect to current and proposed drainage improvements and resilience solutions.

3.5.8 Intergovernmental Cooperative Agreements

There is an interlocal agreement between Sarasota County and the City of Sarasota with respect to stormwater management. The County performs stormwater maintenance for the City under this agreement.

3.5.9 Special Watershed Restoration Plans

There are no plans in the City. However, this watershed master planning project is expected to be a part of a longer-range effort to improve flood resiliency.

3.5.10 Stormwater Pollution Prevention Plans (SWPPPs)

Stormwater Pollution Prevention Plans (SWPPPs) identify primary sources of stormwater pollution at construction sites, best practices to reduce stormwater discharge from construction sites, and procedures to comply with construction permits. As part of the Clean Water Act, it is required that nearly all construction site operators engaged in clearing, grading, and excavating activities that disturb one acre or more, including smaller sites in a larger common plan of development or sale, must obtain a National Pollutant Discharge Elimination System (NPDES) permit for their stormwater discharges. Understanding the requirements of the SWPPP and the NPDES helps address parts of a WMP with regard to stormwater and runoff management. While no specific plan exists in the watershed, the coastal plans of Sarasota, Manatee, and Charlotte County (https://www.swfrpc.org/wp-content/uploads/Projects/Ecosystem_Services/Vulnerability_Assessment_Final.pdf) meet this purpose.

3.5.11 Post-Disaster Redevelopment Plan

Some communities may decide to formalize a Post-Disaster Redevelopment Plan to facilitate long-term recovery following a disaster. A community's Post-Disaster Redevelopment Plan can address issues relating to the identification of key roles, personnel, and agencies for future land use and zoning of areas damaged by disasters. Key sections of Post-Disaster Redevelopment Plans that should be considered when developing a WMP are as follows:

- Mapping Hazard Risks. Aligns the need for geospatial hazard analysis and mapping efforts, which leads to more informed policy recommendations post-disaster.
- Protecting or Restoring Natural Areas. Focuses on the redevelopment process taking place in areas that are less sensitive to development, leaving areas more prone to disaster and allowing them to serve as a buffer or other mitigating effect.
- Funding through Capital Improvement Programs. The identification of funding can assist a community in implementing well-managed growth and redevelopment.

The County is the lead agency for post-disaster recovery and has a plan that includes interaction with other local governments. The following website includes information developed by the County: https://www.scgov.net/home/showpublisheddocument/60886/638282958071400000. The City did not adopt this plan.

3.5.12 Climate Adaptation Action Plan (CAAP)

The adaptation chapter of Florida's Climate Adaptation Action Plan (CAAP) contains a series of 28 varying goals with strategies that work towards addressing the impacts of climate change as they relate to infrastructure, biodiversity, the coasts, and oceans (Georgetown Climate Center, 2018). While all sections of the CAAP are significant, the topics of particular interest to the development of WMP are as follows:

- Coasts and Oceans. Recommends actions to improve overall coastal resilience to bolster both impact communities and ecosystems.
- Water. Identifies the impacts of climate change and how they relate to the water resources of the state. Recommends actions that would improve conservation measures and efforts to understand, quantify, and plan for uncertainties affecting water resources.
- Infrastructure. Identifies development strategies and engineering solutions that can reduce risks from tidal flooding, storm surge, stormwater-driven flooding, and related impacts of sea-level rise when updating coastal management elements of their comprehensive plans.
- Public Health and Emergency Preparedness. Recommends actions that would reduce public health threats from climate change and resilience against the impacts of climate change.

The Southwest Florida Regional Planning Council created a climate change vulnerability action plan (https://www.swfrpc.org/wp-content/uploads/Projects/Ecosystem_Services/Vulnerability_Assessment_Final.pdf). The City does not. The City has its own vulnerability action plan adopted in 2018 and updated for 2024: https://www.sarasotafl.gov/home/showpublisheddocument/6831/637394788346600000.

3.6 Dedicated Funding Sources

Dedicated sources of funding for stormwater improvement projects vary from community to community but generally include state funds, federal funds, county funds, municipal funds and/or funds from local stormwater fees.

3.6.1 State Revolving Fund (SRF) Loan Program

In Florida, borrowing funds for implementation projects can be accomplished at low interest rates from the State Revolving Fund (SRF) loan program that finances the cost of construction for publicly-owned water, wastewater, and stormwater facilities. Authority for the program is found in Chapters 62-503 and 62-504 of the Florida Administrative Code. The Florida Department of Environmental Protection (FDEP) administers the program. Generally, any local government is eligible to apply for SRF loans.

Historically, the City of Sarasota Utilities Department has utilized SRF funds for municipal wastewater projects. Currently, the City has two active SRF loans which it is paying back. The projects are complete and the City is in the process of clearing the loans. One loan went toward improvements to Lift Station 87 and the other was invested into a water line in the same area as that Lift Station. Dually, the Utilities Department plans to utilize up to $80 million in SRF funding in the future for wastewater and water main projects.

3.6.2 Sarasota County Stormwater Environmental Utility (SEU) Fund

Sarasota County implements a stormwater utility program fully dedicated to drainage and stormwater maintenance and improvements. Sarasota's Stormwater Utility Area includes unincorporated Sarasota County and the City of Sarasota. The cities of North Port, Venice, and the Town of Longboat Key are excluded. Sarasota County sets and collects service assessment fees associated with the Stormwater Utility program. All parcels within the service area are considered customers because all parcels can generate stormwater runoff. The City of Sarasota contracts with Sarasota County for maintenance and construction given the City residents pay a fee.

3.6.3 Penny Tax Funds

The Sarasota County Penny Sales Tax is a countywide voter-approved one percent sales tax used to invest in local infrastructure projects, including stormwater improvement projects. Sarasota County voters vote on these funds approximately every 10 to 15 years, the last vote being in 2022 to continue the Penny Sales Tax for another 15 years to fund local infrastructure projects. Proceeds from the sales tax are distributed among Sarasota County, Sarasota County Schools, the Town of Longboat Key, the City of North Port, the City of Venice and the City of Sarasota, with 25 percent conveyed to the school district and 75 percent to the county and municipalities.

The City of Sarasota routinely includes the input of its citizenry in selecting infrastructure projects to be funded by Penny Tax Funds. Currently, $567 million in Stormwater Utility Projects are listed in the City of Sarasota's 2022-2026 Capital Improvement Plan (CIP) to be funded by the Penny Tax. These projects are identified as "Level of Service" issues not addressed by the Interlocal Agreement with Sarasota County and to aid in Low Impact Development (LID) efforts for Stormwater Mitigation City-wide and National Pollutant Discharge Elimination System (NPDES).

4.0 ASSESSMENT OF VULNERABLE AREAS

Defining flood risk due to compounding hydrographic influences is the central concern of a WMP effort. Modeling and assessment of vulnerability for the study area focused on the combination of a high water table, heavy rainfall, and impervious urban conditions that can lead to localized nuisance flooding events. Through previous surveys conducted with local officials, the number of days of continuous nuisance flooding that the public will tolerate before that flooding is considered destructive is about 4 days (E Sciences 2014).

For a large study area, small parts may be most at risk. The key is to identify where further study might be needed. A screening tool accomplishes this goal applied to the subwatershed scale to designate areas that are susceptible to periodic flooding events. Utilizing the information collected and analyzed in Chapters 1 and 2, and comparing it to data in Chapter 3, vulnerability can be assessed.

4.1 Vulnerability Maps

4.1.1 Screening Tool

The screening tool utilizes data from various sources, as described in Chapter 2 of this document. The design storm was the 3-day 25-year storm, which is the standard used by SFWMD for flood management. The reason this is critical is that to do any modeling (as required by the CRS program), a screening tool should be used to identify regions with a high risk of inundation based on multiple collected datasets and hydrological models. Figure 42 shows how the GIS layers interface in the tool and how they are combined for spatial analysis.

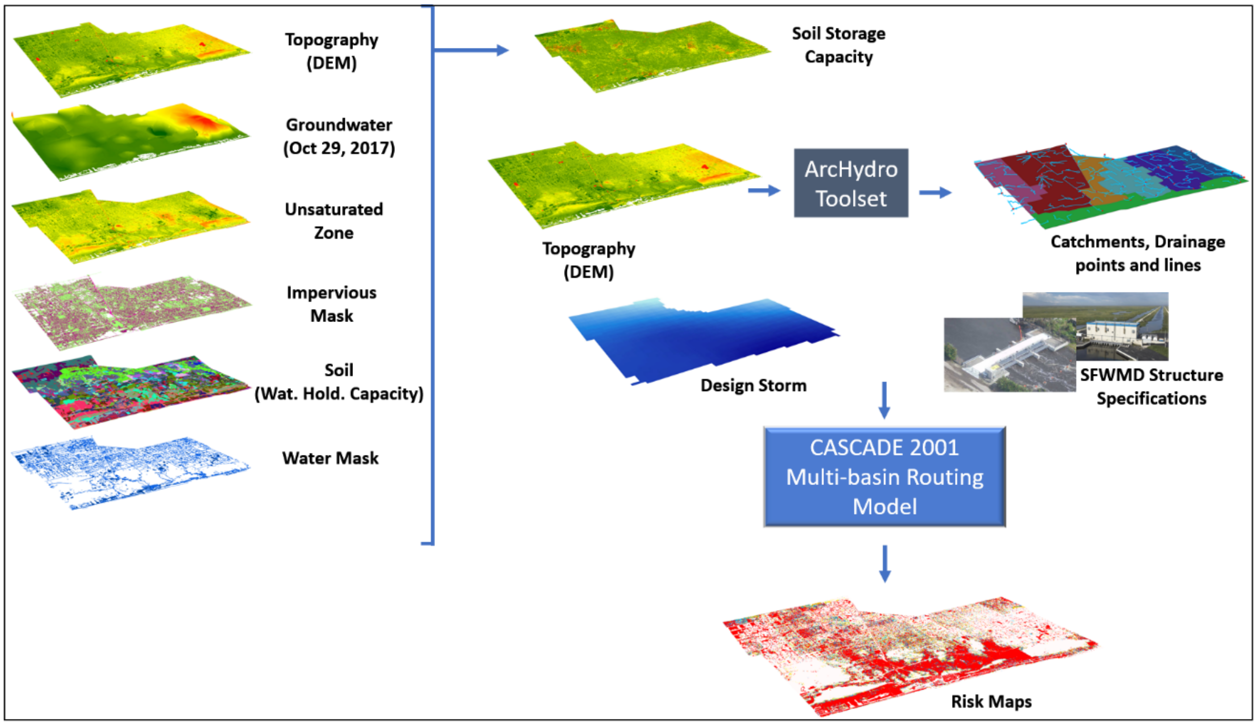


Figure 42. Screening tool methodology for creating flood risk maps

The model chosen for this screening tool is Cascade 2001, which is a multi-basin hydrologic/hydraulic routing model developed by the SFWMD. The model permits the investigator to run different storm events to determine various important flooding scenarios. The boundaries are critical for basin studies and must be chosen carefully. The following data layers collected in the prior section are processed to develop the input files for Cascade 2001:

- Topography
- Soils
- Development intensity
- Groundwater elevations
- Surface water/Outlet locations

The model creates a glass box where water rises to a certain level and then decreases. Running the simulation requires defining the basin (HUC or sub-HUC) and input of the following data:

- Study area
- The portion of the area above a given elevation
- Initial groundwater stage
- Longest travel time for the runoff to reach the most distant point of discharge
- Ground storage as estimated from the USDA gridded National Soil Survey Geographic Database (gNATSGO)
  Ground storage ≈ (Water holding capacity) × (Surface elevation – GW elevation)

= 2 × (AWS for a soil layer of 0-150 cm) / 150cm × (Surface elevation – GW elevation)

- Available water storage (AWS) for a soil layer of 0-150 cm
- Average amount of precipitation that can be stored in the soil layer

Note Chapter 2 detailed each of the data layers required for the modeling effort. The appendix outlines the entire HUC 12, which is what NFIP will be interested in. By modeling the flood response to a 3-day 25-year design storm (as required by the SFWMD), and including the 5-year, 10-year, and 100-year storm events to further classify flood risk as the probability of inundation, it is possible to identify critical target areas that are particularly vulnerable to flooding and are subject to further study through a scaled-down modeling approach. The screening tool should first be applied at the subwatershed level to provide an initial risk assessment focused on the hydrologic response to a specified rainfall event given the unique characteristics and features of the watershed. The output from the model is an elevation surface that can be used to develop flood maps for the study area. The figures in Chapter 4 are a subset of these results that can be used for public discussion.

4.1.2 Identification of Vulnerable Areas

Given these assumptions and the model simulation outputs, the goal of this methodology was to produce a spatially temporally quantified understanding of nuisance-destructive flood potential in the study area given observed values. Risk is a function of compounding geo-hydrological features, namely, surface water, groundwater, topography, build-out, and time of year. A GIS-based algorithm and spatial interpolation generated layers of the greatest observable hydrographic surfaces. These outputs were then compared with high-resolution topographic LiDAR data to develop digital elevation models that reflect the observed risk landscape. These simulations produced vector and volume information, in combination with soils, vegetation, and percentage of impervious surfaces, allowing the observed model outputs to be extrapolated into a more predictive context.

To evaluate the flood vulnerability at this scale, the analysis started with a binary flooding surface (0 = below 50% chance of flooding; 1 = above 50% flooding) based on output from the screening tool for a specified design storm. Next, attributes of that raster based on “VALUE = 1” query are extracted using *Extract by Attributes* tool. Then the *Batch Project* tool was used to map critical facilities data to the common coordinate system (NAD83 UTM Zone 17N), unit = meters. Then a field was added using *Add Field* for [PriorityTier] = assigned Tier #1-4 value from the DOR codes and [Area_sqmeter]. The critical facilities layers were then merged into a single layer to calculate the polygon geometry for [Area_sqmeter] using the *Merge* tool. Next, *Zonal Statistics as a Table* is used to calculate the SUM of flooded values (1) within each critical parcel. The output table has fields for SUM (i.e., total # of flooded pixels per critical parcel) and AREA in map units of square meters (since each pixel in the flooding surface has a cell size of 3-meter × 3-meter, each area is equal to the SUM value multiplied by 9 m^2). Using the *Join Field* tool, the SUM and AREA fields were joined to the merged critical facilities layer based on a key attribute, first renaming these fields for clarity (e.g., AREA_FLOODED_3d25y). Once all field data was included, the next step involved using *Export Table* to export the dataset as a CSV file.

Note that non-flooded parcels have zero flooded areas, so they receive a <Null> value from the zonal statistics tool. To replace null values with zeros, we use *Calculate Field* in the attribute table along with the following Python expression (replacing the respective field name): "0 if !AREA_FLOODED_3d25y! is None else !AREA_FLOODED_3d25y!".

Next, the CSV file was saved as an Excel Workbook (.xlsx). The Range was converted to an Excel Table, and the columns were rearranged in the desired order. Finally, the "percent-flooded" columns were calculated as follows:

- PCT_FLOODED_3d25y = ([@[AREA_FLOODED_3d25y]]/[@[TotalArea_sqmeter]])*100
- PCT_FLOODED_1d100y = ([@[AREA_FLOODED_1d100y]]/[@[TotalArea_sqmeter]])*100

After this calculation, the table was sorted to show the higher priority tiers and higher percent-flooded values first. To reduce the number of critical facilities shown in the final table, a filter was created to show only critical facilities with 10% or more flooded areas in the parcel during both storm events (3-day 25-year and 1-day 100-year). Records with duplicate parcel ID numbers were removed from the table. The results of this procedure are discussed in Section 5.1 of this document.

Figure 43 shows the predicted flooding after the 3-day 25-year storm event compared to the repetitive loss property maps superimposed to the GIS platform as a separate layer with the repetitive loss map. They compare favorably. The lighter blue areas represent land that floods, while the dark blue areas are classified as wetlands, lakes, rivers, streams, and other waterbodies.

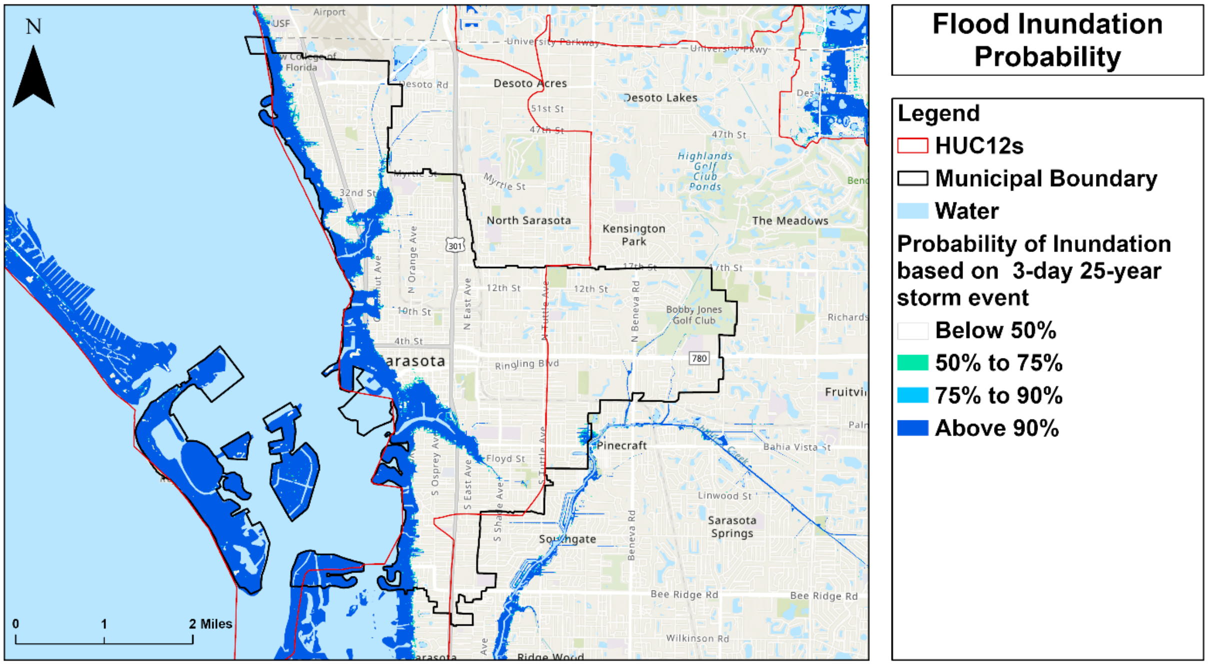


Figure 43. Flooded areas during a 3-day 25-year storm in Sarasota, as generated by FAU CWR3

The spatial distribution of probabilities of flooding during the 1-day 100-year storm event is shown in Figure 44. Likewise, the 1-day 10-year storm event is shown in Figure 45 and the 1-day 5-year storm event is shown in Figure 46. Note that just because a property is predicted to flood does not mean it always floods.

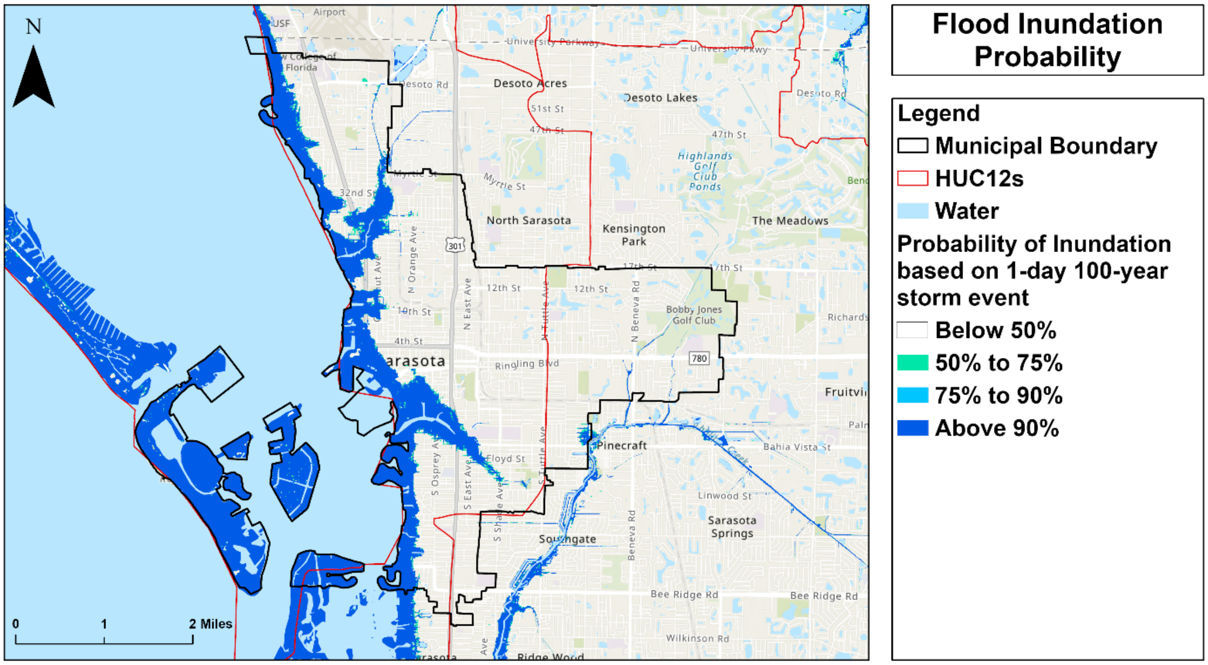


Figure 44. Probability of flood risk map for Sarasota County for the 1-day 100-year flood event, as generated by FAU CWR3

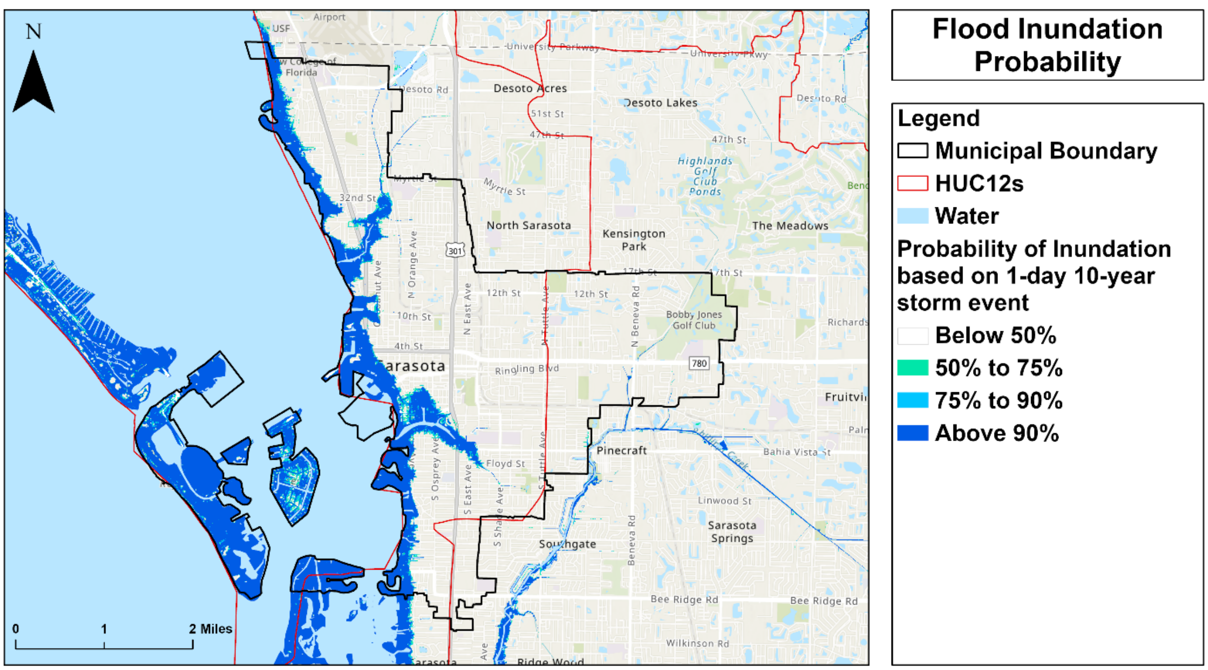


Figure 45. Probability of flood risk map for Sarasota County for the 1-day 10-year flood event, as generated by FAU CWR3

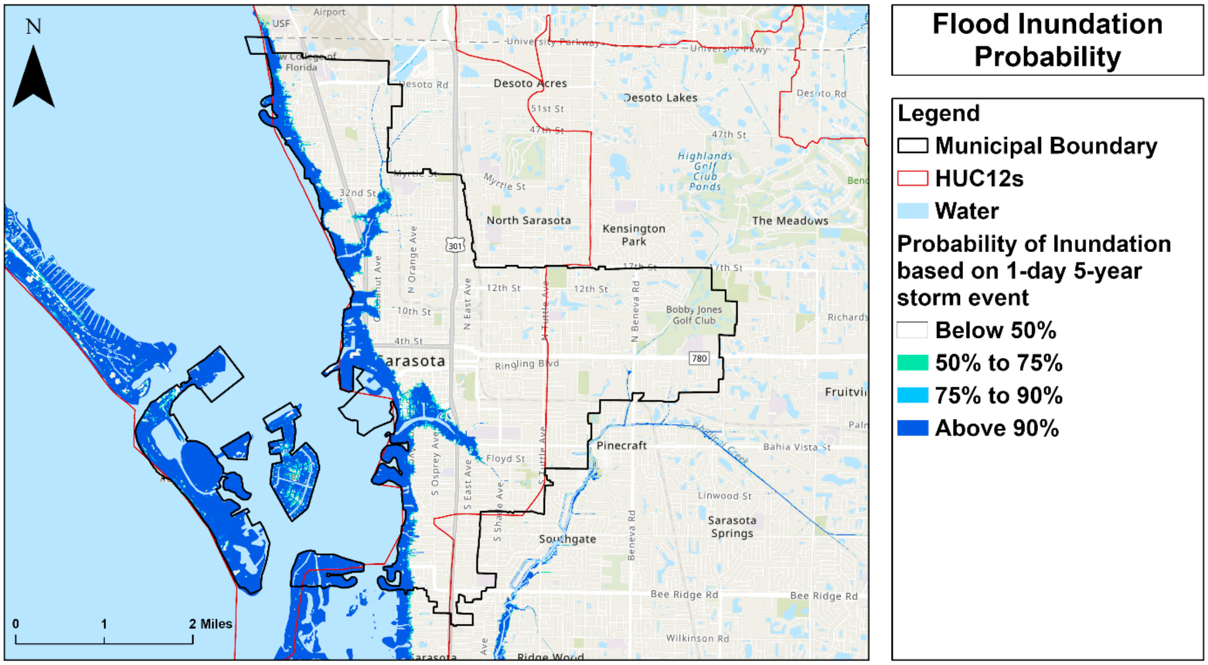


Figure 46. Probability of flood risk map for Sarasota County for the 1-day 5-year flood event, as generated by FAU CWR3

4.2 Flood Inundation Maps

By modeling the City's flood response to storm events and further classifying flood risk as the probability of inundation, it is possible to identify critical target areas that are particularly vulnerable to flooding and are subject to further study through a scaled-down modeling approach. The screening tool should first be applied at the subwatershed level to provide an initial risk assessment focused on the hydrologic response to a specified rainfall event given the unique characteristics and features of the watershed. For example, characteristics of the County's subwatersheds are incorporated to represent possible driving factors of flooding in the region such as low ground surface elevations, a high groundwater table, low soil storage capacity, and heavy rains. At this scale, flooding generally occurring around large waterbodies, namely the Gulf of Mexico (downstream), is a major concern. Each of HUC 12s that involve the coastal waters was modeled for sea level rise at 1, 2, 3, 4, and 5 ft for each storm event. Since the 5-year and 10-year are below the development protocol for the City, those will be included in the appendices. Figure 46 to Figure 66 represent those results using all 4 storm events with 1 through 5 ft of sea level rise across the County. Note that the critical blue areas will be further modeled and solutions investigated for chapter 5. As the City is coastal, King tides also create flooding and exacerbate sea level rise (see Figure 67 to Figure 79).

However, to prioritize funding for future mitigation and planning efforts at the local level, it is necessary to identify areas of concern within the subwatershed that are highly susceptible to flooding. Understanding localized flooding conditions is crucial for developing strategies to protect vulnerable communities and infrastructure. A closer look at the flood risk maps provides additional drilldown perspectives, increasing the displayed level of detail.

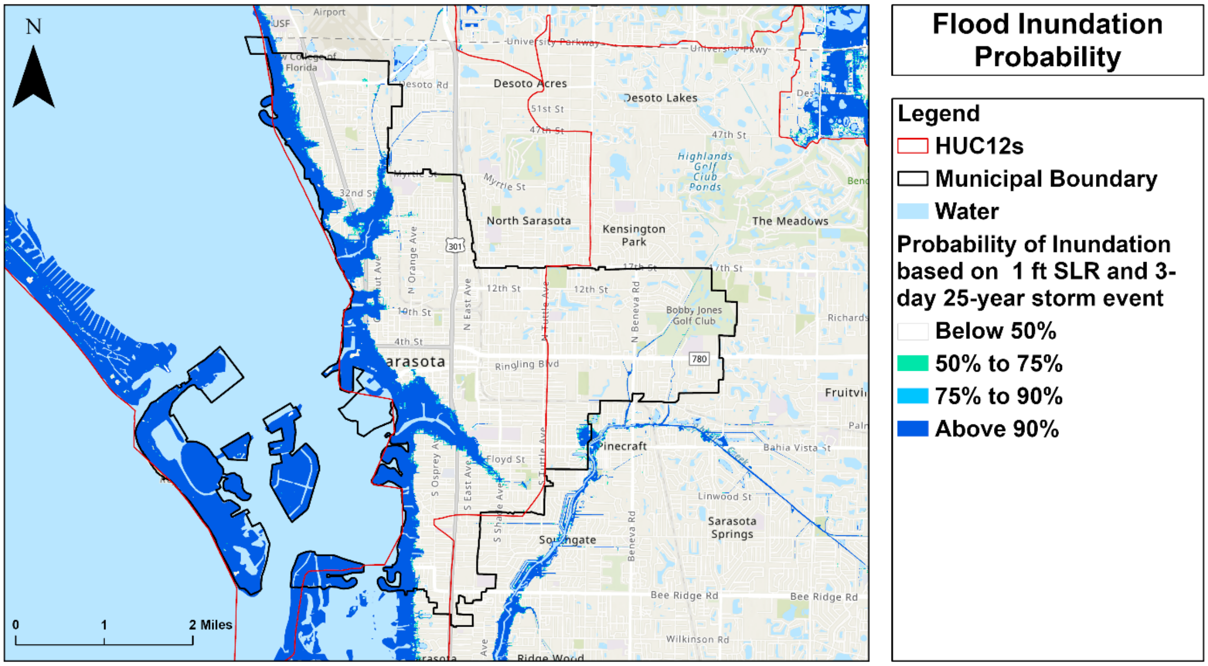


Figure 47. Probability of inundation based on 1-ft SLR and 3-day 25-year storm event, as generated by FAU CWR3

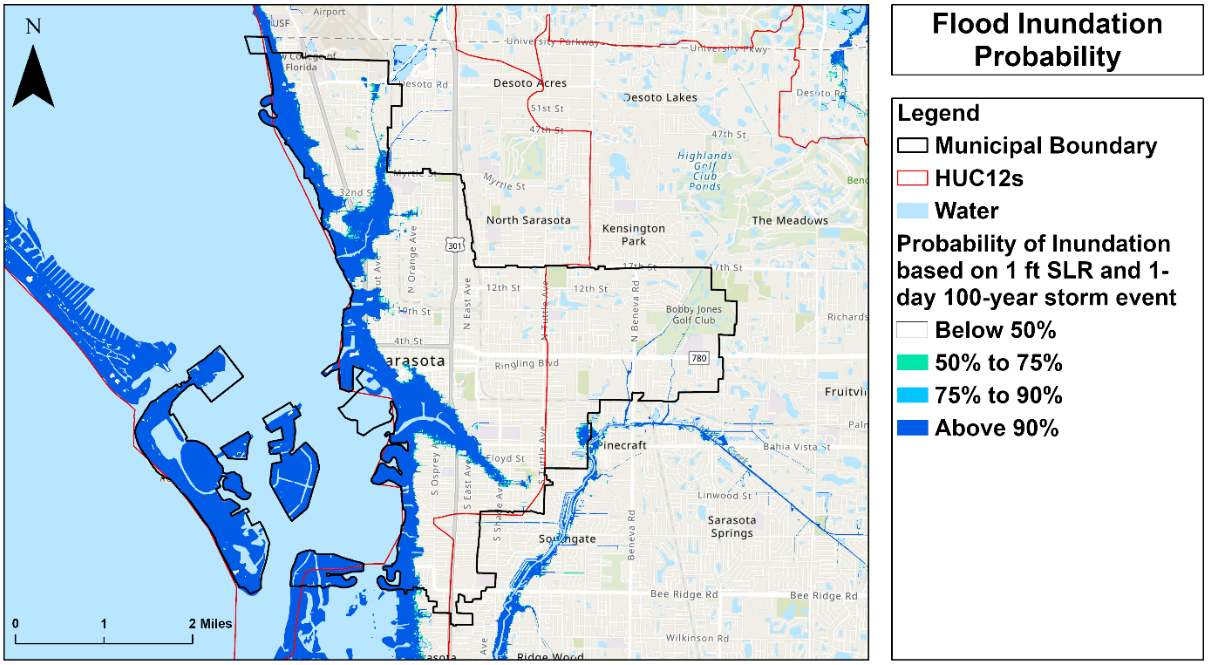


Figure 48. Probability of inundation based on 1-ft SLR and 1-day 100-year storm event, as generated by FAU CWR3

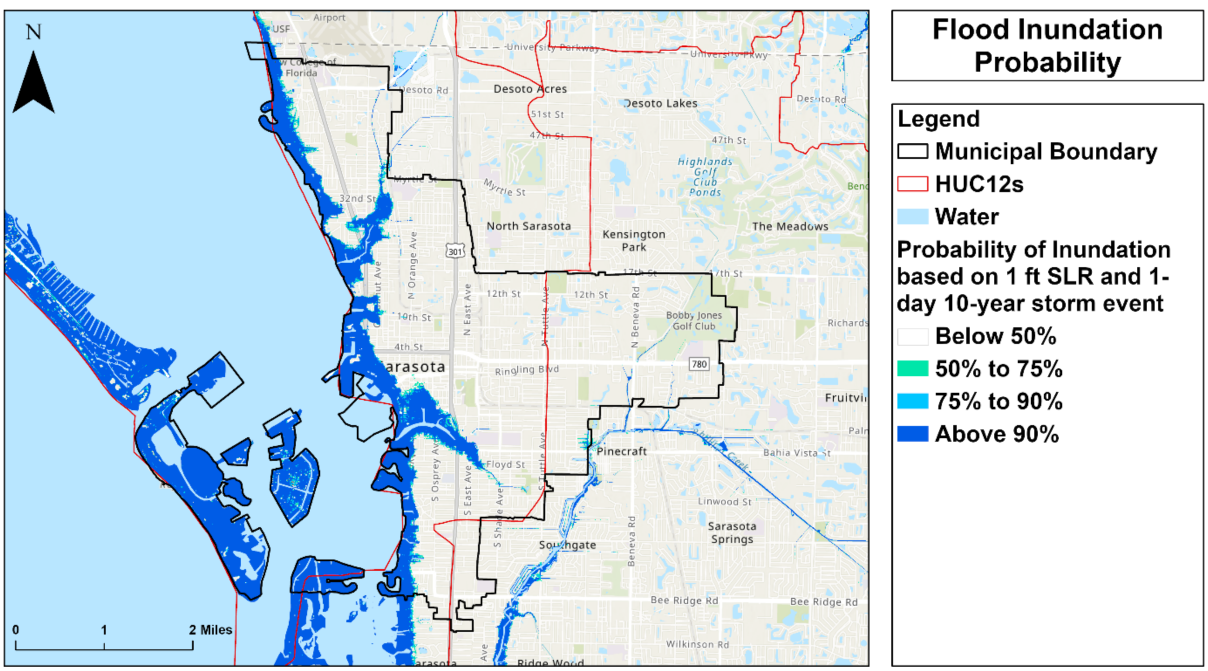


Figure 49. Probability of inundation based on 1-ft SLR and 1-day 10-year storm event, as generated by FAU CWR3

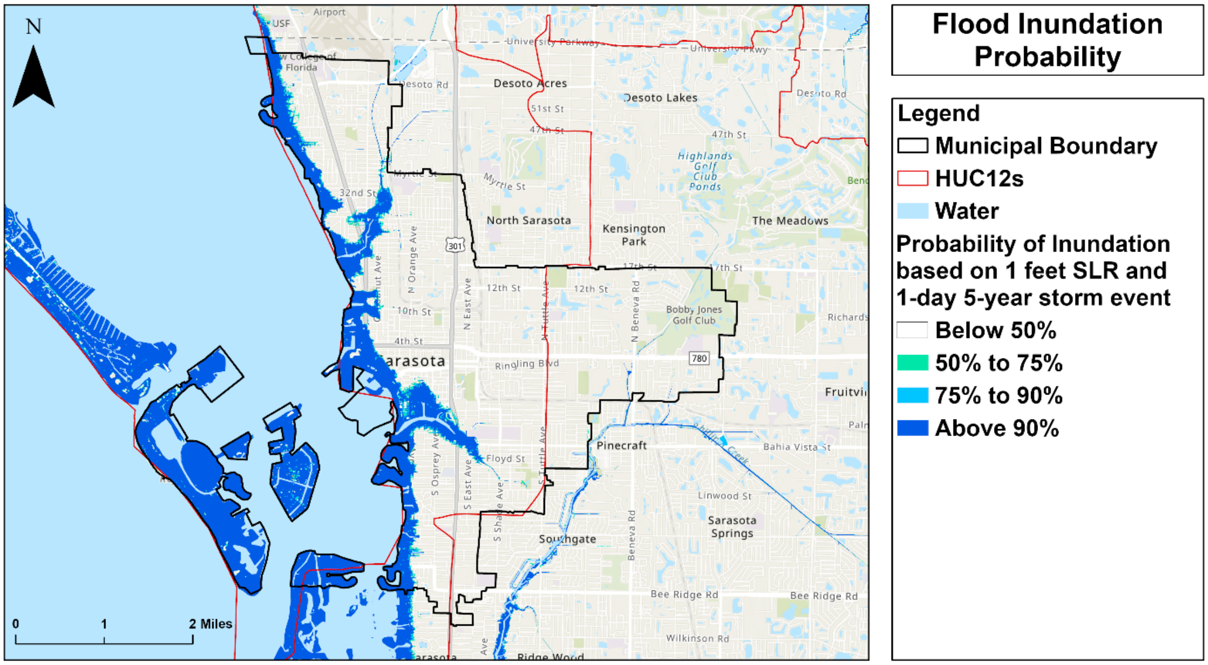


Figure 50. Probability of inundation based on 1-ft SLR and 1-day 5-year storm event, as generated by FAU CWR3

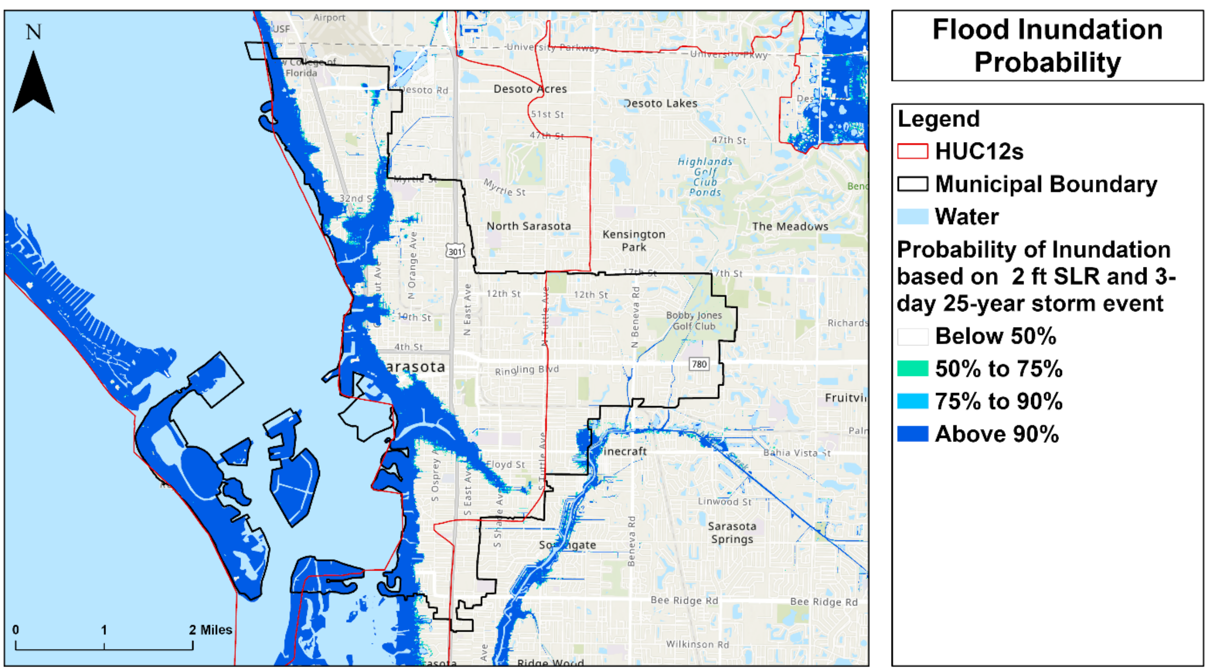


Figure 51. Probability of inundation based on 2-ft SLR and 3-day 25-year storm event, as generated by FAU CWR3

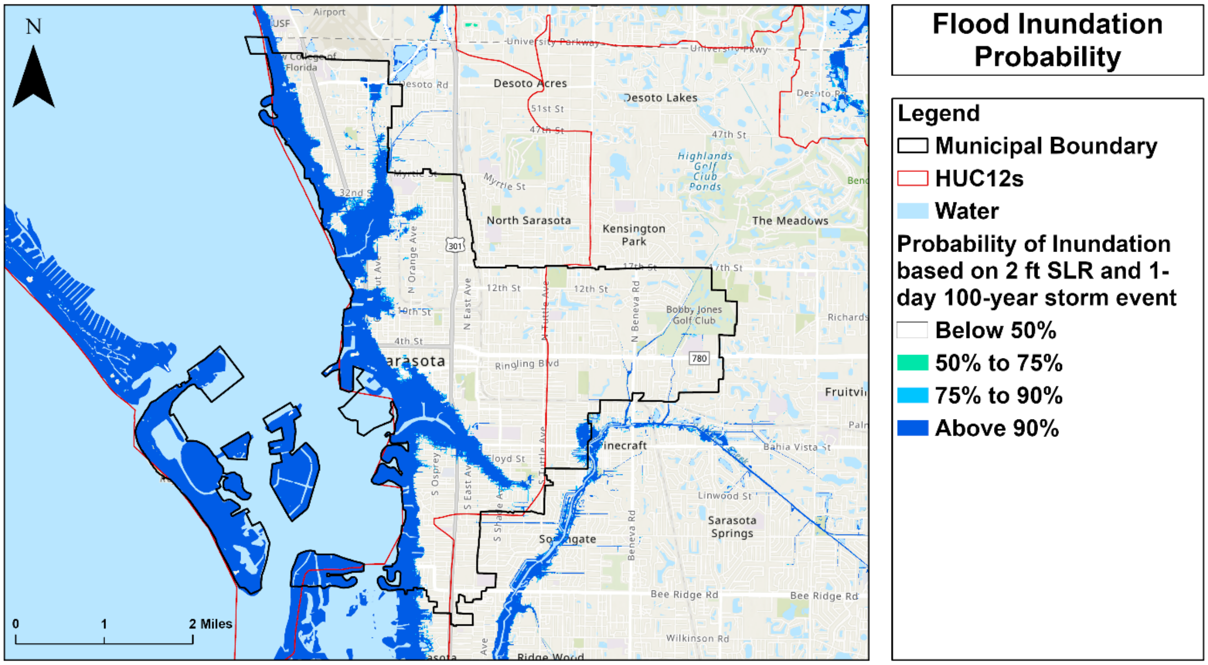


Figure 52. Probability of inundation based on 2-ft SLR and 1-day 100-year storm event, as generated by FAU CWR3

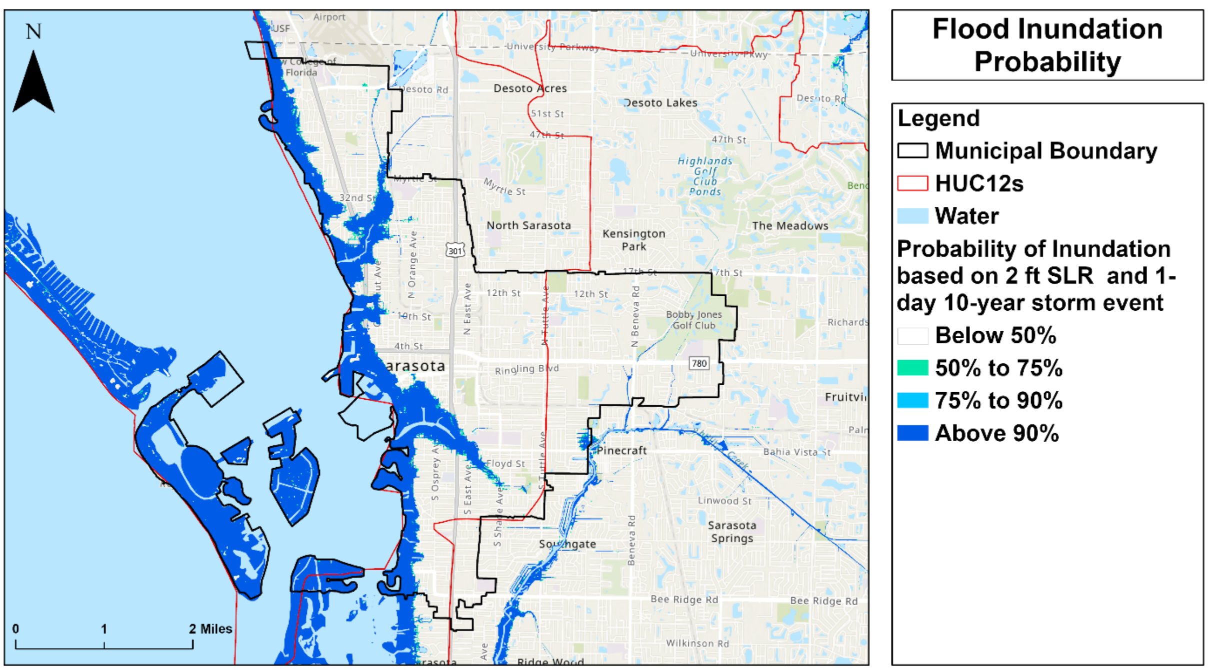


Figure 53. Probability of inundation based on 2-ft SLR and 1-day 10-year storm event, as generated by FAU CWR3

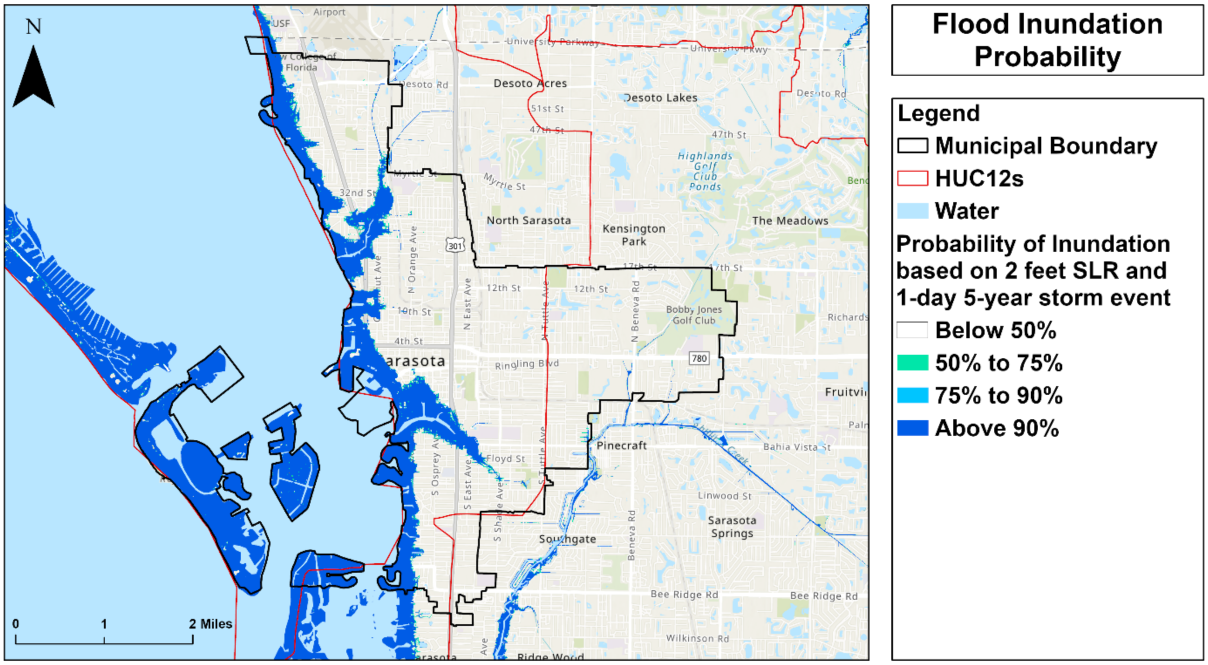


Figure 54. Probability of inundation based on 2-ft SLR and 1-day 5-year storm event, as generated by FAU CWR3

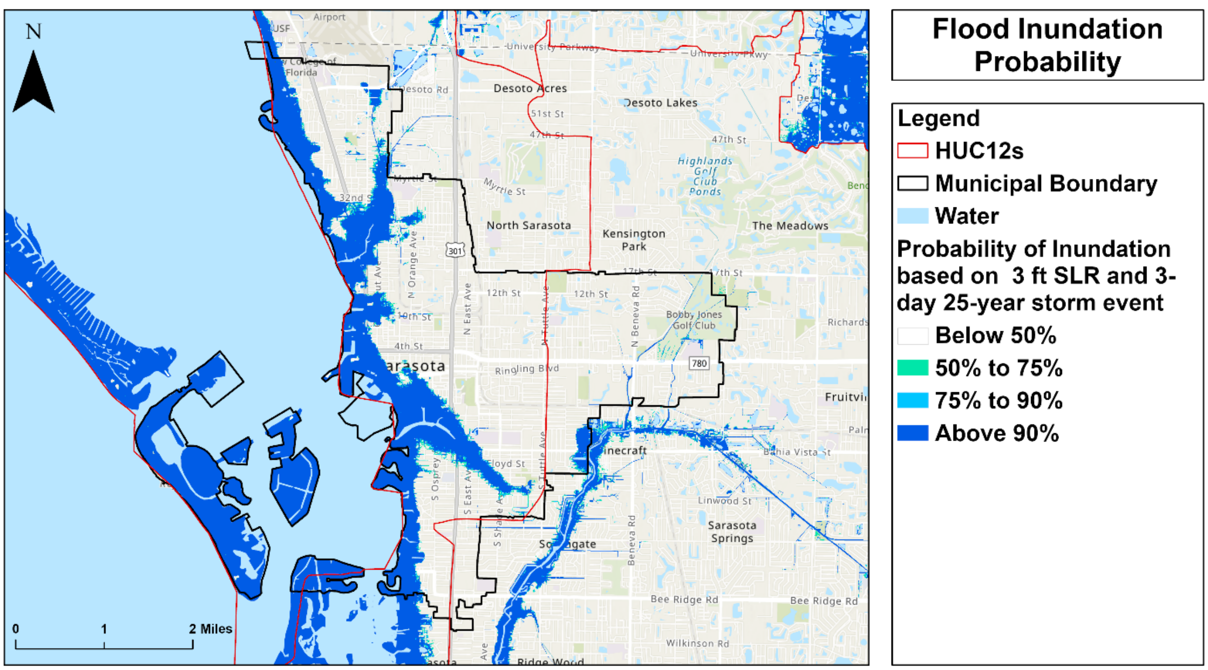


Figure 55. Probability of inundation based on 3-ft SLR and 3-day 25-year storm event, as generated by FAU CWR3

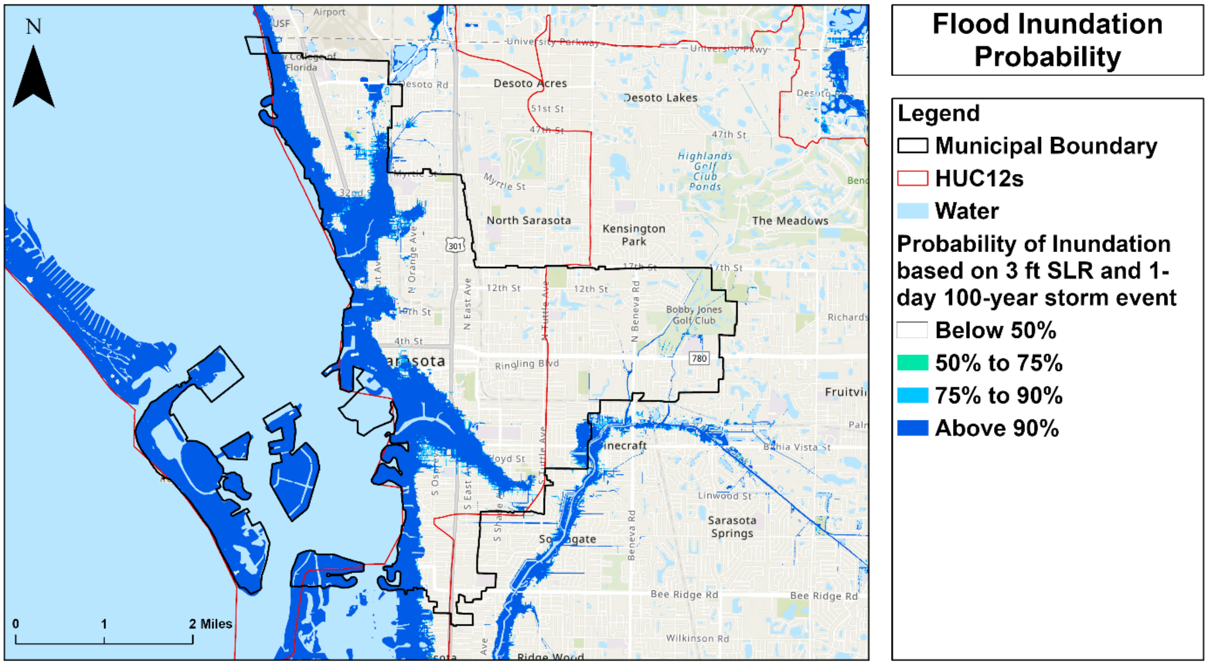


Figure 56. Probability of inundation based on 3-ft SLR and 1-day 100-year storm event, as generated by FAU CWR3

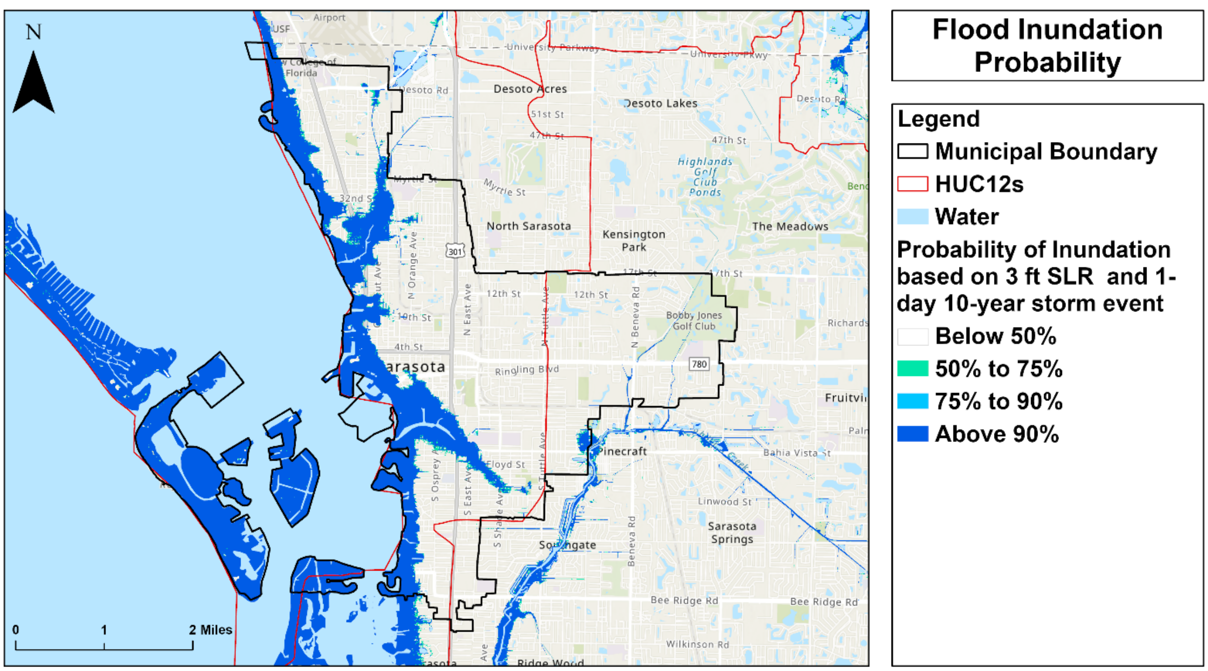


Figure 57. Probability of inundation based on 3-ft SLR and 1-day 10-year storm event, as generated by FAU CWR3

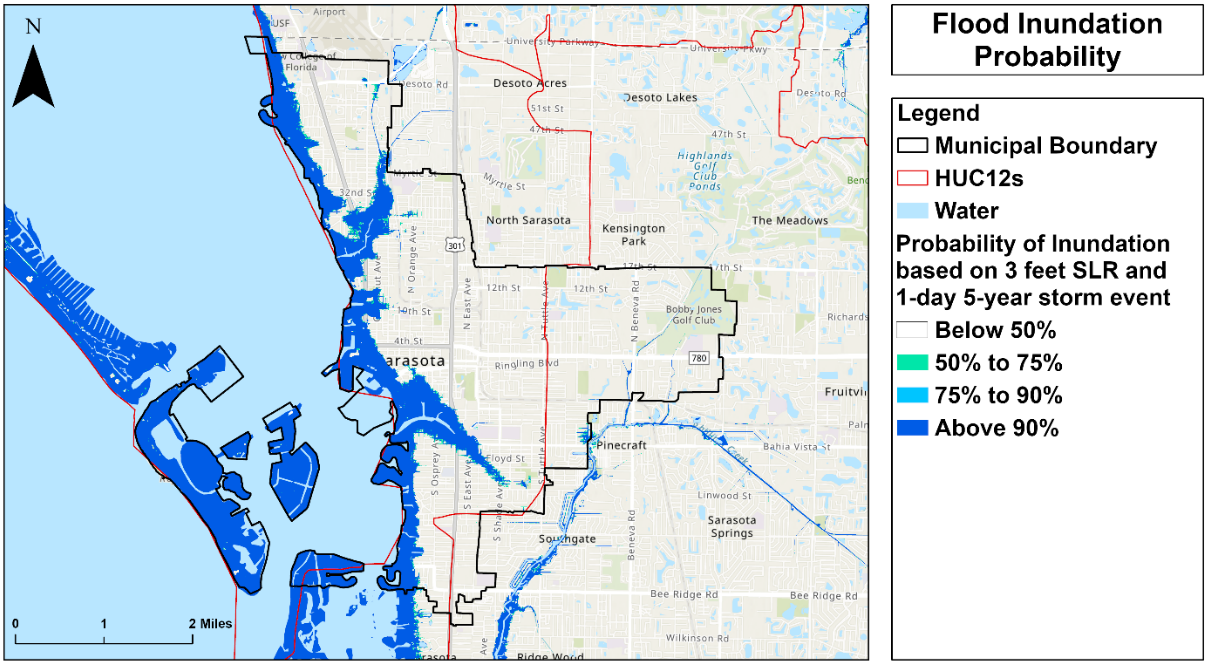


Figure 58. Probability of inundation based on 3-ft SLR and 1-day 5-year storm event, as generated by FAU CWR3

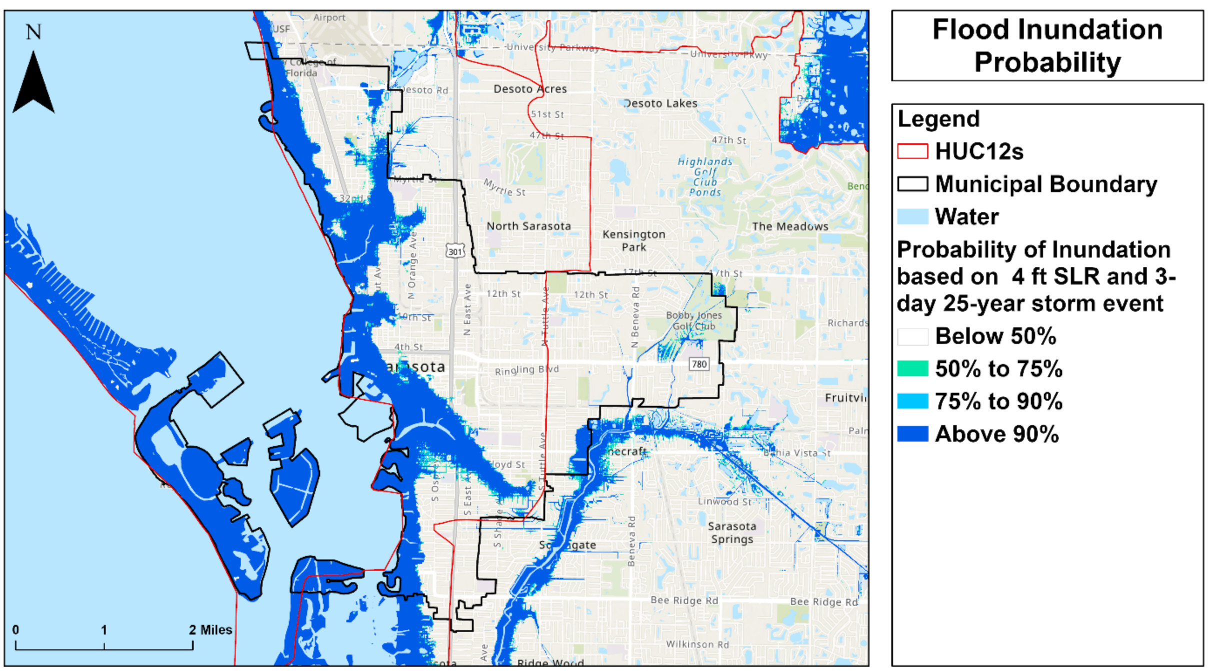


Figure 59. Probability of inundation based on 4-ft SLR and 3-day 25-year storm event, as generated by FAU CWR3

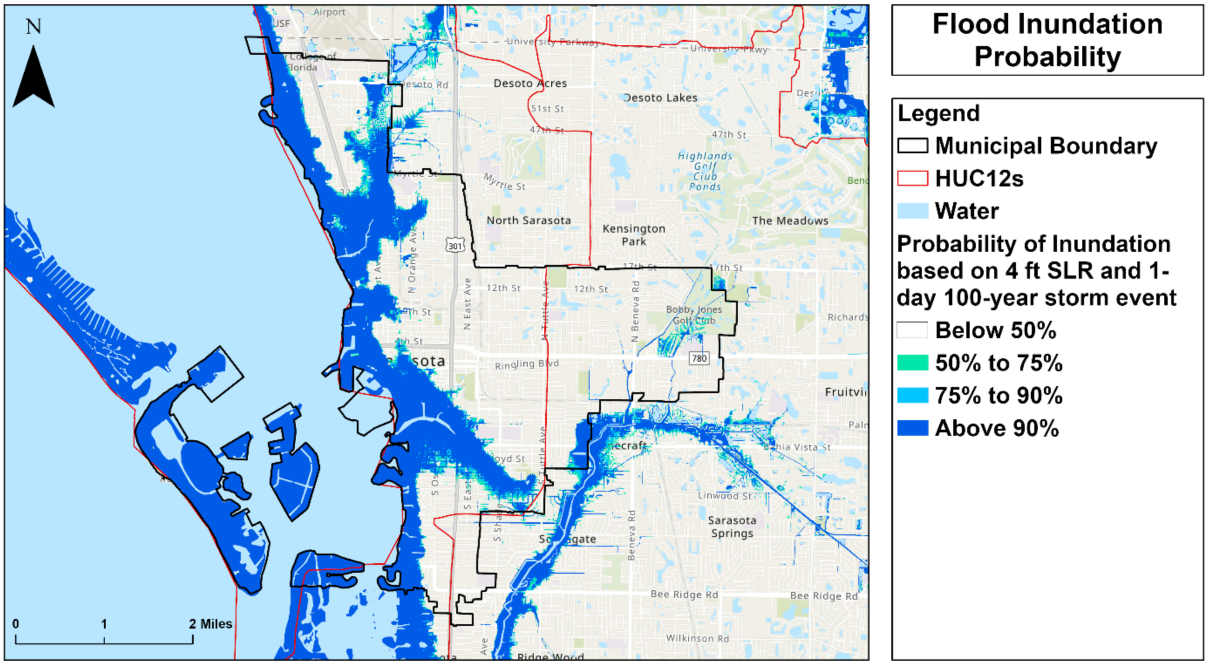


Figure 60. Probability of inundation based on 4-ft SLR and 1-day 100-year storm event, as generated by FAU CWR3

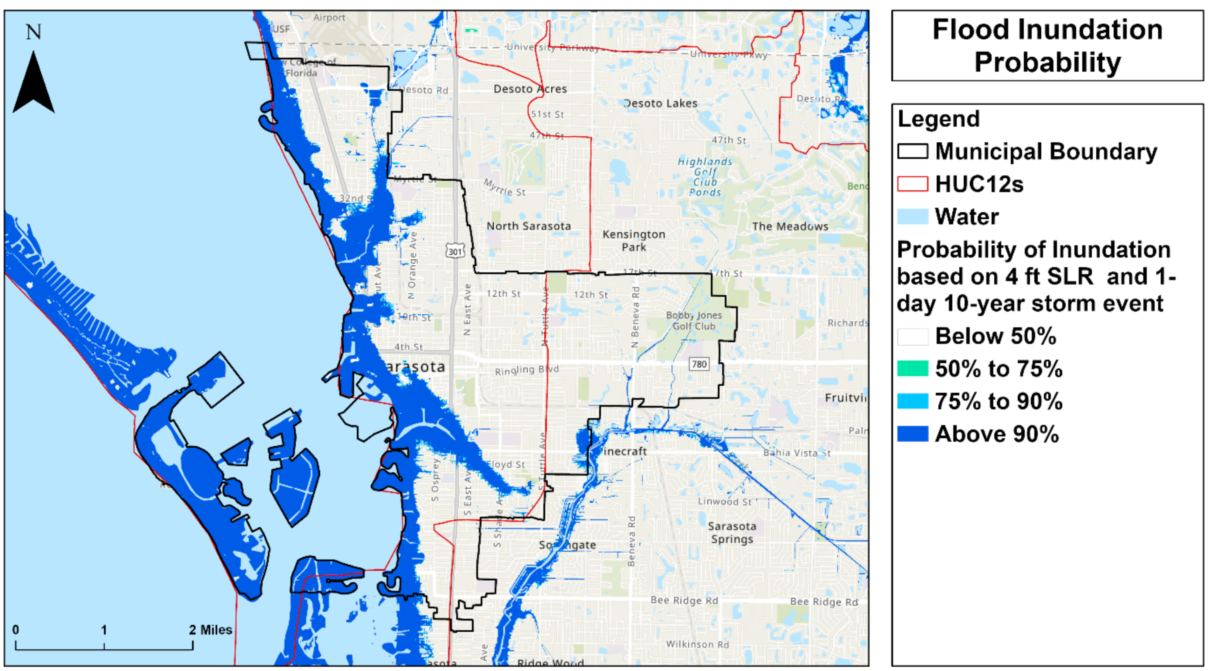


Figure 61. Probability of inundation based on 4-ft SLR and 1-day 10-year storm event, as generated by FAU CWR3

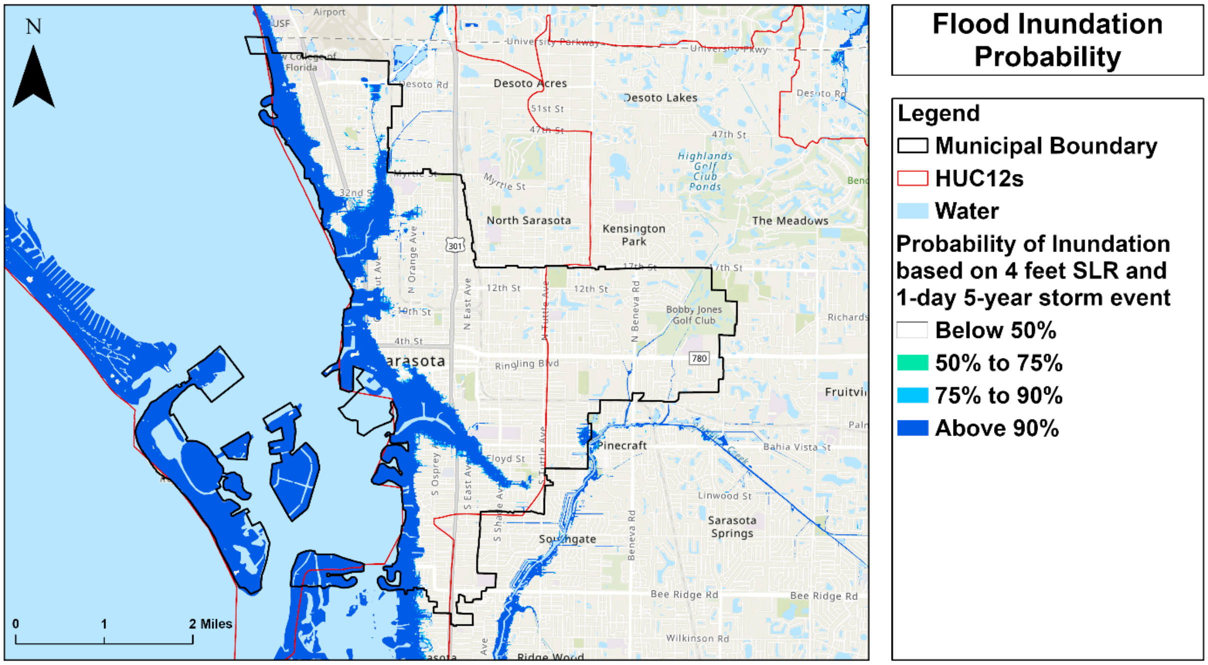


Figure 62. Probability of inundation based on 4-ft SLR and 1-day 5-year storm event, as generated by FAU CWR3

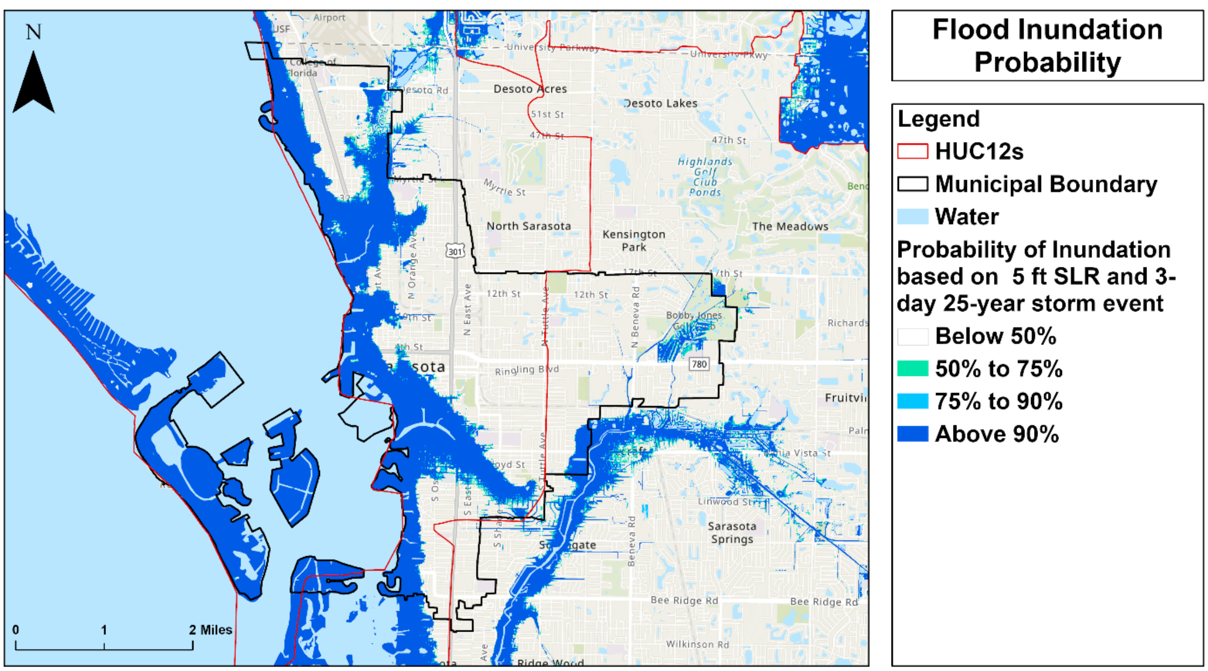


Figure 63. Probability of inundation based on 5-ft SLR and 3-day 25-year storm event, as generated by FAU CWR3

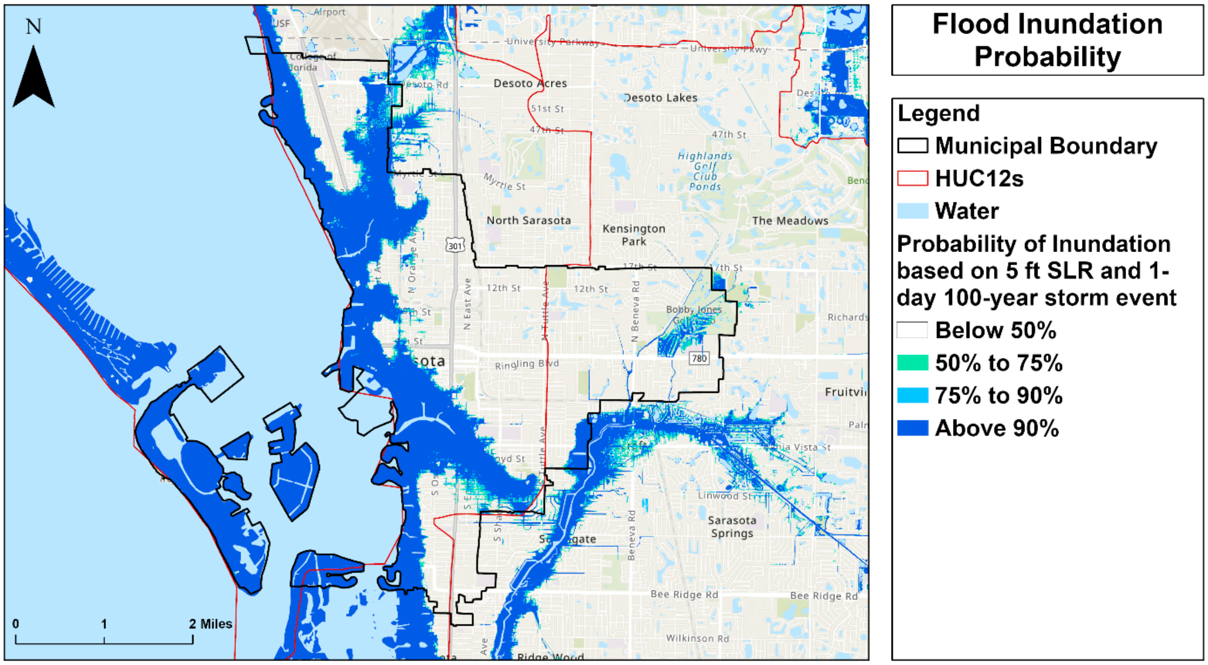


Figure 64. Probability of inundation based on 5-ft SLR and 1-day 100-year storm event, as generated by FAU CWR3

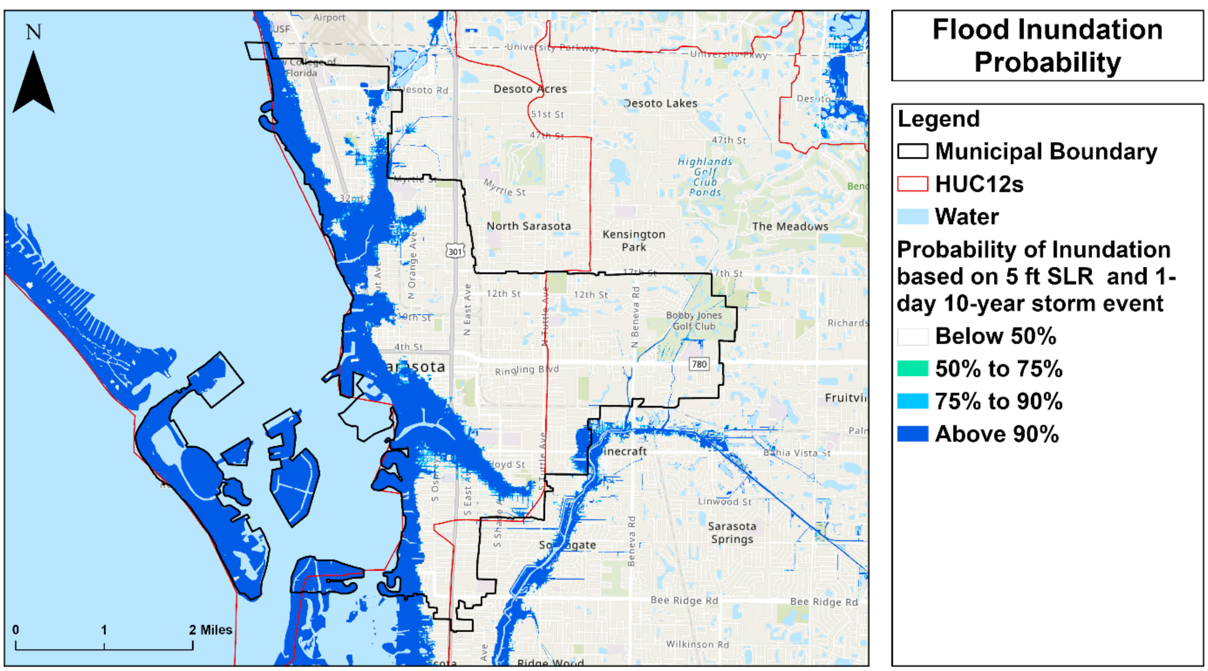


Figure 65. Probability of inundation based on 5-ft SLR and 1-day 10-year storm event, as generated by FAU CWR3

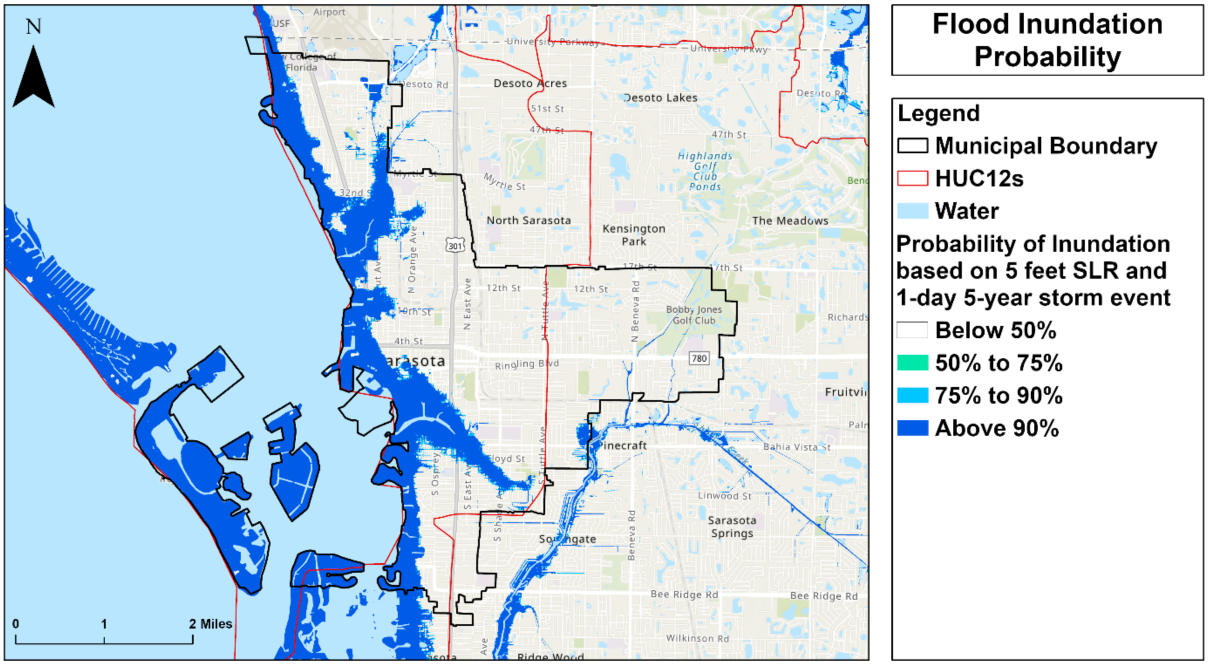


Figure 66. Probability of inundation based on 5-ft SLR and 1-day 5-year storm event, as generated by FAU CWR3

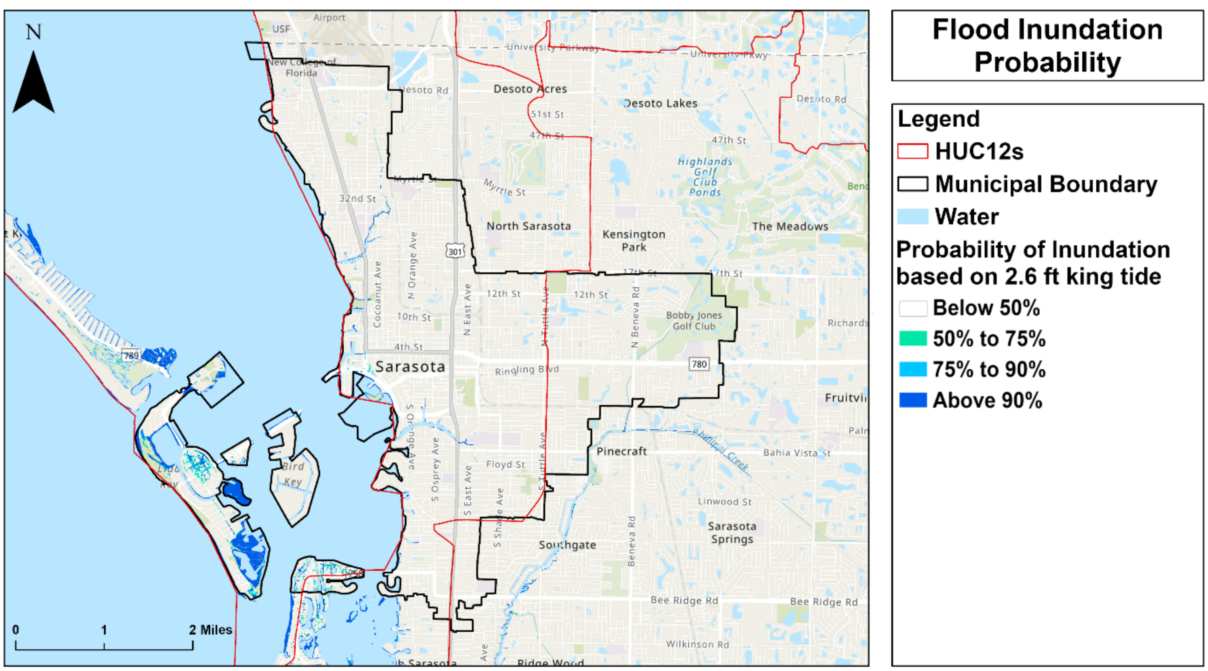


Figure 67. Probability of inundation based on King tide, as generated by FAU CWR3

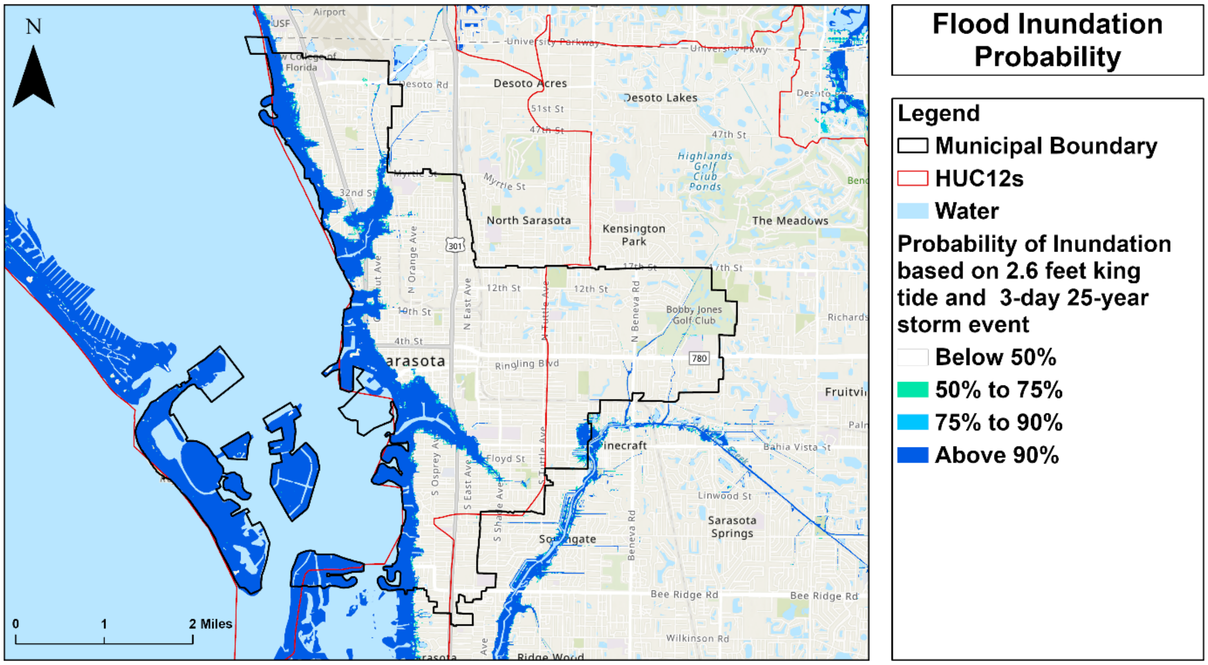


Figure 68. Probability of inundation based on King tide plus and 3-day 25-year storm event, as generated by FAU CWR3

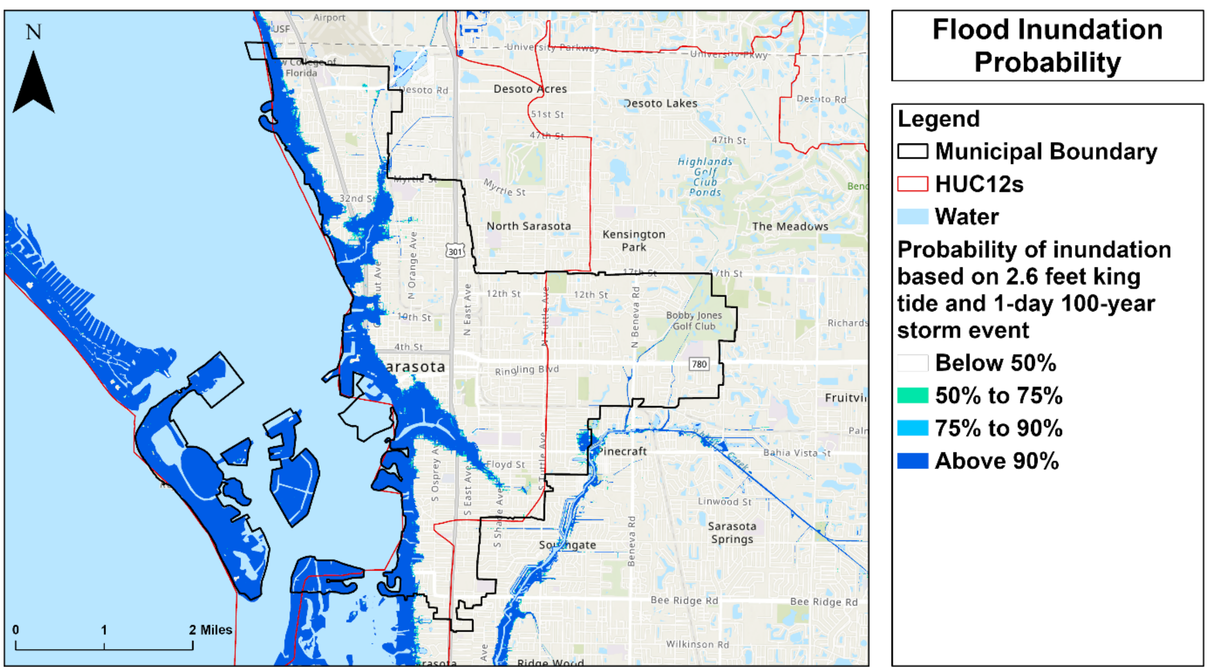


Figure 69. Probability of inundation based on King tide and 1-day 100-year storm event, as generated by FAU CWR3

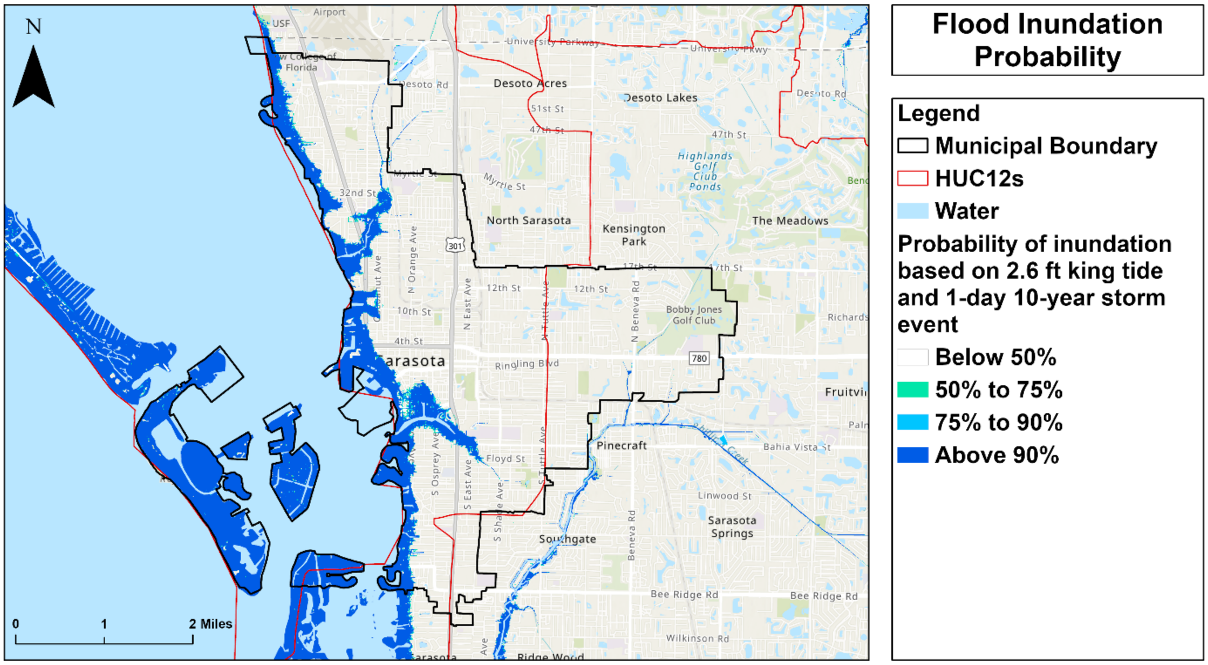


Figure 70. Probability of inundation based on King tide plus 1-ft SLR and 3-day 25-year storm event, as generated by FAU CWR3

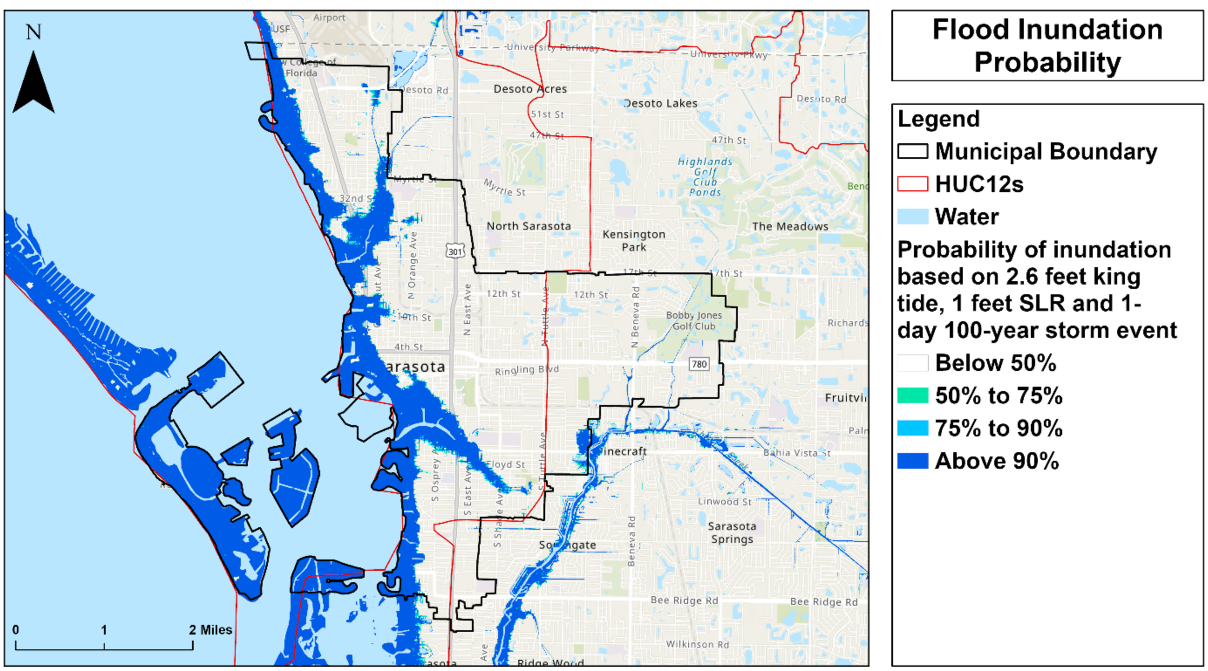


Figure 71. Probability of inundation based on King tide plus 1-ft SLR and 1-day 100-year storm event, as generated by FAU CWR3

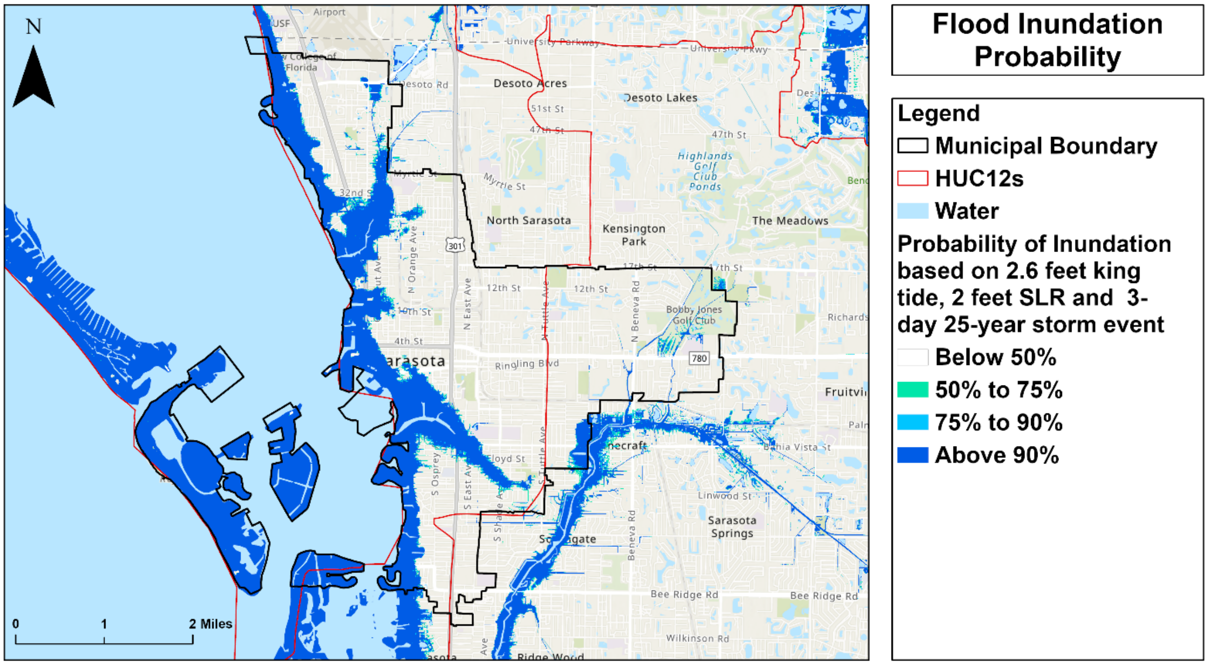


Figure 72. Probability of inundation based on King tide plus 2-ft SLR and 3-day 25-year storm event, as generated by FAU CWR3

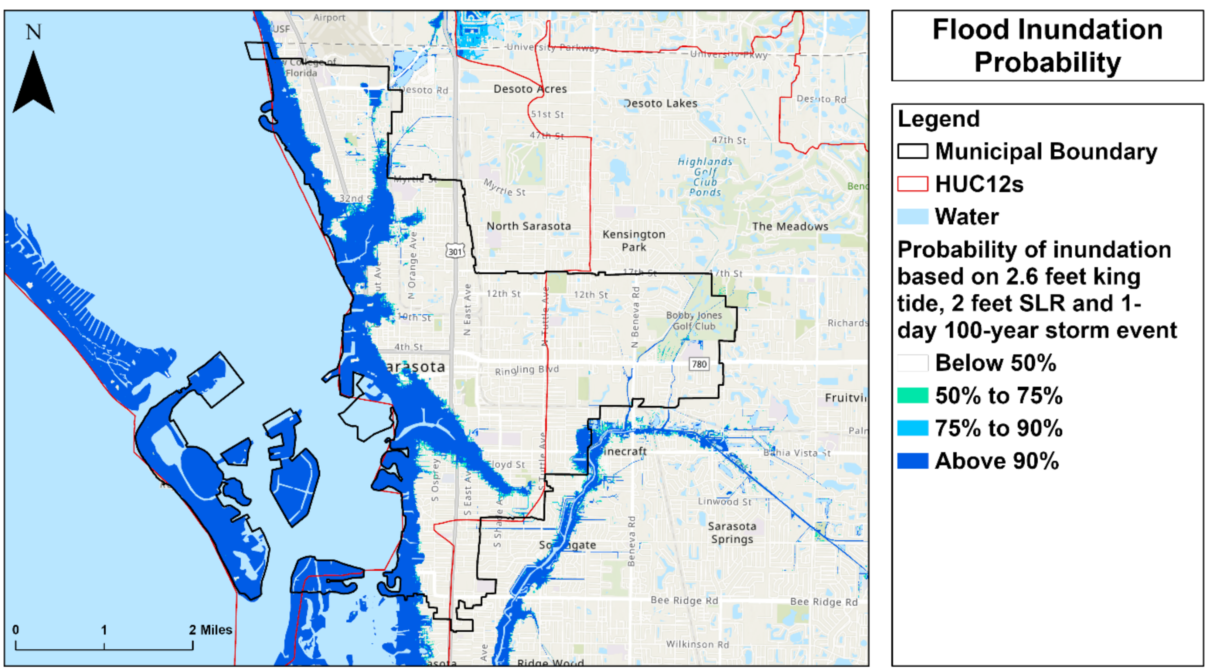


Figure 73. Probability of inundation based on King tide plus 2-ft SLR and 1-day 100-year storm event, as generated by FAU CWR3

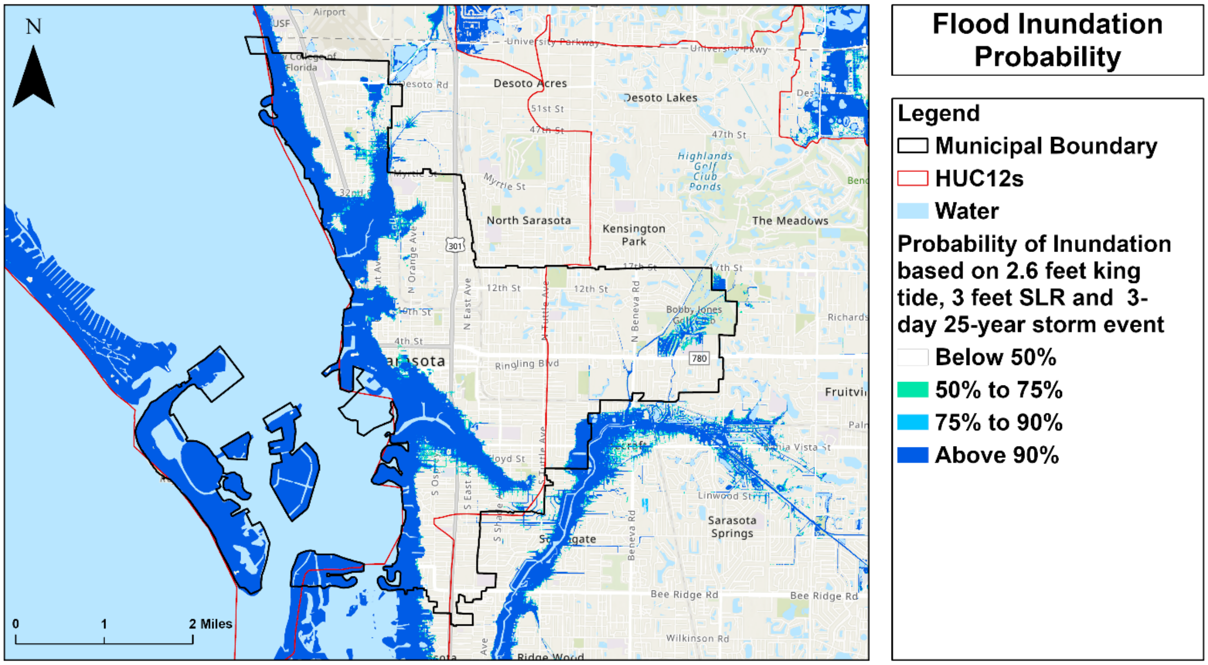


Figure 74. Probability of inundation based on King tide plus 3-ft SLR and 3-day 25-year storm event

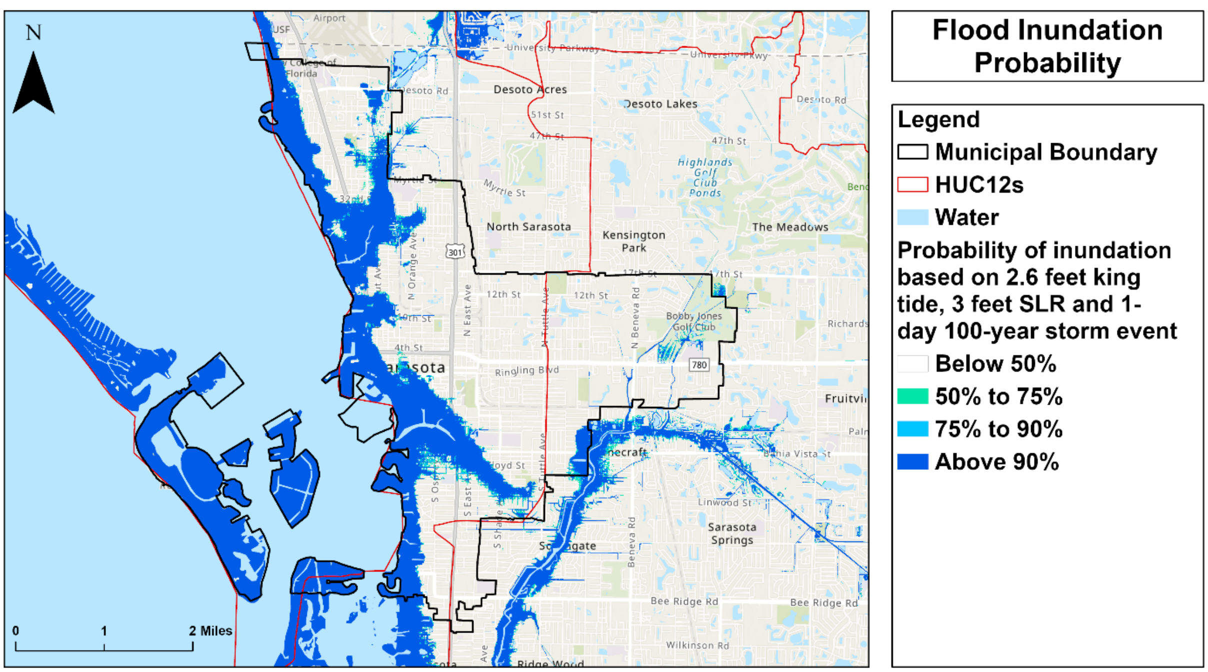


Figure 75. Probability of inundation based on King tide plus 3-ft SLR and 1-day 100-year storm event

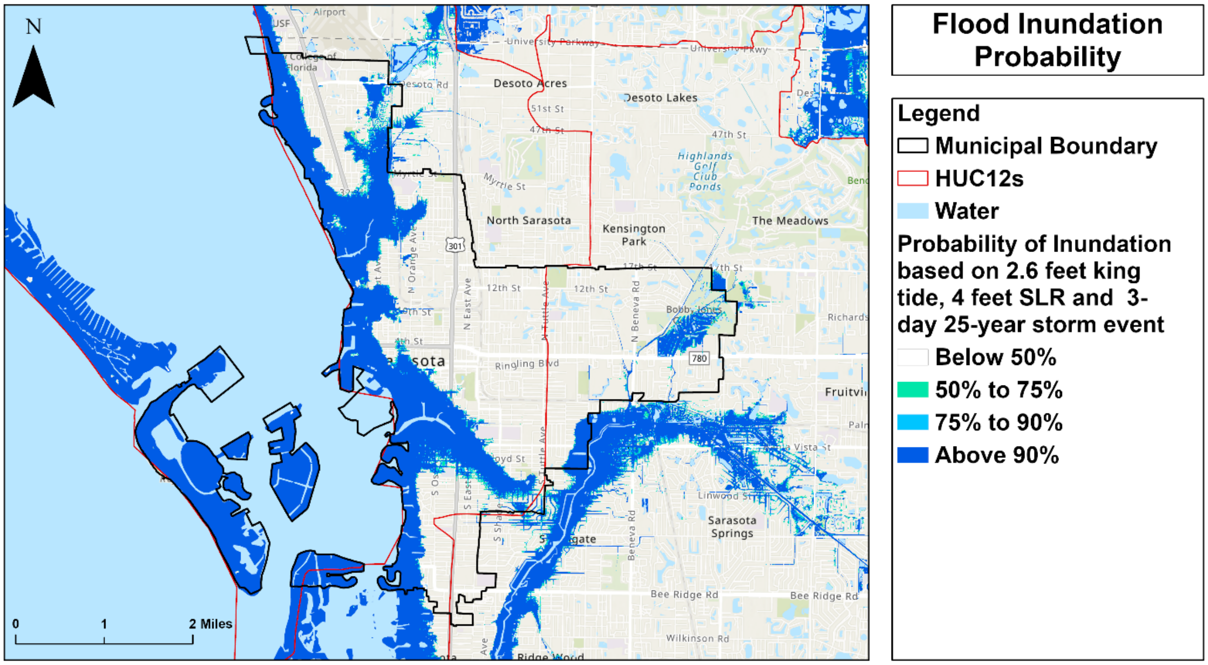


Figure 76. Probability of inundation based on King tide plus 4-ft SLR and 3-day 25-year storm event

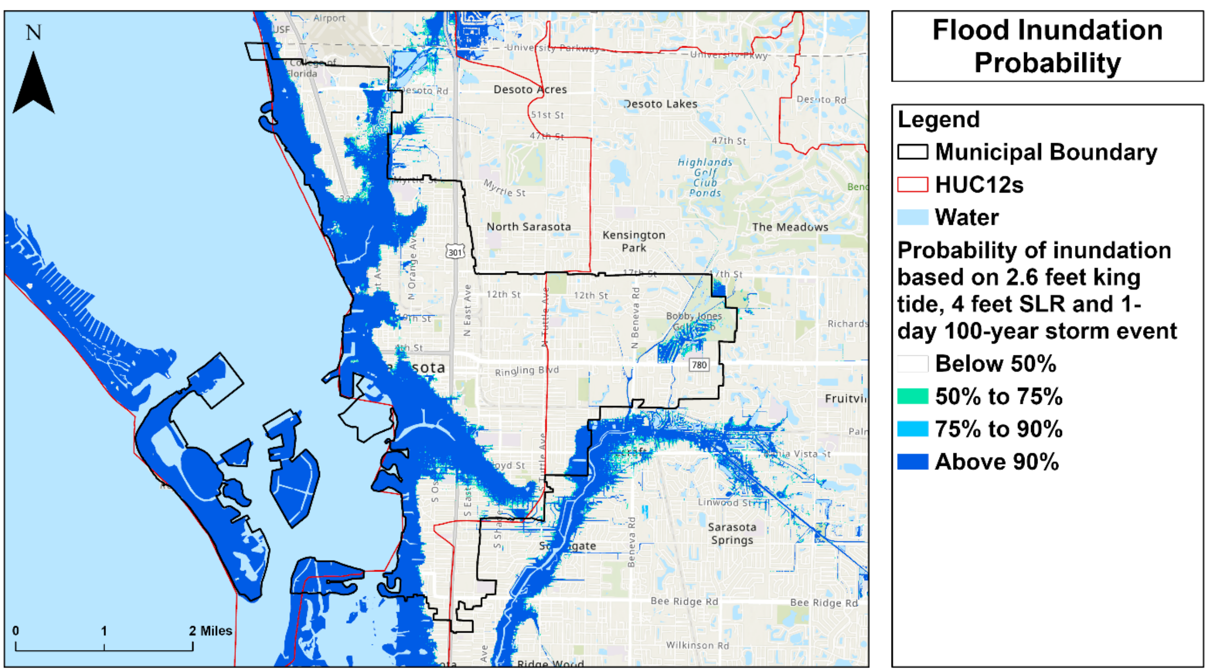


Figure 77. Probability of inundation based on King tide plus 4-ft SLR and 1-day 100-year storm event

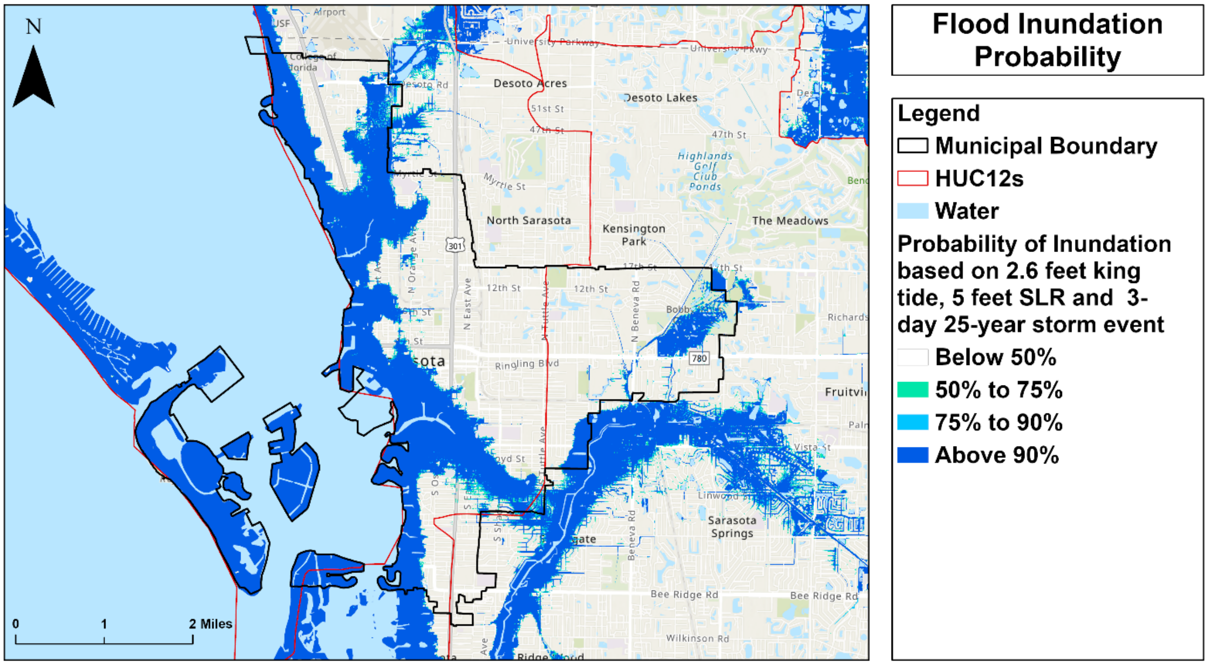


Figure 78. Probability of inundation based on King tide plus 5-ft SLR and 3-day 25-year storm event

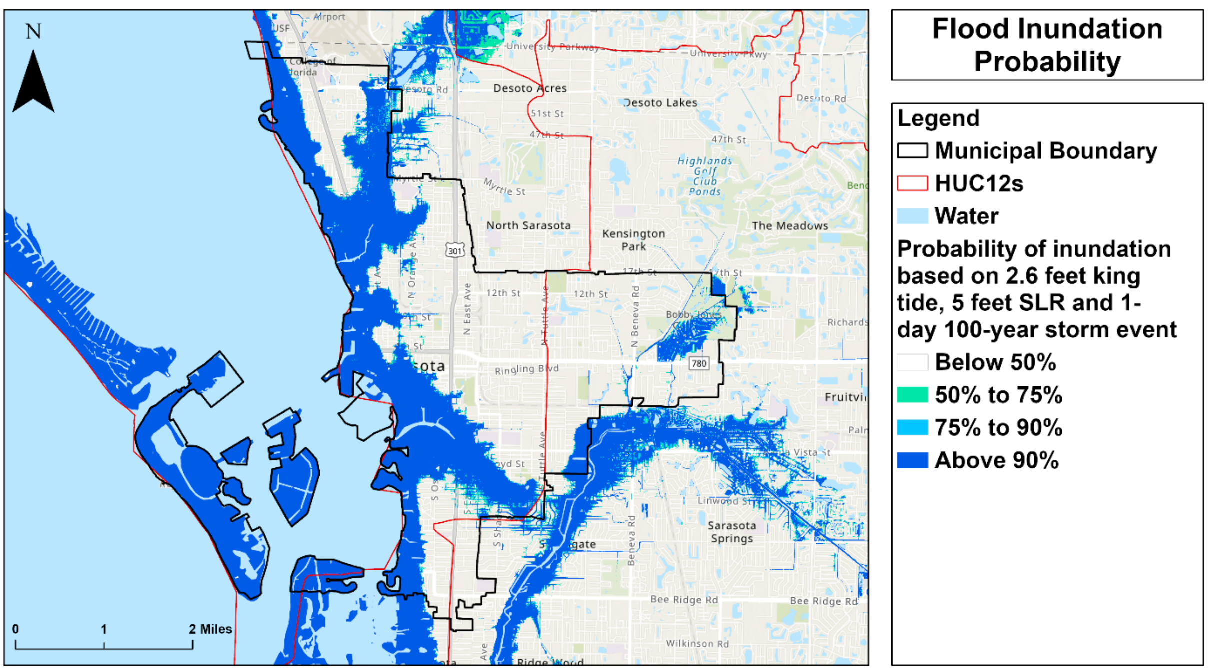


Figure 79. Probability of inundation based on King tide plus 5-ft SLR and 1-day 100-year storm event

4.3 Future Challenges of Sea Level Rise and Climate Change

Global observations from satellites and long-term data collection have made it possible to document and analyze patterns in the Earth's climate. Scientific analysis of the impact of these changes has helped to improve the understanding of future flood hazard driving forces and long-term impacts on human activities and watershed master planning (http://www.research.noaa.gov/climate/t_observing.html). Examples of impacts are rising global average air and ocean temperatures, increased and earlier snow and ice melt, shorter subtropical rainy seasons, shifted seasons, sea level rise, and greater variations in temperature and precipitation (IPCC, 2013; Freas et al., 2008; Marshall et al., 2004; Bloetscher et al., 2010). Marshall et al. (2004) specifically focused on the Florida peninsula to predict changes in rainfall and warmer temperatures but interspersed lower low temperatures due to the potential loss of wetlands.

Figure 80 shows the accumulated precipitation average prior to 1973 versus 1994. Marshall et al. (2004) state that "because sea breezes are driven primarily by contrasting thermal properties between the land and adjacent ocean, it is possible that alterations in the nature of land cover of the peninsula have had impacts on the physical characteristics of these circulations." Their modeling suggests that land use changes have reduced total rainfall by 12% since 1900, probably as a result of the loss of wetlands. This confirms the finding of Pielke (1999) who reported that "development has exacerbated their severity since landscape changes over south Florida have already appeared to have reduced average summer rainfall by as much as 11%" (Pielke, 1999). Future changes in climate will add to the existing impacts, at a time when the population of the state is expected to nearly double by 2030. Additional research and high-resolution climate modeling for the Florida peninsula and local jurisdictions are needed to help guide long-term plans like WMPs.

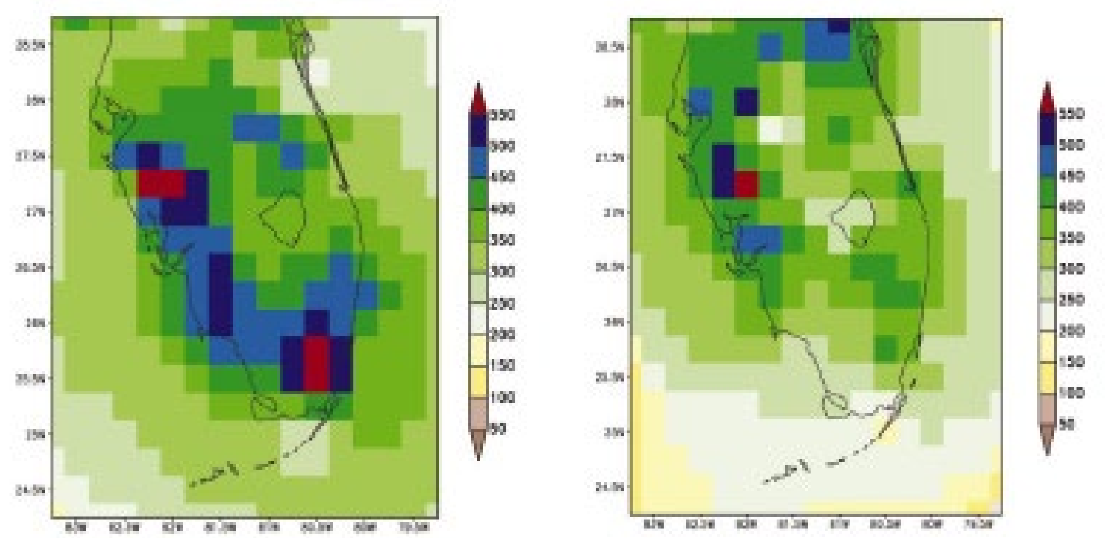


Figure 80. Accumulated precipitation 1973 (left) and 1994 (right) (Marshall et al., 2004)

Marshall et al. (2004) report that “while there is a great deal of spatial variability in these values, the results show that daytime maximum generally increased with the use of the 1993 land cover.” When converted to heat flux, Marshall et al. (2004) noted that “the latent heat flux difference exhibits a consistent decrease of nearly 10% of the grid-average pre-1900 value.” Figure 81 shows the change in average rainfall and the change in average temperature from 1924 to 2000. Note the reversed trend (higher temperatures and lower rainfall), which means groundwater inputs are reduced (Marshall et al., 2004) leading to the conclusion that land use changes (loss of wetlands) contribute to the higher variability of temperature.

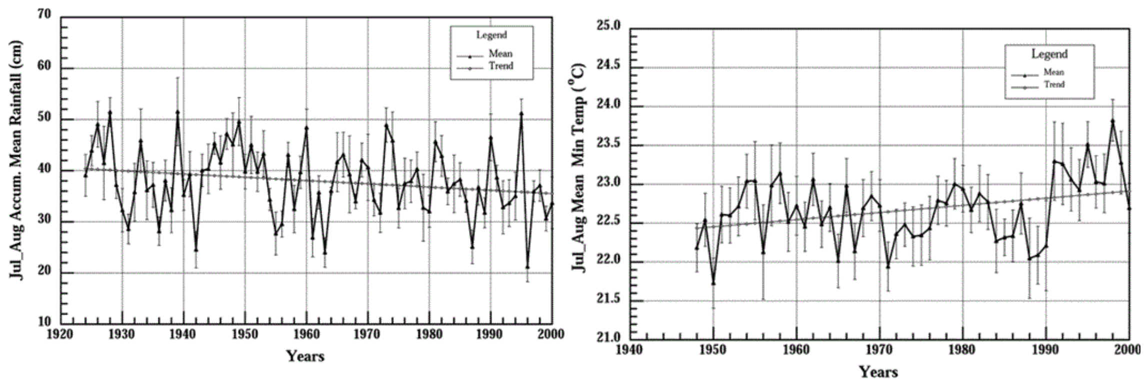


Figure 81. Change in average rainfall and change in average temp 1924 to 2000. Note the reversed trend, which means groundwater input variability is lessened (Marshall et al., 2004)

Climate change is likely to: 1) threaten the integrity and availability of fresh water supplies and 2) increase the risk of flooding, not only in the low-lying coastal areas but also in the interior flood plains. Other issues include a) saltwater intrusion, which may be intensified by sea level rise, b) prolonged droughts that will contribute to water supply shortages and wildfires, and c) heavier rains during the rainy season and higher hurricane storm surge, which may increase the risk due to flooding. More frequent and damaging floods are likely to become an ever-increasing problem as the sea level continues to rise because of: a) increasing groundwater table elevations and surface water gage heights, b) reduced groundwater seepage through the aquifer to the ocean, c) increasingly compromised stormwater drainage systems, and d) more frequent inundation of barrier islands and coastal areas.

NOAA and IPCC (2013) predictions suggest that by 2100, global temperatures will be on the order of 2-3°C (3-5°F) higher, and sea levels will rise by up to 3.9 feet according to the NOAA intermediate high sea level rise scenario.

5.0 INVENTORY OF POTENTIAL SOLUTIONS

The next step is the drill into the areas that experience the most significant flood potential for the purposes of identifying the actual vulnerability and the risk. The risk is based on land uses as described in section 5.1. Then the drilldown vulnerabilities are compared to the risk to use these factors to help with the prioritization of projects.

Once watershed master planning assessments are completed and strategies (both adaptive and hardening) are identified and evaluated, decisions must be made to implement priority projects. At the center of these planning efforts, there should also exist the provision for an adequate drainage system, designed to accommodate an increased volume of water and/or increased peak flows.

5.1 Risk and Vulnerability

The screening tool modeling exercise from Section 4.2.2 identified areas within the communities that are vulnerable to flooding. Higher priority concerns should be those properties or assets that are considered essential and need to be kept in service during a flooding event. The major regional issues in the greater watershed are capital projects associated with the SFWMD plans for controlling discharges that impact the ecosystem at the west end of the watershed. Hence regional water management districts and USACE projects have higher priority due to the larger area served. All other improvements are distinctly local. To help with prioritization, the following is suggested:

- Tier 1 - Critical facility protection (water/sewer utilities, public safety, hospitals, schools, power).
- Tier 2 - Essential facilities (groceries, pharmacies, roadways)
- Tier 3 - Economic centers (protecting jobs)
- Tier 4 - At-risk communities
- Tier 5 - Other urban/suburban property
- Tier 6 - Agriculture/public property/vacant/undeveloped

Table 5 outlines the US Department of Revenue (DOR) codes from the property appraiser's office and assigns an associated priority level to each parcel. Note that for residential property, identifying at-risk communities (income, age, disability, health) requires a further drilldown to the neighborhood level (i.e., wealthy neighborhoods with few older, poor-health individuals would have a lower priority than at-risk communities, which may have lower value housing and denser development). In the latter case, more people are impacted with less ability to mitigate that risk. Based on these priorities, the relative risk priority DOR land use codes were evaluated based on a scale of 1 to 6, where 1 is the most vulnerable and 6 is the least vulnerable.

Table 5. Department of Revenue (DOR) land use codes

DOR (use code)	Description	Priority	Delineator
000	Vacant Residential	6	
001	Single Family Residential	Depends	Value, Age, Income
002	Mobile Homes	4	
003	Multi-Family >9 units	4	
004	Residential Condo	Depends	Value, Age, Income
007	Misc. Residential	5	
008	Multi-Family <10	4	
009	Residential Common Area	6	
010	Vacant Commercial	6	
011	One-Story Stores	3	
012	Mixed Use Store	4	
013	Department Store	3	
014	Supermarket	2	
015	Regional Shopping Center	3	
016	Community Shopping Center	3	
017	Office Non Professional	3	
018	Service Multi-Story	3	
019	Professional Services Building	3	
020	Terminals	3	
021	Restaurant	3	
022	Drive-in	5	
023	Financial	2	
026	Laundry	3	
027	Service Station	3	
028	Mobile Home Sales, Parking Lot, Mobile Home Parks	5	
031	Drive-in Theater	5	
032	Auditoriums/Indoor Theaters	5	
033	Bar	5	
034	Skating Rinks, Poolhalls,	5	

DOR (use code)	Description	Priority	Delineator
	Bowling Alleys		
035	Tourist Attractions	5	
038	Golf Course	6	
039	Hotel	3	
040	Vacant Industrial	6	
041	Light Manufacturing	4	
048	Warehouse Distribution	5	
049	Open Storage	6	
052	Cropland	6	
063	Grazing Land	6	
066	Orchard	6	
067	Poultry	6	
069	Ornamentals	6	
070	Vacant without Features	6	
071	Church	5	
072	Private School	3	
073	Private Hospital	2	
074	Home for the Aged	4	
075	Orphanage	4	
076	Cemetery	6	
077	Club, Hall	5	
078	Convalescent Homes	4	
080	Vacant Government	6	
082	Military, Forest, Parks	6	
083	Public School	2	
084	Public College	2	
086	County	Depends	Utilities, Arterial =1
087	State	Depends	Arterial = 1
088	Federal	6	
089	Municipal	1	
091	Utility	Depends	Water/Wastewater Treatment Plants, Public Safety = 1
094	Right of Way	Depends	Florida Department of Transportation (FDOT), Arterial = 1

DOR (use code)	Description	Priority	Delineator
095	Submerged, lakes	6	
096	Sewage Disposal	1	
099	Other Non-Agricultural Acreage	6	

Having identified the vulnerable properties in Section 4.2.2 by determining the risk priority from 1 to 6 in the DOR codes and the percentage of the parcel that floods during the applicable design storm, properties that are more critical to the function of the community can be identified. The methodology is to first convert the DOR code priority tier to its inverse scale by the following equation:

Consequence of risk factor = 7 – DOR Code Priority Tier

The flood risk factor from the screening tool is interpreted based on flooding probability. We take all parcels in tiers #1-4 that have a greater than 50% chance of flooding during a particular design storm and calculate the percent of the parcel that would flood during that event. The percentage is converted to a 6-point scale termed as the Flood Risk Factor, as follows:

Percent of Parcel Flooded	Flood Risk Factor
90-100%	6
80-89%	5
70-79%	4
60-69%	3
50-59%	2
<50%	1

Next, the protocol assigns 75% of the importance to the consequence of flooding and 25% importance to flood risk, or three times the importance to the consequence of flooding to come up with a composite score as follows:

Flood Risk Factor × 25% + Consequence of Risk Factor × 75% = Composite Score

Example:

$1 \times 25\% + 6 \times 75\% = 4.75$

Once watershed master planning assessments are made and strategies (both adaptive and hardening) are identified and evaluated, decisions must be made to implement priority projects. At the center of these planning efforts should also exist the provision for an adequate drainage system, designed to accommodate an increased volume of water and/or increased peak flows.

5.2 Drilldown Vulnerability

Figure 82 shows the facilities in the tiers from based on land use from the Sarasota County Property Appraiser's office. Figure 83 shows the items in Figure 82 for Tiers 1-3 overlaid on the 1:100 year 5 ft Sea level rise flood map in Chapter 4. Figure 84 shows the flood and property consequence factors together in one figure. As a result, efforts in the County should be geared toward protecting the projects with the highest priority scores. From the outreach discussions in Chapter 6. These areas can be prioritized.

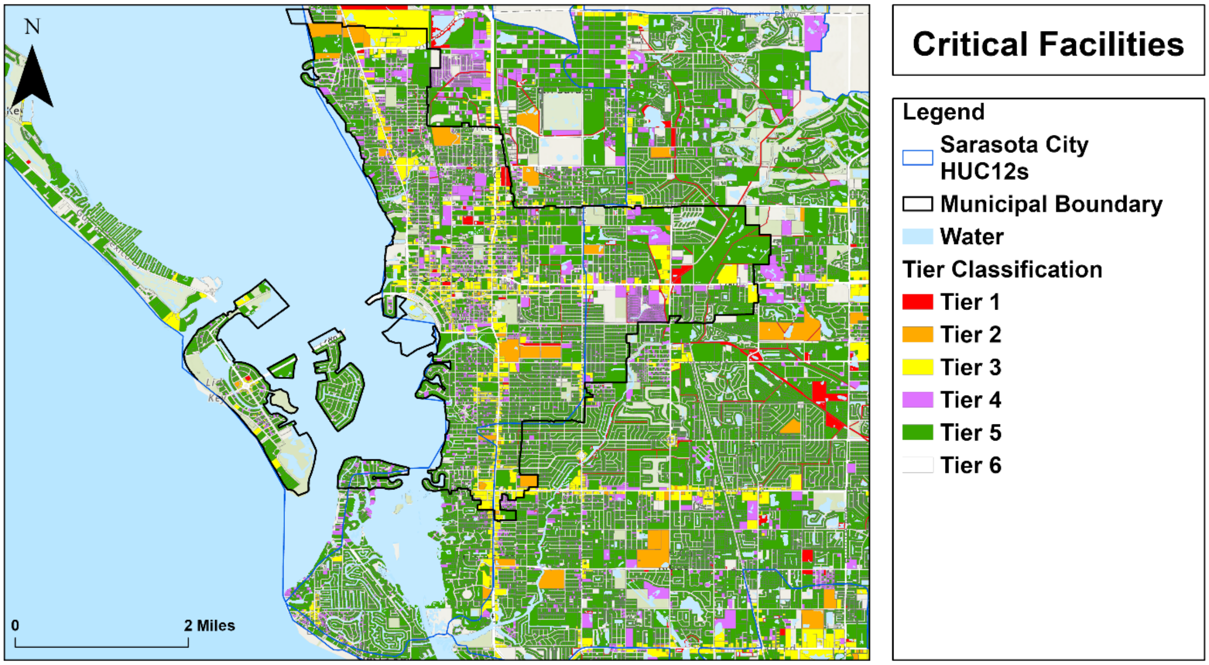


Figure 82. Priority of land uses (Property consequence factor) in the tiers from based on land use from the Sarasota County Property Appraiser's Office, as generated by FAU CWR3

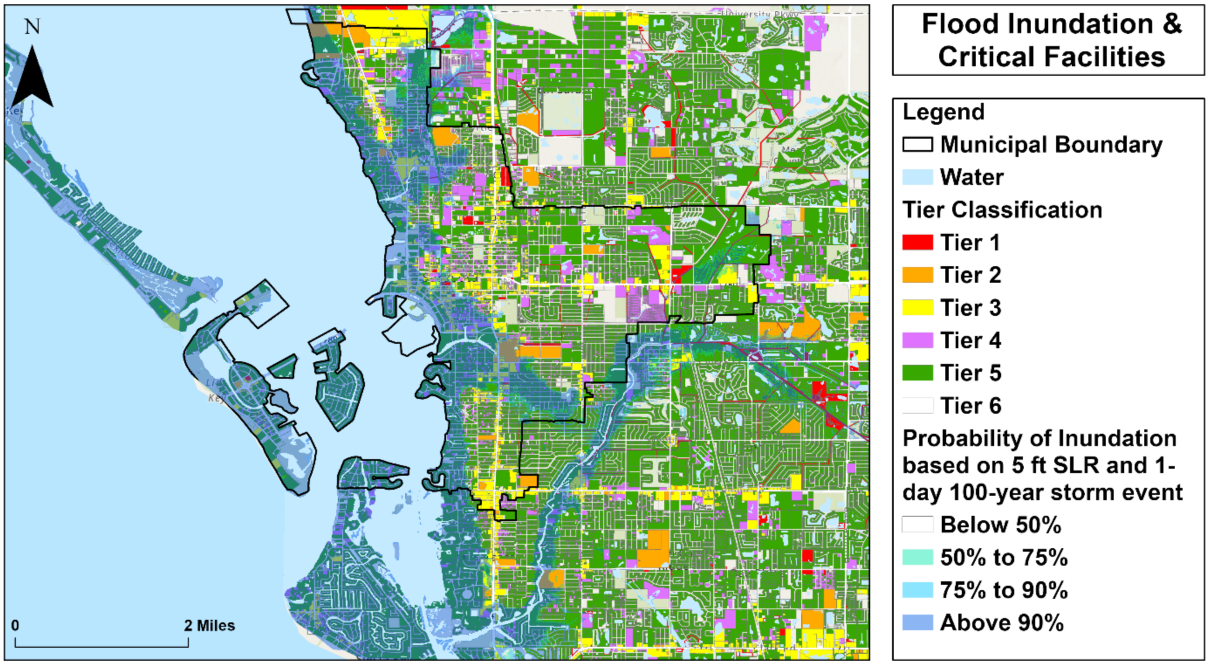


Figure 83. 1-day100-year 5-ft Sea level rise flood map and property consequence factors together on one map, as generated by FAU CWR3

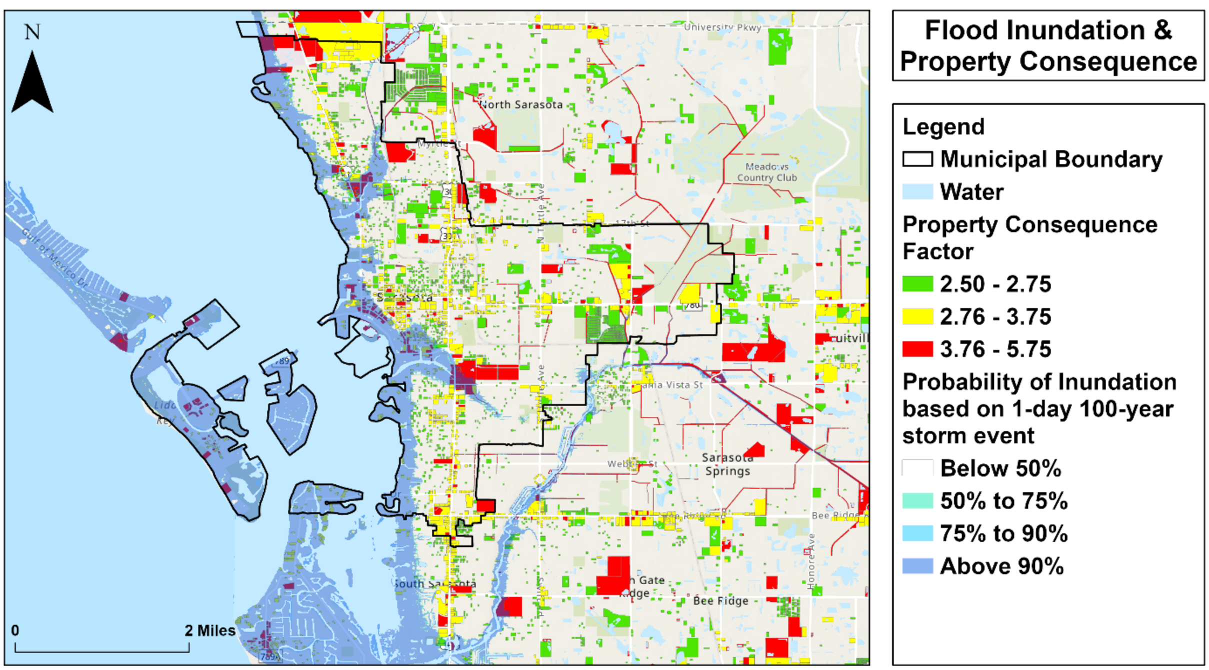


Figure 84. flood and property consequence factors together, as generated by FAU CWR3

Once watershed master planning assessments are made and strategies (both adaptive and hardening) are identified and evaluated, decisions must be made to implement priority projects. At the center of these planning efforts should also exist the provision for an adequate drainage system, designed to accommodate an increased volume of water and/or increased peak flows. The drilldowns are outlined in the next section, along with potential solutions or modeled solutions to address flooding.

5.3 Drilldown to Flood-Prone Areas

The process of identifying potential mitigation measures to implement begins with narrowing down the feasible engineering alternatives using threshold criteria and quantifiable selection criteria that include measures of effectiveness, cost, and added benefit to the community. The toolbox describes a variety of strategies that could be used to improve potential flood management conditions. They are community-specific and most require significant engineering and planning to determine the most efficient configuration to achieve the community's goals. Hard infrastructure systems are usually the first systems to be impacted because they are built at lower elevations than the finished floor of structures. In addition, many infrastructure systems are located within the roadways (water, sewer, stormwater, power, phone, cable tv, internet, etc.). At present, most roadway base courses are installed above the water table. If the base stays dry, the roadway surface will remain stable. As soon as the base is saturated, the roadway can deteriorate.

Catastrophic flooding should be expected during heavy rain events if there is nowhere for the runoff to go. The vulnerability of infrastructure will require the design of more resistant and adaptive infrastructure and network systems. This will, in turn, involve the development of new performance measures to assess the ability of infrastructure systems to withstand flood events and to enhance resilience standards and guidelines for the design and construction of facilities. Specifically, considerations include retrofitting, material protective measures, rehabilitation, and in some cases, the relocation of facilities to accommodate sea-level rise impacts. As they are related, groundwater is, similarly, expected to have a significant impact on flooding in these low-lying areas because of the loss of soil storage capacity. Evapotranspiration in low-lying areas with high groundwater will become more important which is why ecologically based stormwater management that employs natural native vegetation will become more important over time in certain communities.

Hence, the next step was to zoom into neighborhoods with significant flooding. The figures in Chapter 4 indicated that much of the island was at risk. Discussions with the City staff included identifying challenges and solutions on this island (Figure 85). Note that water levels in the Gulf of Mexico are the major flood driver – all water drains to coastal waters and the topography of the island permits very limited areas to store water, and those that can are very shallow.

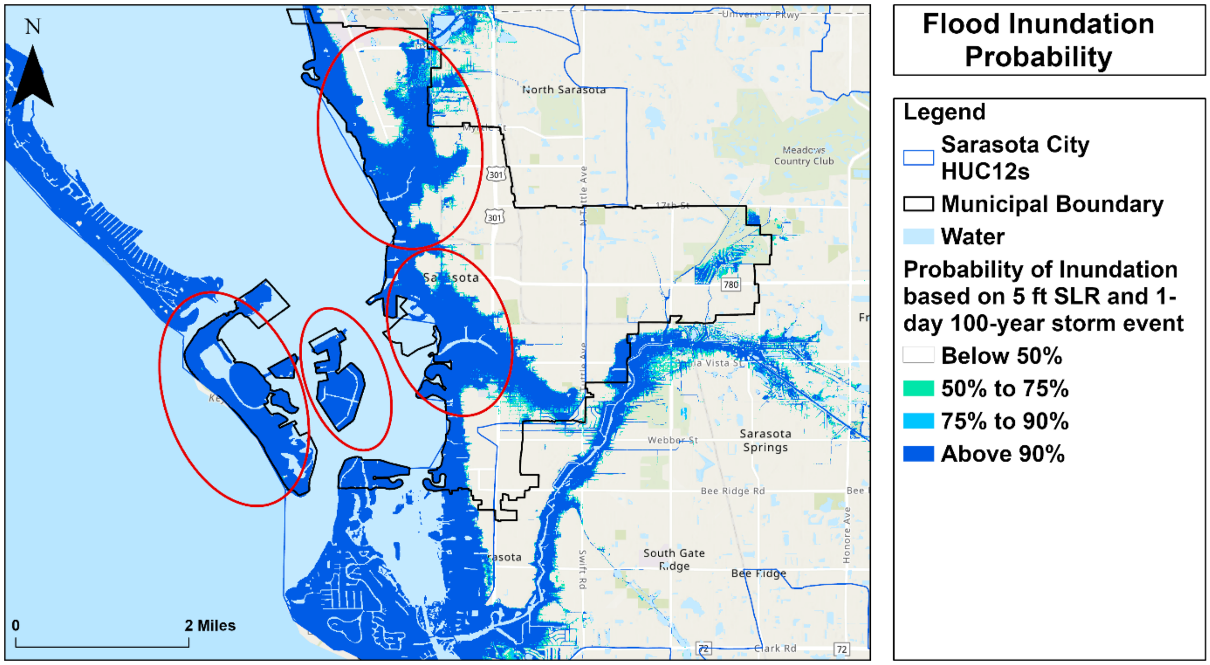


Figure 85. Priority areas for City Staff, as generated by FAU CWR3

Figure 86 shows the aerial of the north end of the City. At 0 ft sea level rise, The entire coastal bay floods halfway to US 41 (see Figure 87). This is a low-lying area. Sea walls are needed, or need to be raised to address coastal flooding and any drains need to have backflow devices installed so that coastal flooding does to create roadway flooding. Hence sea wall elevations, a regulatory requirement, should be implemented in the long term. Figure 88 The water also migrates up Philippi Creek. With 5 feet of sea level rise, Figure 89 shows that the water migrates significantly up Philippi Creek and Whitaker Bayou.

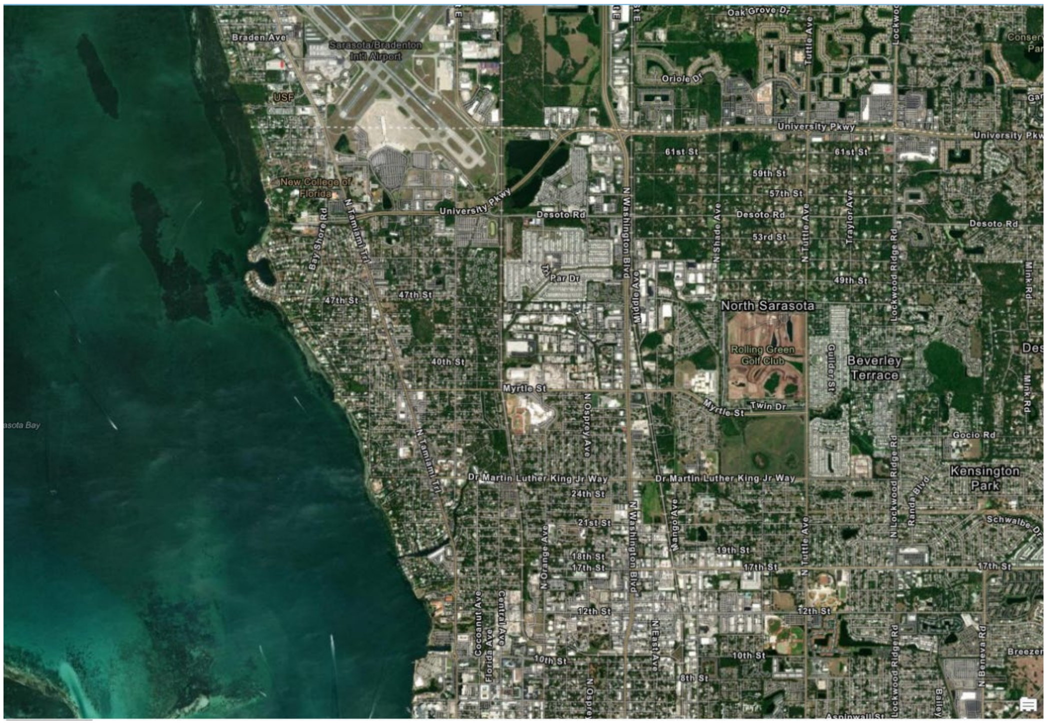


Figure 86. Section 1 zoomed-in aerial image of the northwest corner of the City

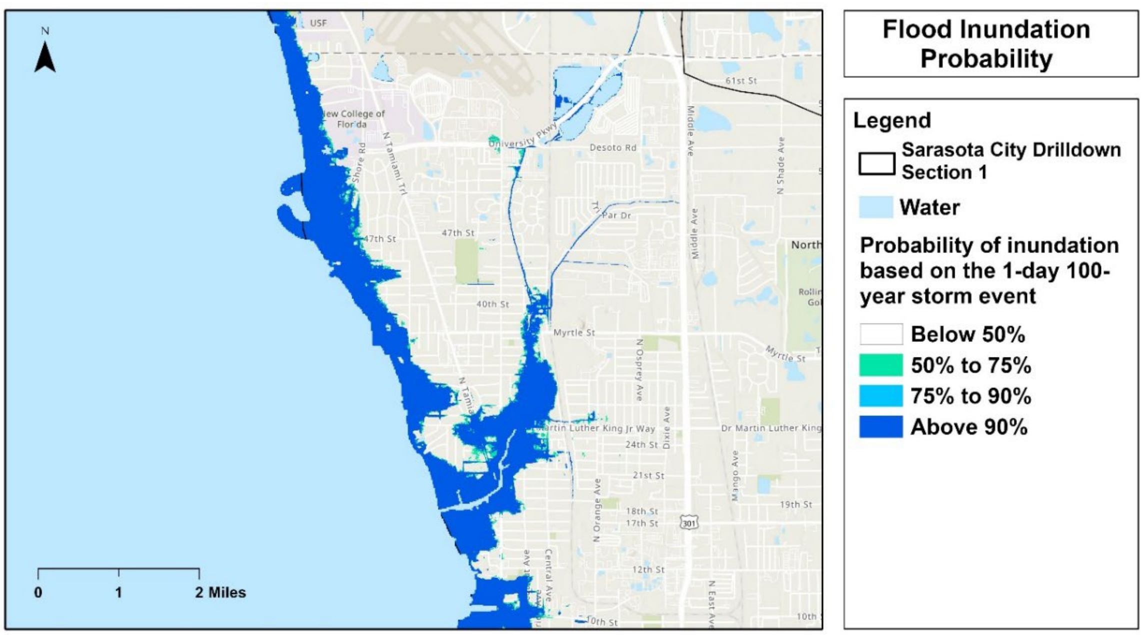


Figure 87. Drilldown Section 1, based on 1-day 100-year rainfall in the northeast section of the City, as generated by FAU CWR3

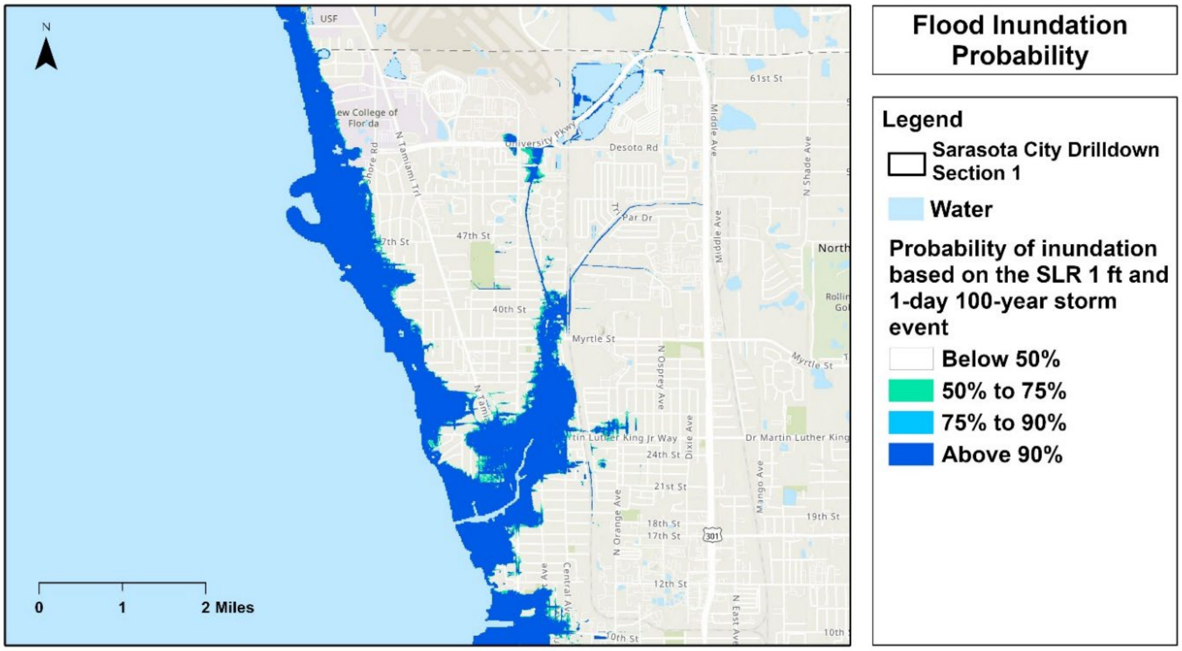


Figure 88. Drilldown Section 1, based on 1-ft SL and 1-day 100-year rainfall event, as generated by FAU CWR3

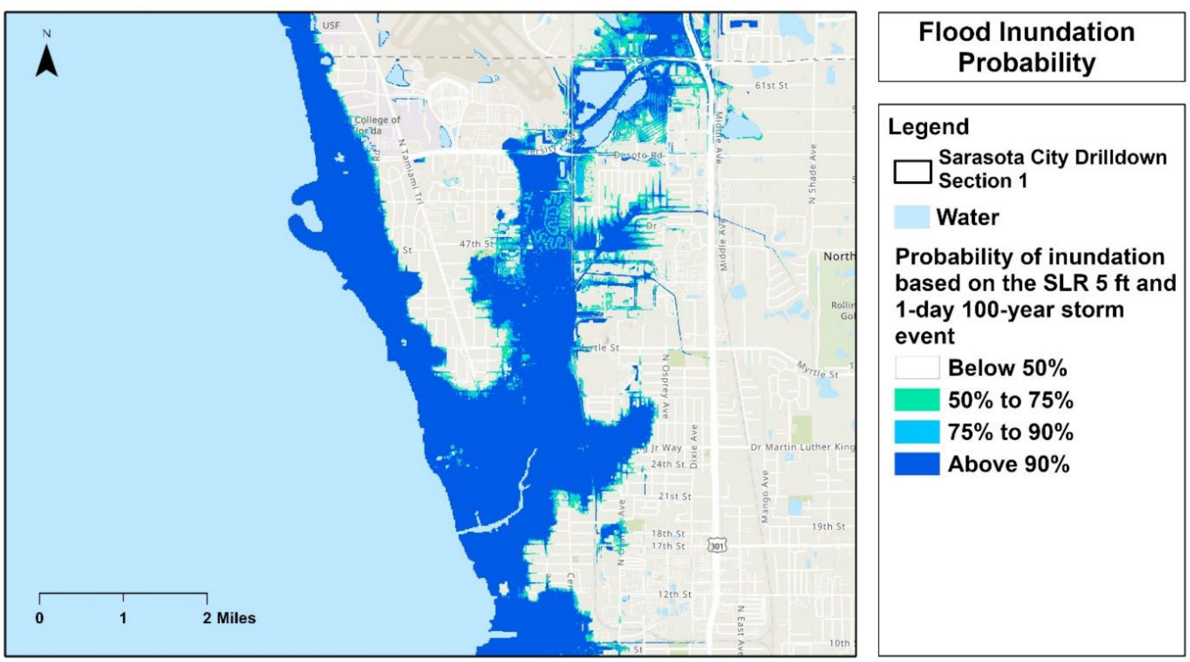


Figure 89. Drilldown Section 1, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Drilling down into this area, **Error! Reference source not found.** through Figure 113 show drilldowns from north to south along the bay. The aerial photo, 1-day 100-year and 1-day 100-year with 5 ft of sea level rise are shown. The road closest to the bay, and the associated properties flood first. Progressively water creeps inland in all cases, starting with roads. Hence roadway bases have probably already started failing.

Figure 90. Aerial view of northwest area –New College area

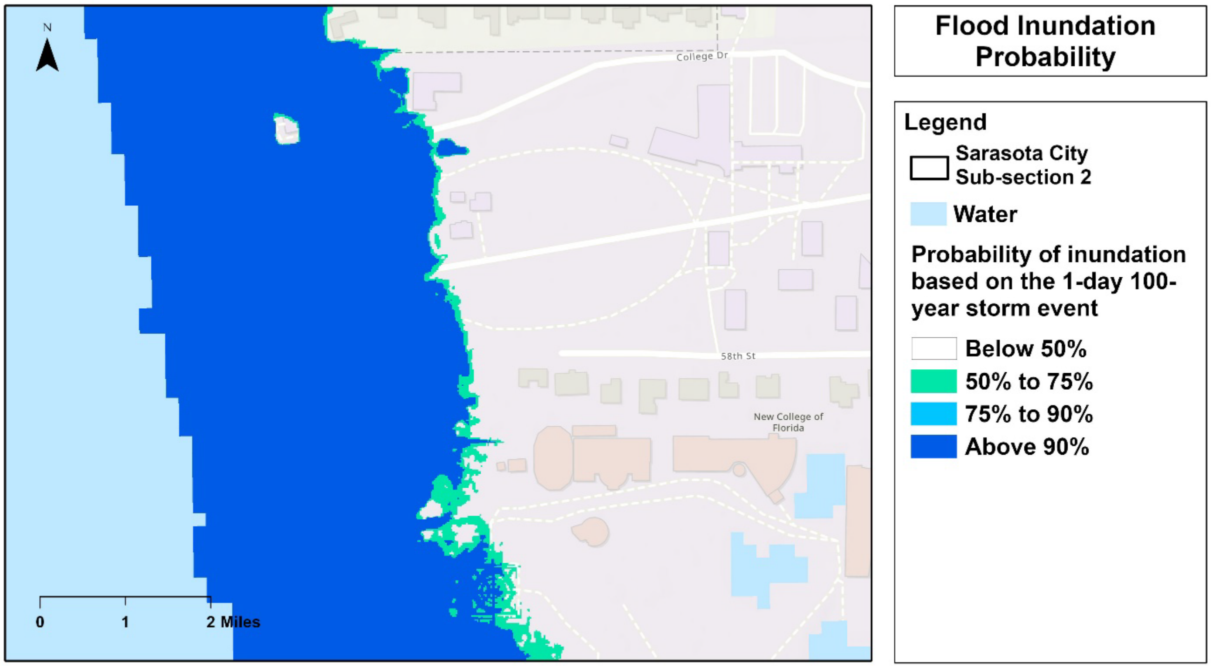


Figure 91. Drilldown New College area, based on 1-day 100-year rainfall event, as generated by FAU CWR3

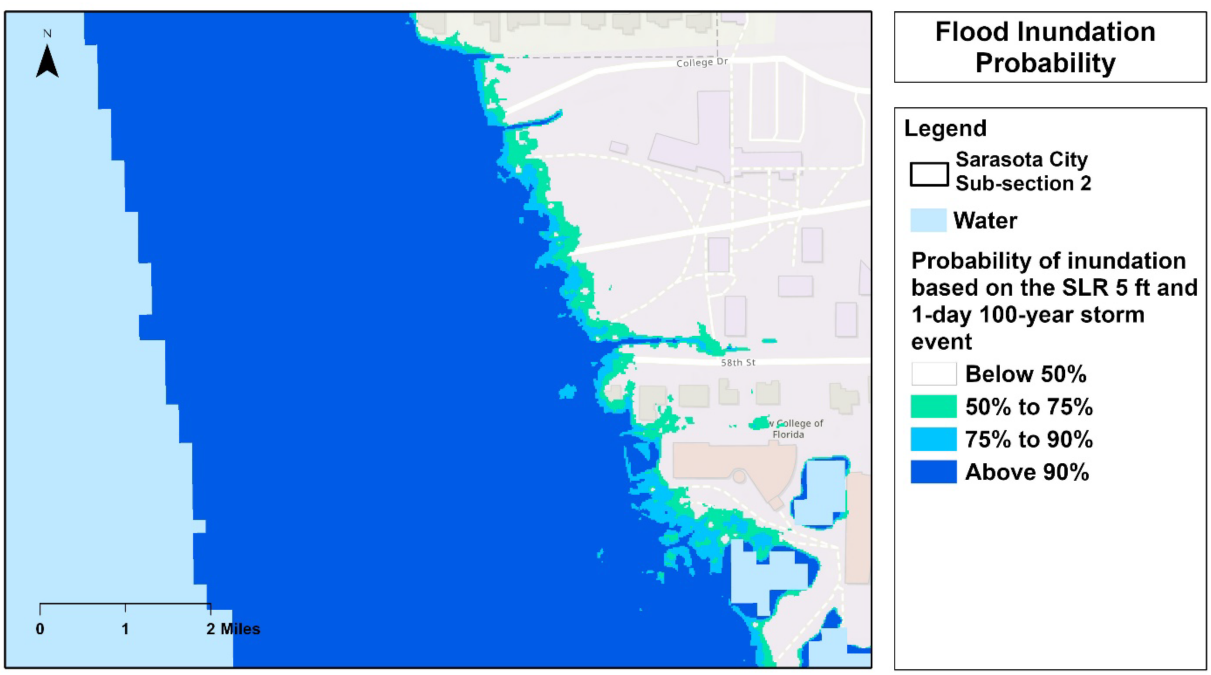


Figure 92. Drilldown New College area, based on the 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 93. Aerial view of Ringling museum area.

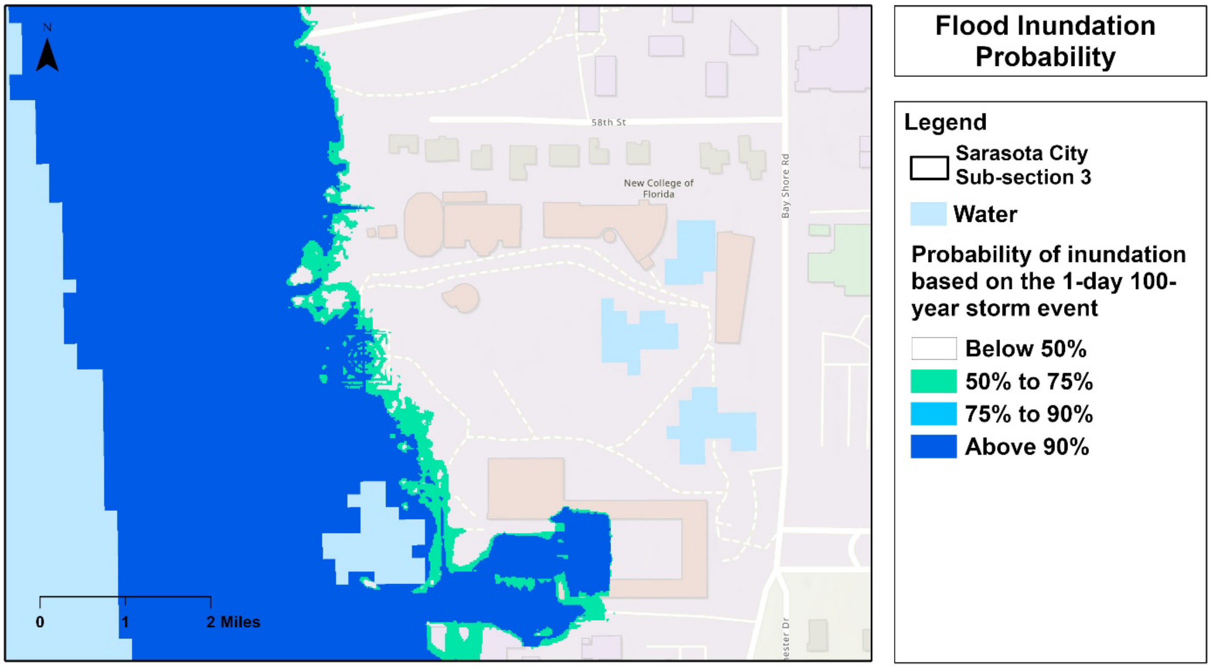


Figure 94. Drilldown Ringling museum area, based on 1-day 100-year rainfall event, as generated by FAU CWR3

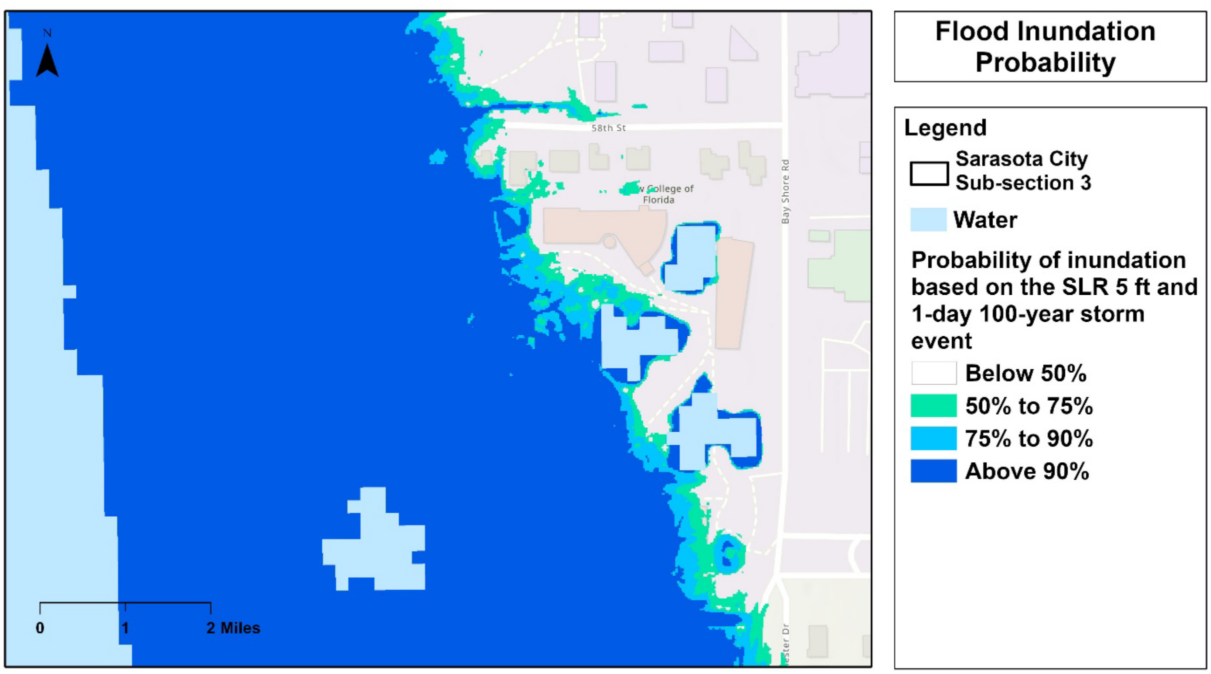


Figure 95. Drilldown Ringling museum area, based on the 5-SLR and 1-day 100-year rainfall event, as generated by FAU CWR3.

Figure 96. Aerial view of Sapphire Shores Park area

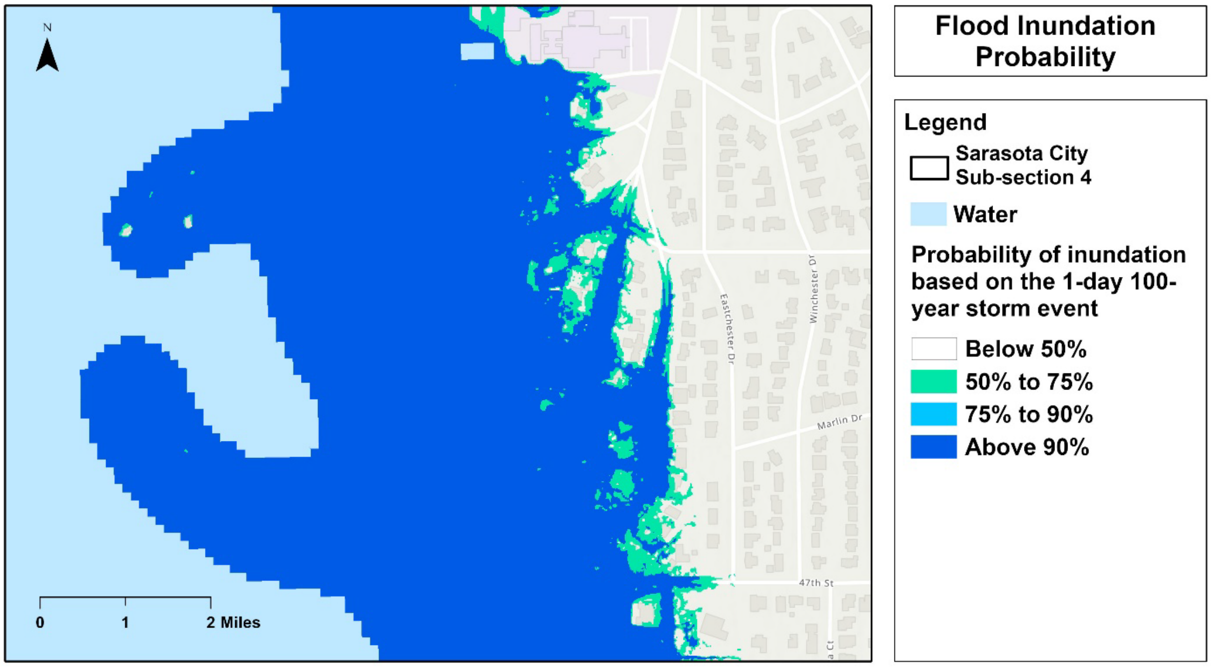


Figure 97. Drilldown of Sapphire Shores Park area, based on 1-day 100-year rainfall event, as generated by FAU CWR3

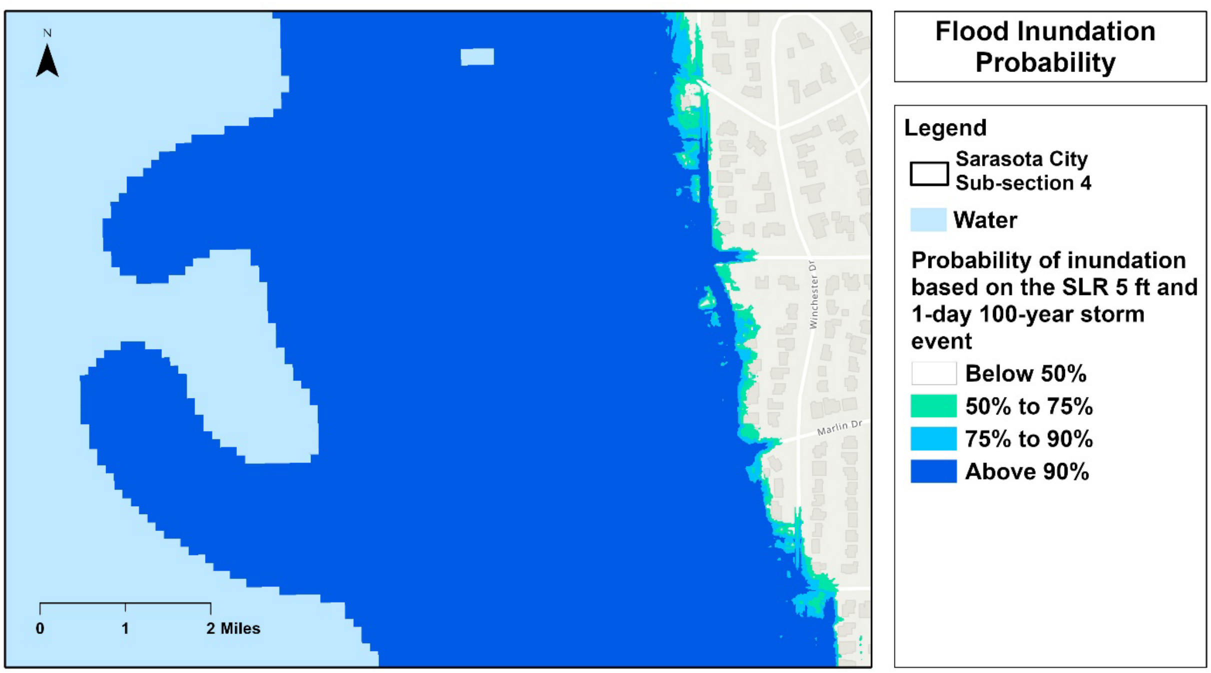


Figure 98. Drilldown of Sapphire Shores Park area, based on the 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 99. Aerial view of subsection south of Sapphire Shores Park

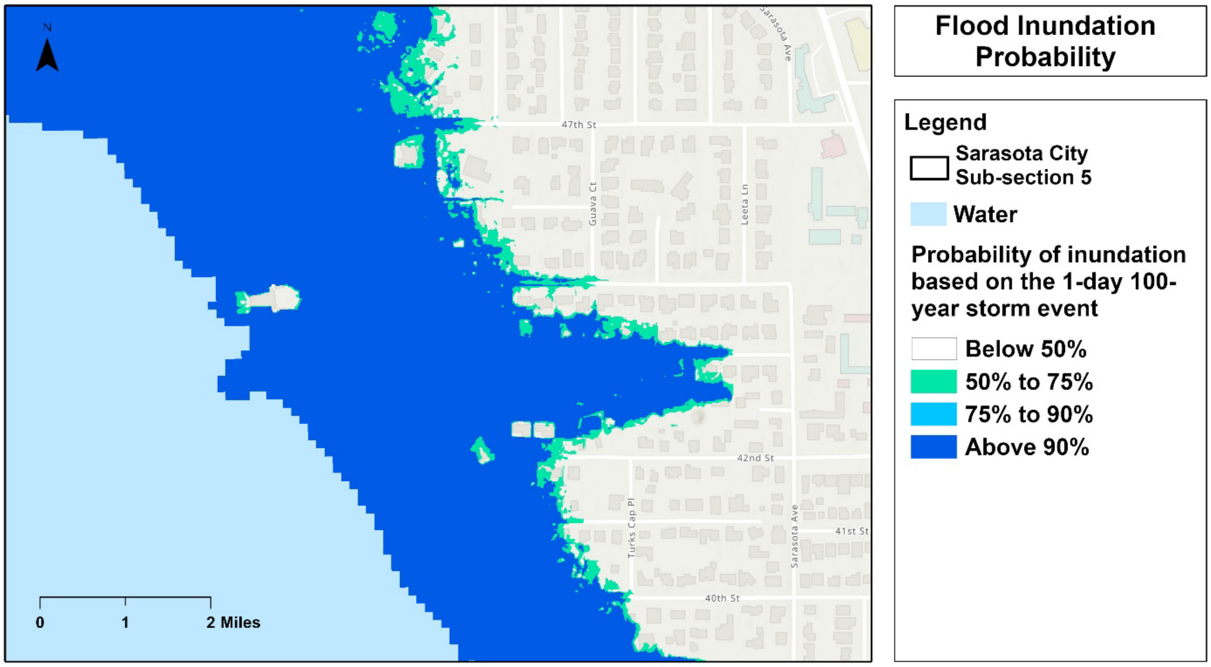


Figure 100. Drilldown south of Sapphire Shores Park, based on 1-day 100-year rainfall event, as generated by FAU CWR3

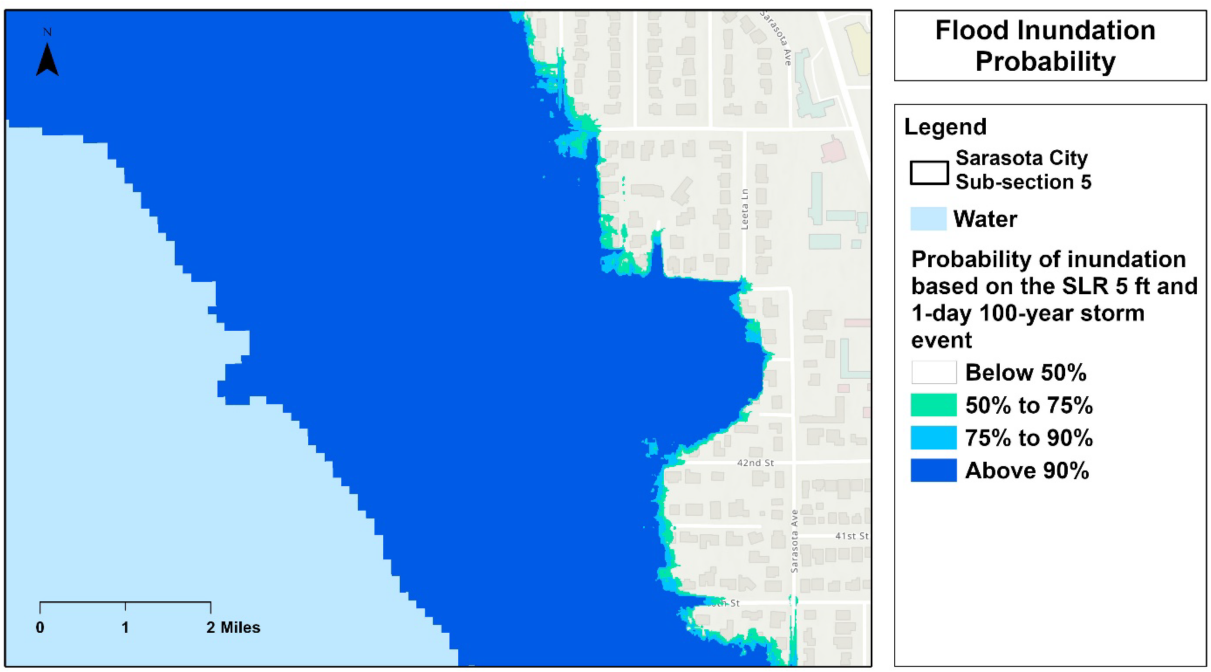


Figure 101. Drilldown south of Sapphire Shores Park, based on the 5-SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 102. Aerial view of Sarasota Jungle Garden area

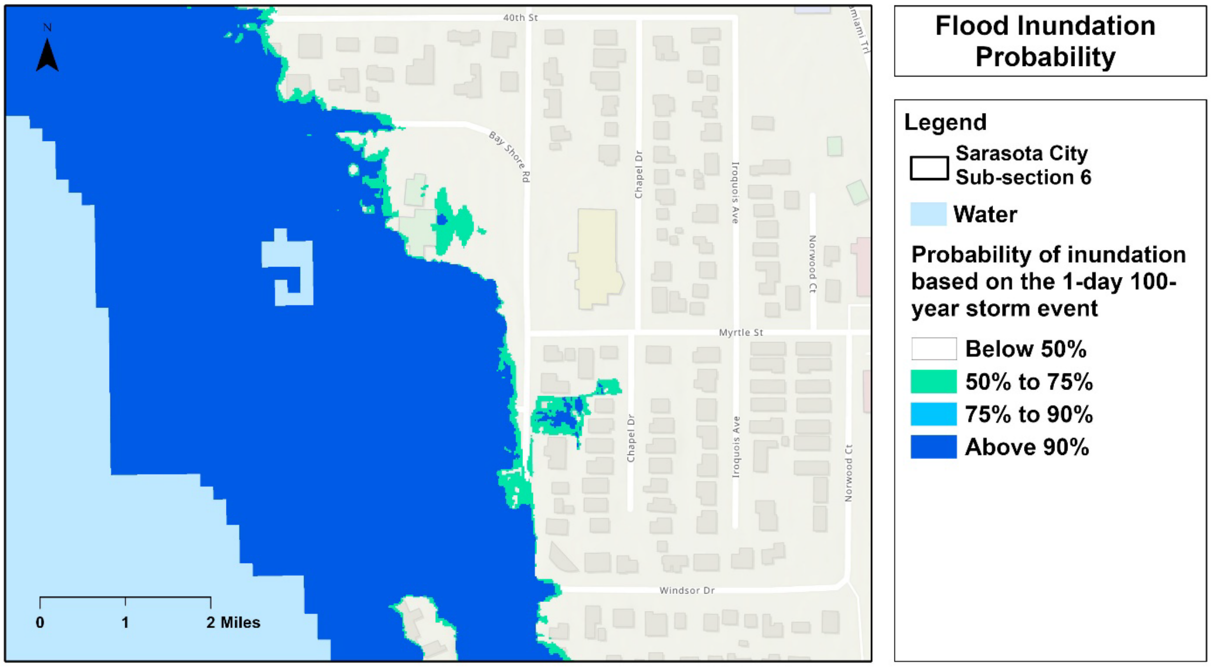


Figure 103. Drilldown of Sarasota Jungle Garden area, based on 1-day 100-year rainfall event, as generated by FAU CWR3

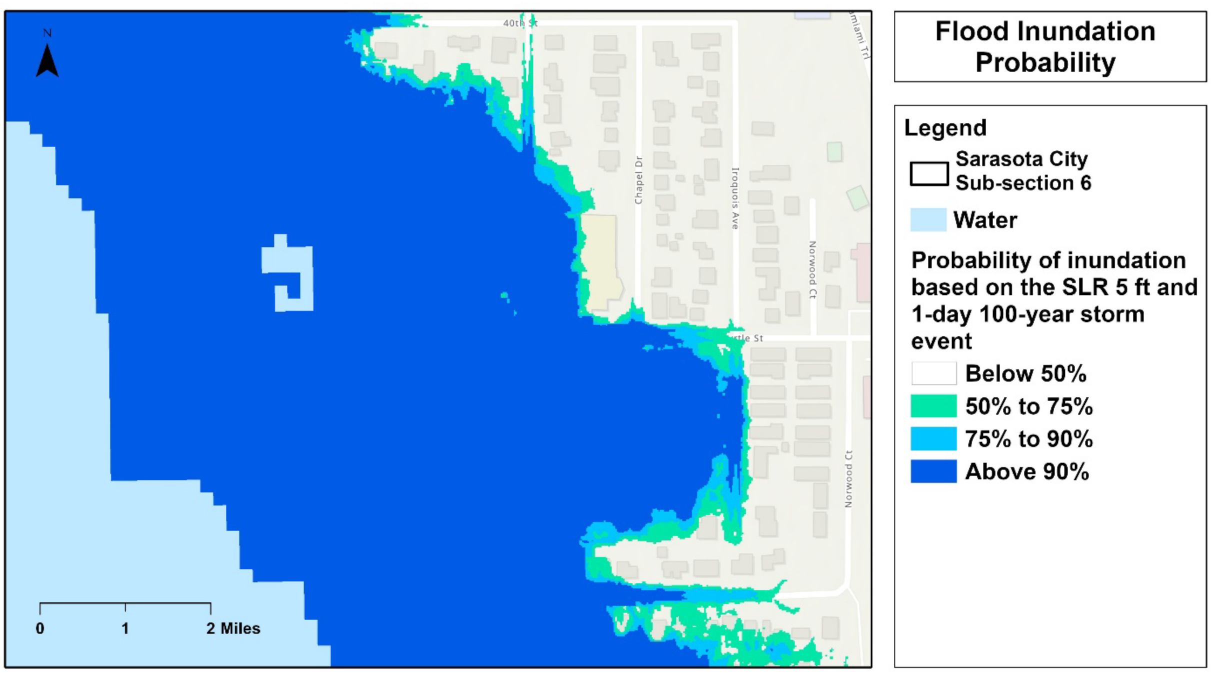


Figure 104. Drilldown to Sarasota Jungle Garden area, based on the 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

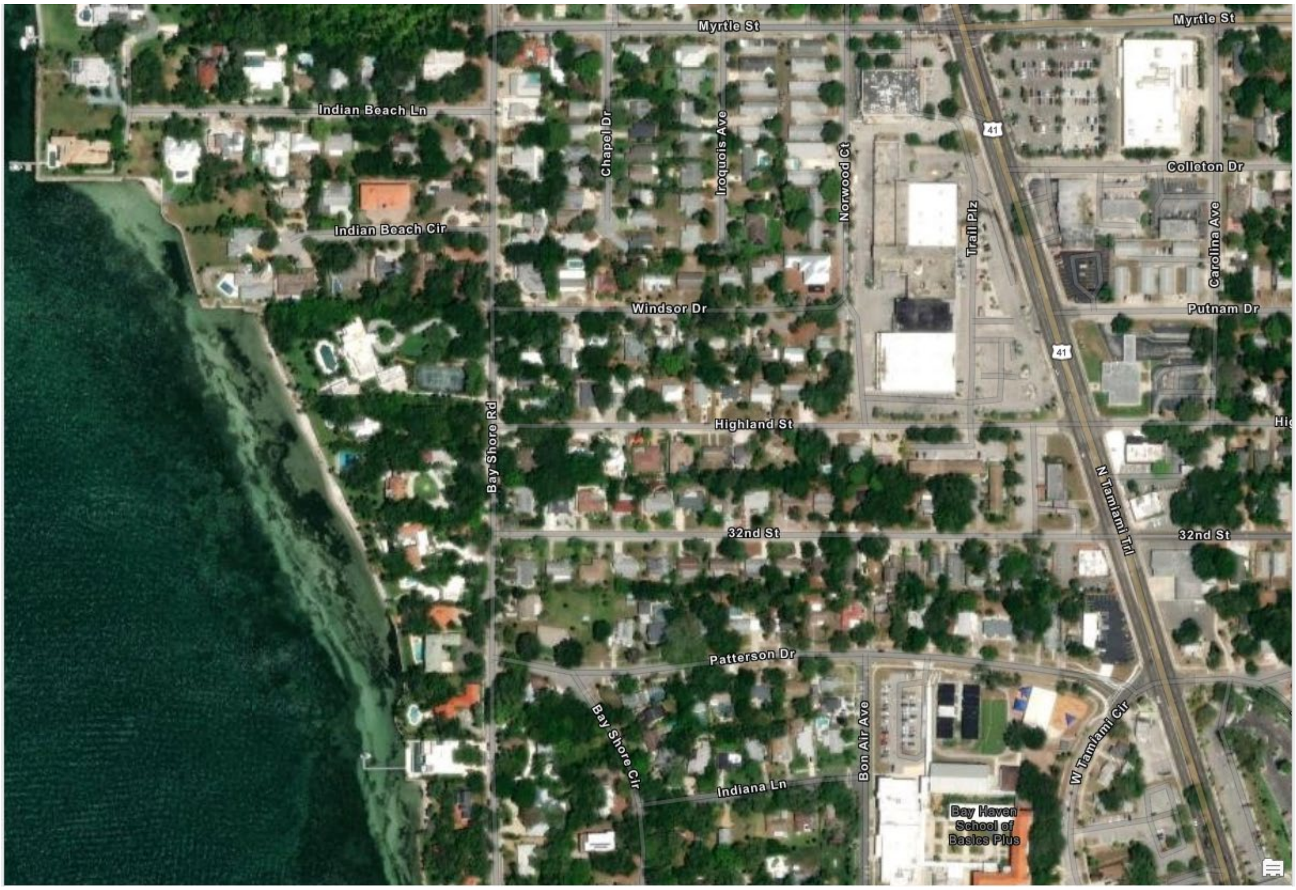


Figure 105. Aerial view of Bay Haven School area

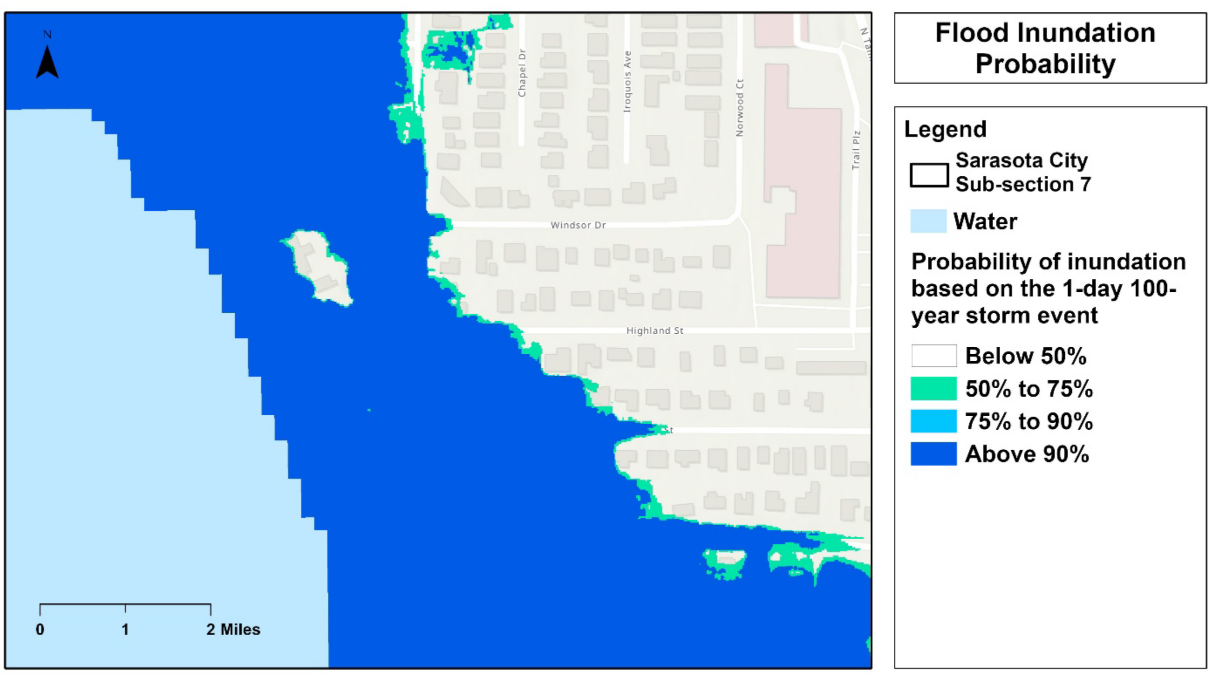


Figure 106. Drilldown of Bay Haven School area, based on 1-day 100-year rainfall event, as generated by FAU CWR3

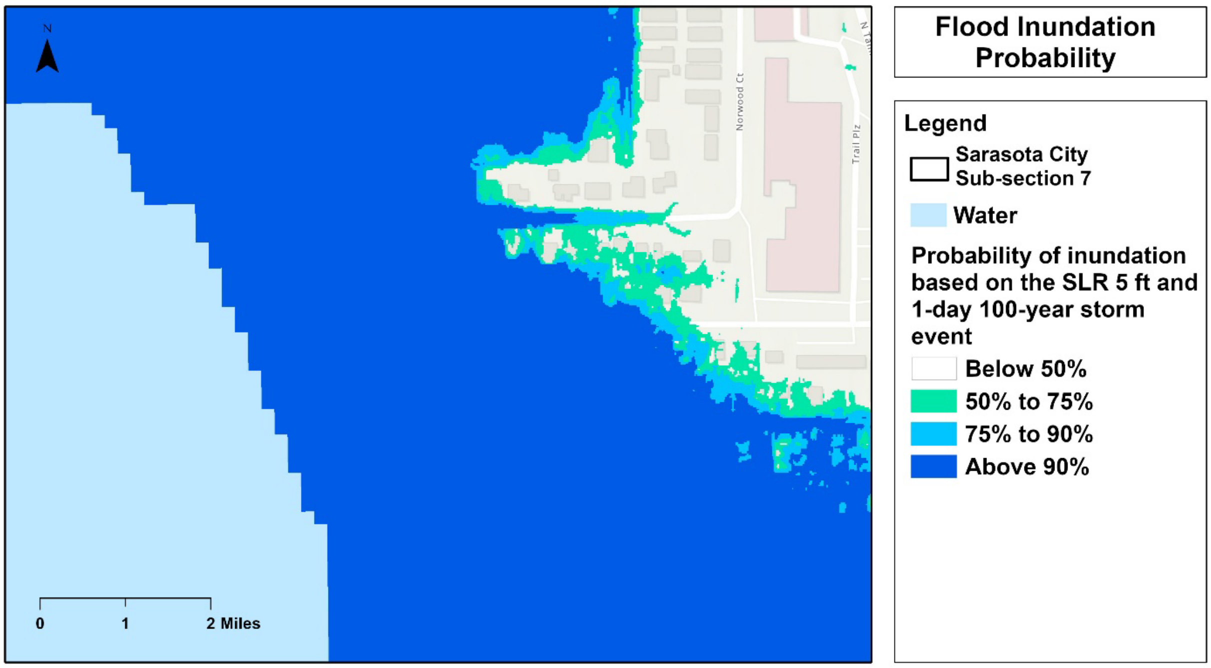


Figure 107. Drilldown of Bay Haven School area, based on the 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 108. Aerial view of Indian Beach Park area

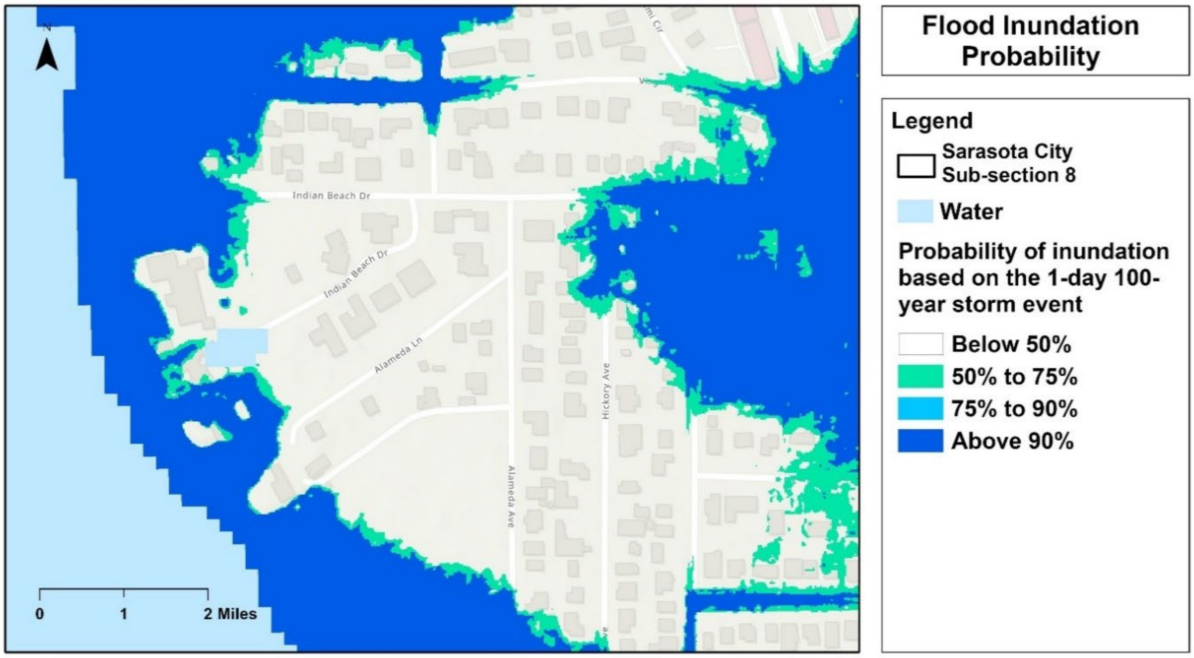


Figure 109. Drilldown of Indian Beach Park area, based on 1-day 100-year rainfall event, as generated by FAU CWR3

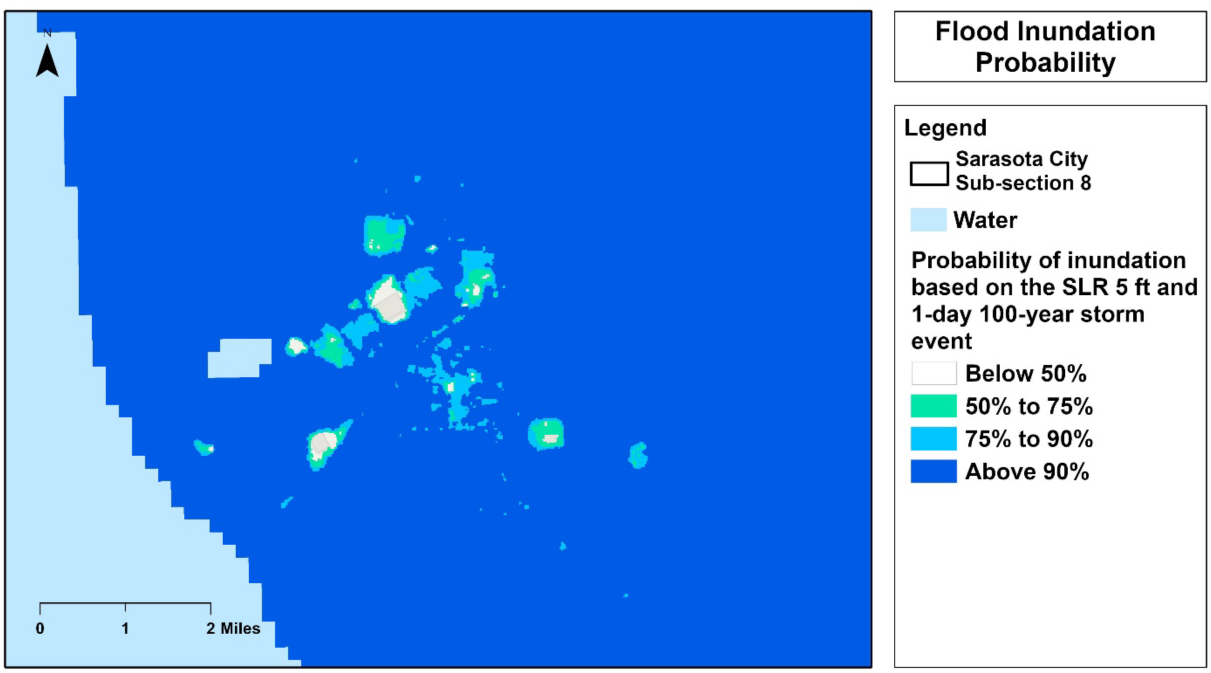


Figure 110. Drilldown of Indian Beach Park area, based on the 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 111. Aerial view of Sarasota Bay Club area

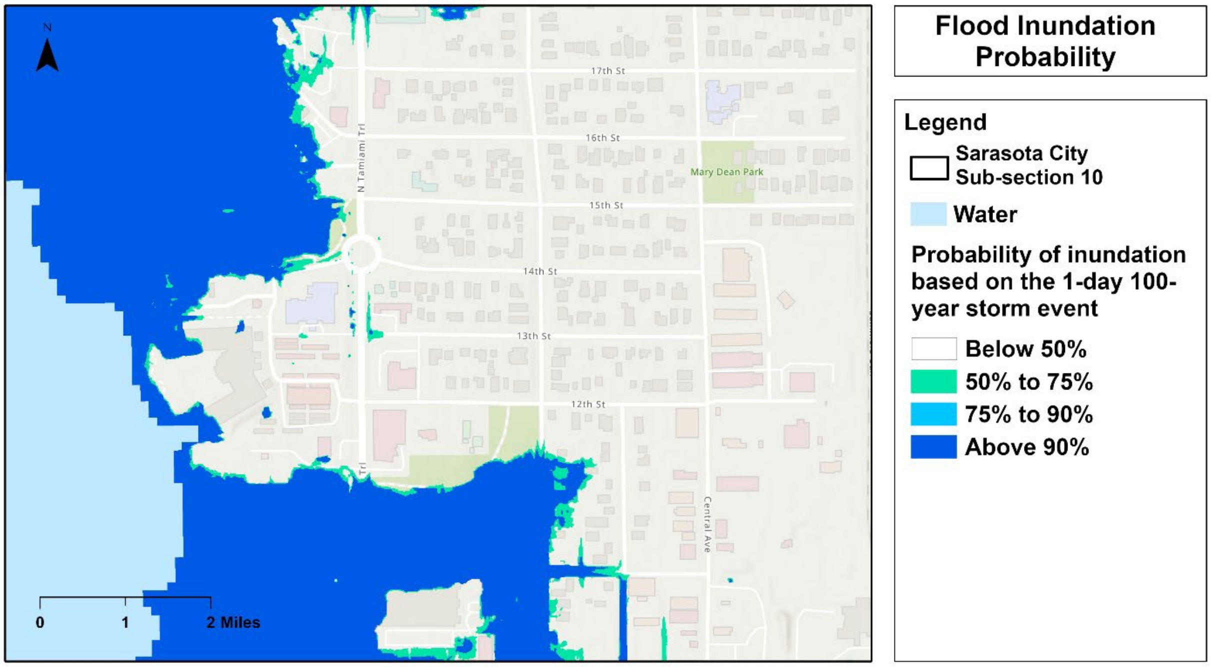


Figure 112. Drilldown of Sarasota Bay Club area, based on 1-day 100-year rainfall event, as generated by FAU CWR3

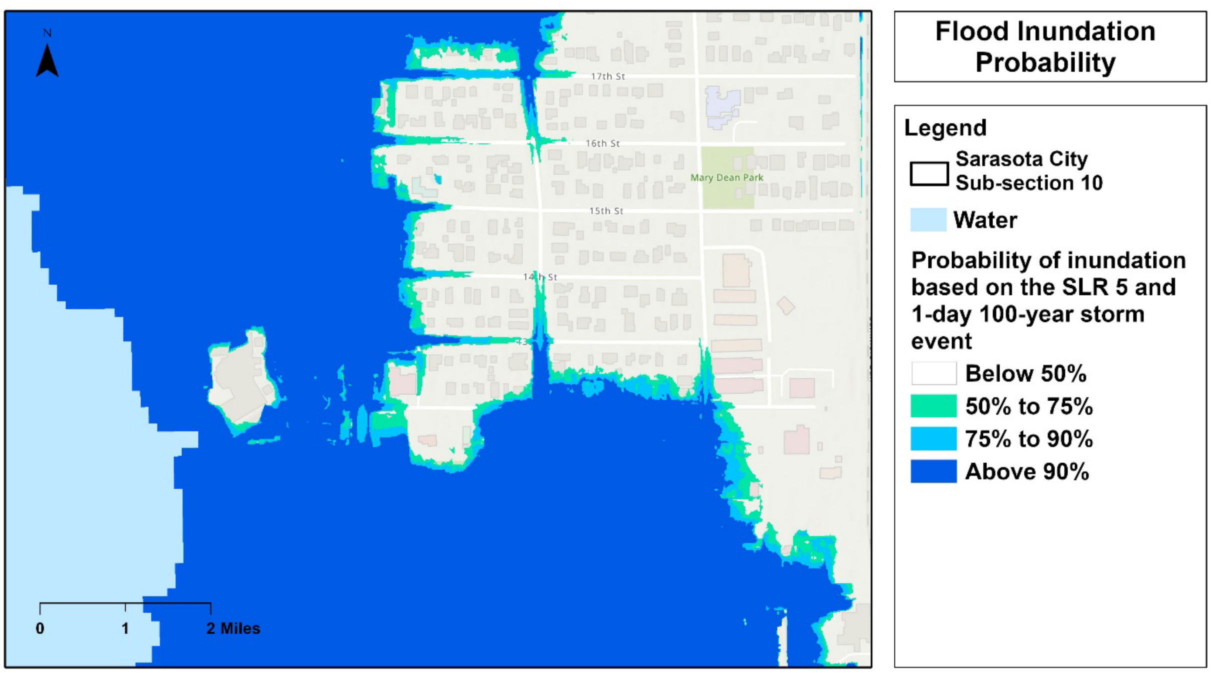


Figure 113. Drilldown of Sarasota Bay Club area, based on the 5-ft SLR and 1-day 100-year rainfall even, as generated by FAU CWR3

Figure 114 shows the downtown/marina area of the City. This is a low-lying area. At 0 ft sea level rise, flooding occurs a block or so from the bay (see Figure 115). While there are structures and elevated roadways in the area, they are not sufficient to prevent migration of water inland, nor to permit is to drain quickly. Bayfront Park is inundated. Sea walls with backflow devices installed to that coastal flooding do create roadway flooding. Note raising roads further may conflict with property flood insurance – roadway crowns must be 18" or more below finished floors. Figure 116 shows that the water is only moderately higher with 2 ft of SLR, but inland roadway flooding increases with 5 ft SLR (Figure 117).

Figure 114. Downtown/Marina in aerial image

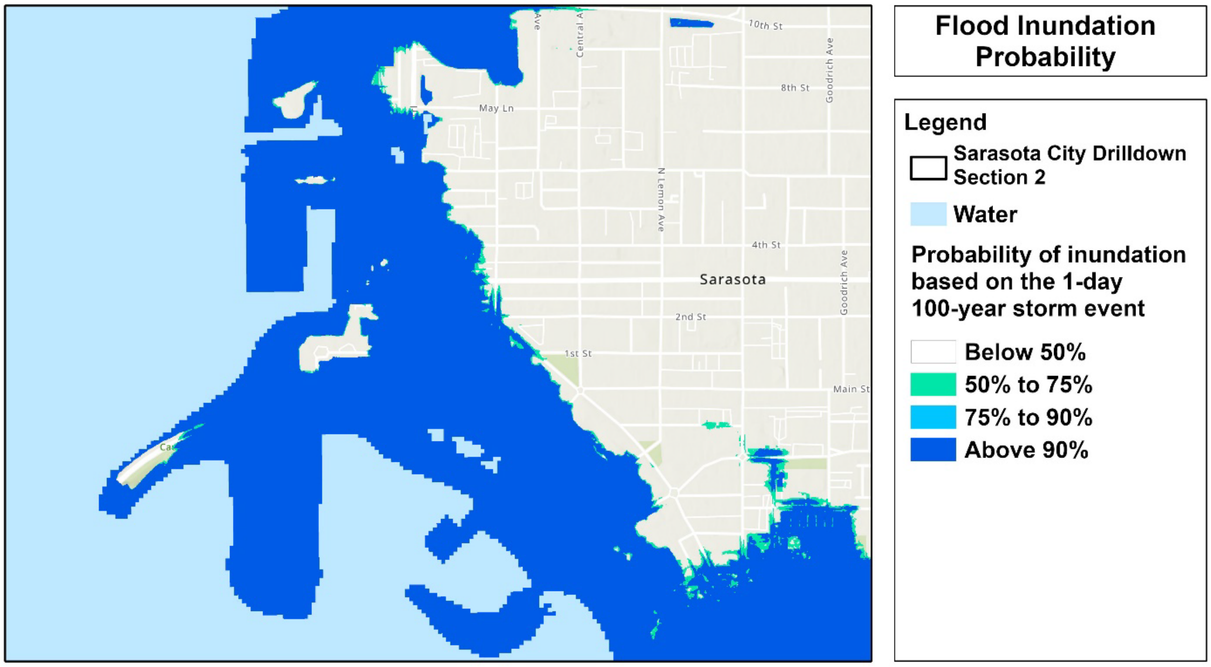


Figure 115. Drilldown S of downtown/marina, based on 1-day 100-year rainfall event, as generated by FAU CWR3

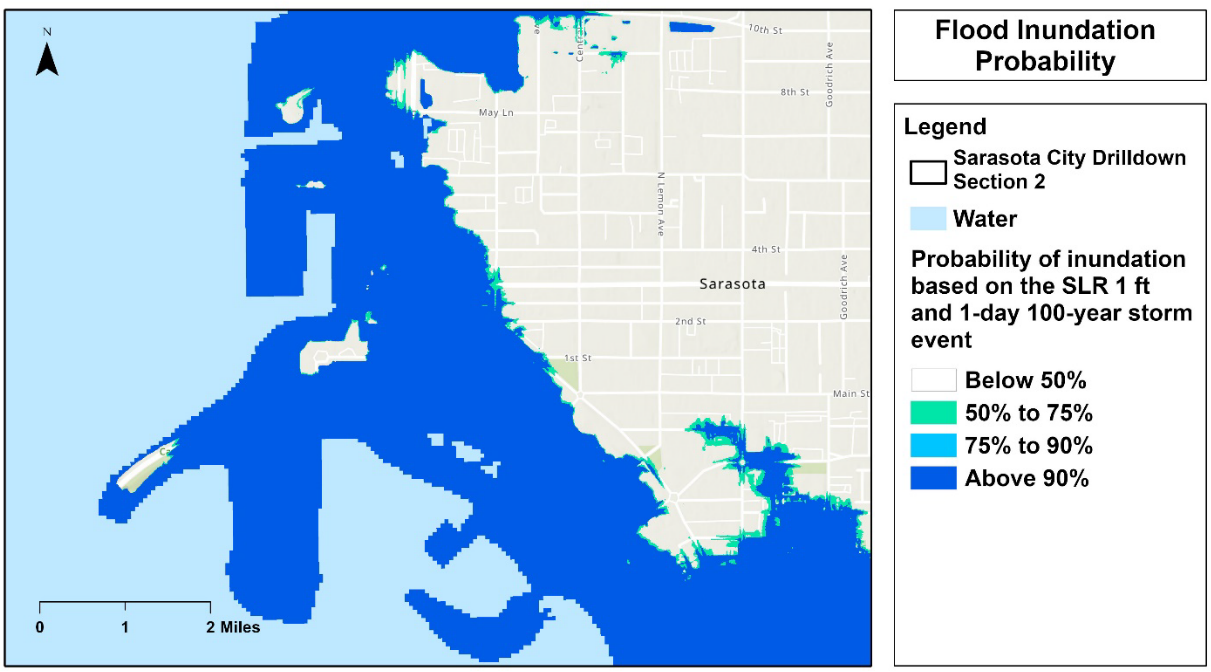


Figure 116. Drilldown of downtown/marina area, based on 1-ft SLR and 1-day 100-year 1d rainfall event, as generated by FAU CWR3

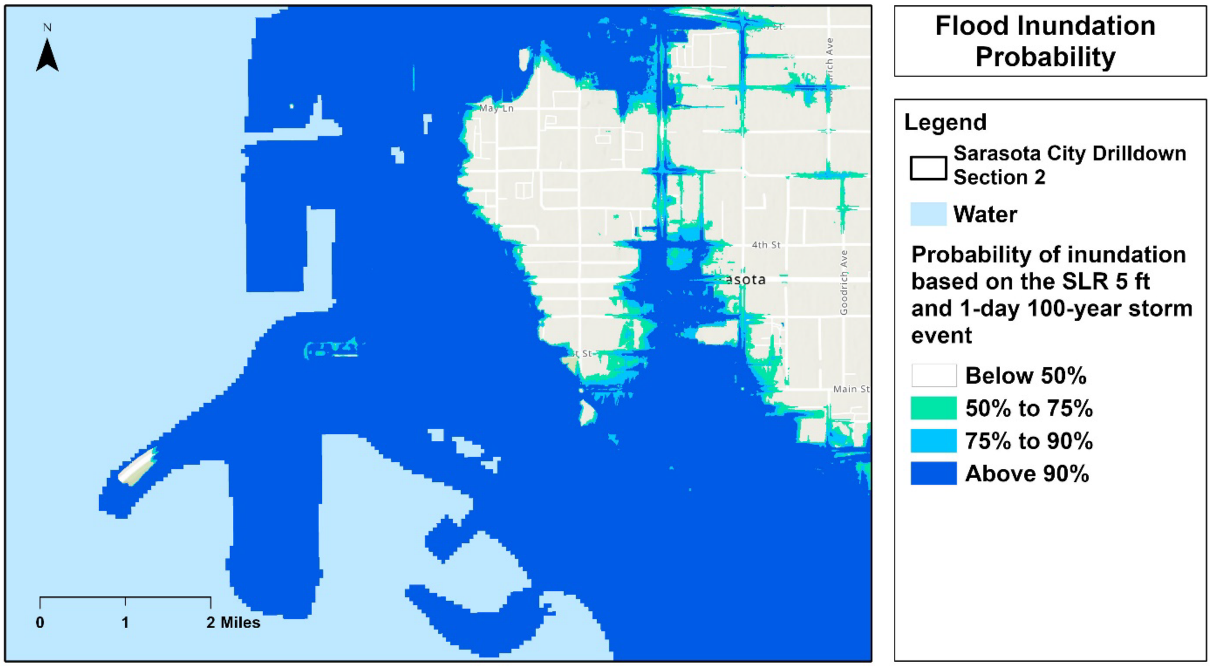


Figure 117. Drilldown of downtown/marina area, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 118 shows Bird Key. At 0 ft sea level rise and the 1-day 100-year rain event, flooding occurs virtually everywhere (see Figure 119). This is a low-lying area. Sea walls are likely not high enough, a policy issue that should be visited in time. Drains through the seawalls also need backflow devices to prevent street flooding. Note raising roads further may conflict with property flood insurance – roadway crowns must be 18” or more below finished floors. The problem persists with the 1 ft SLR (Figure 120) and 5 ft SLR (Figure 121). A drilldown to the island shows flooding persists (Figure 122).

Figure 118. Zoomed in the aerial image of Bird Key

Figure 119. Drilldown of Bird Key, based on 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 120. Drilldown of Bird Key, based on 1-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

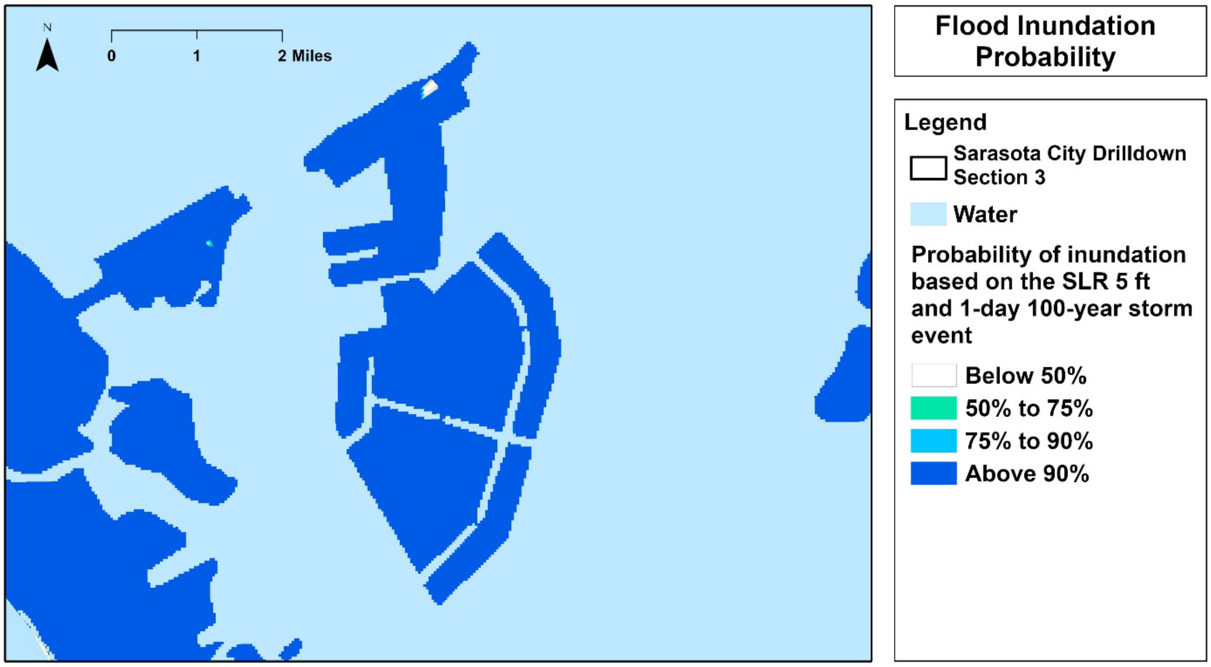


Figure 121. Drilldown of Bird Key, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

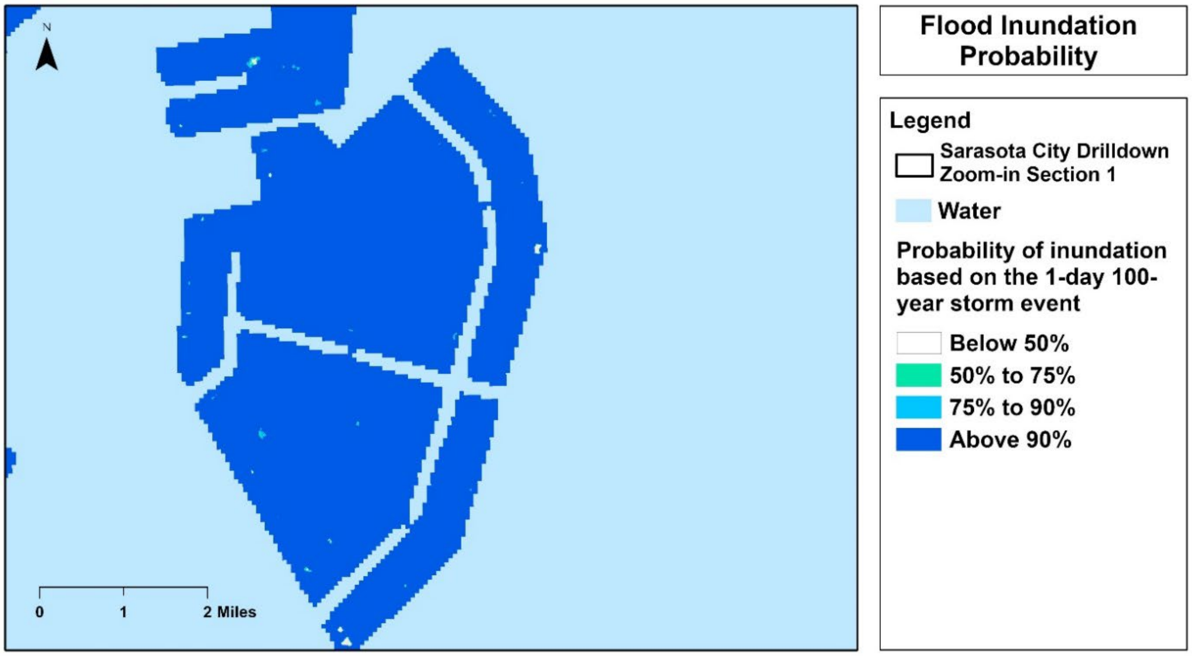


Figure 122. Zoomed in image of Bird Key, based on 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 123 shows Lido Beach. At 0-ft sea level rise and the 1-day 100-year rain event, the beach dunes are exposed and the mangroves are submerged. Flooding occurs virtually everywhere else (see Figure 124). Sea walls are likely not high enough, a poli cy issue that should be visited in time. Drains through the seawalls also need backflow devices to prevent street flooding. Note raising roads further may conflict with property flood insurance – roadway crowns must be 18" or more below finished floors. The problem persists with the 1-ft SLR (Figure 125) and 5-ft SLR (Figure 126). Drilling further into the central island shows more flooding (Figure 127).

Figure 123. Zoomed-in aerial image of Lido Beach

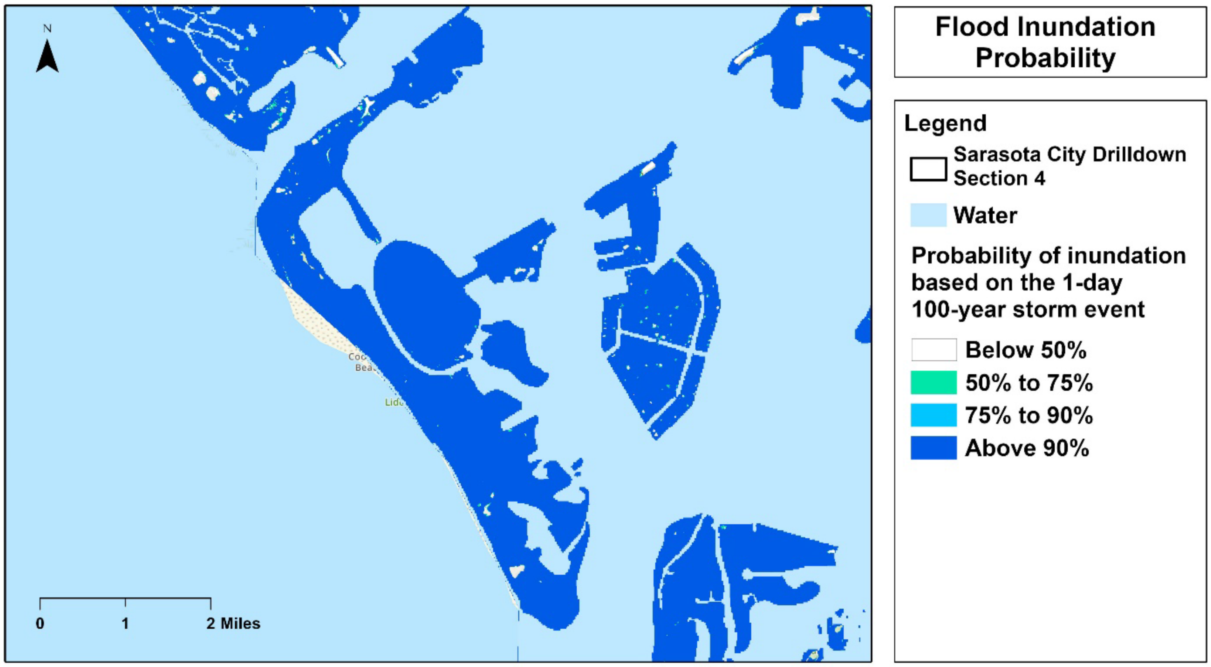


Figure 124. Drilldown to Lido Beach based on 1-day 100-year rainfall event, as generated by FAU CWR3

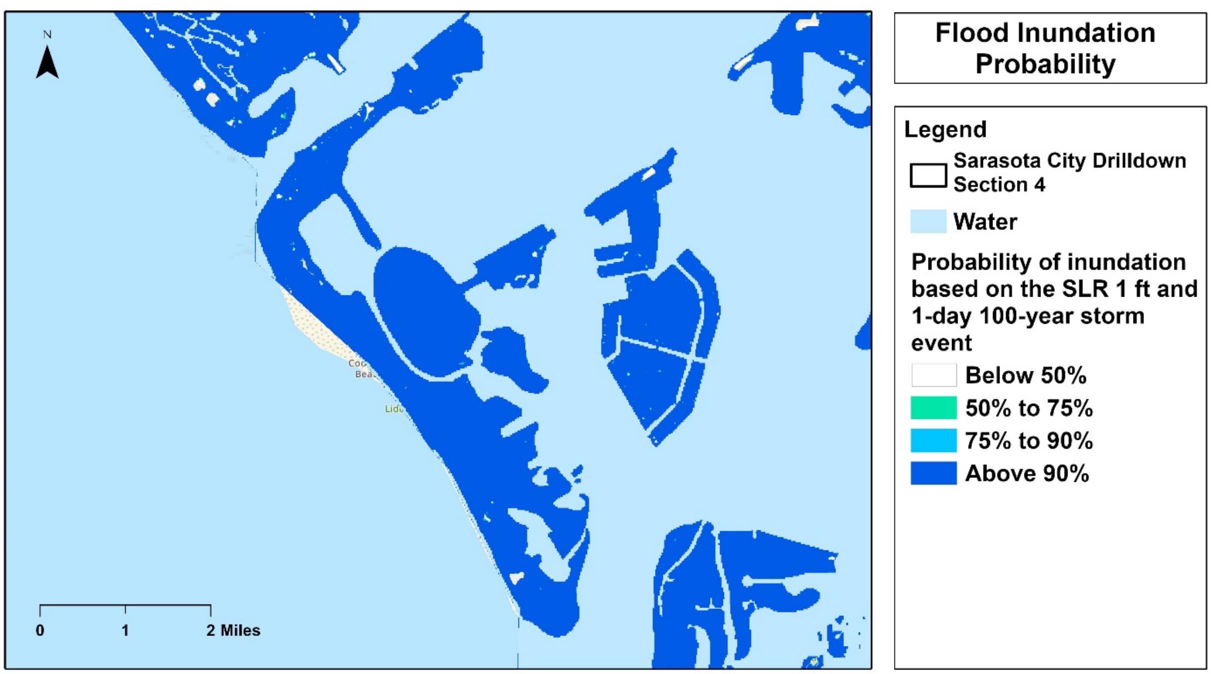


Figure 125. Drilldown Section of Lido Beach, based on 1-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

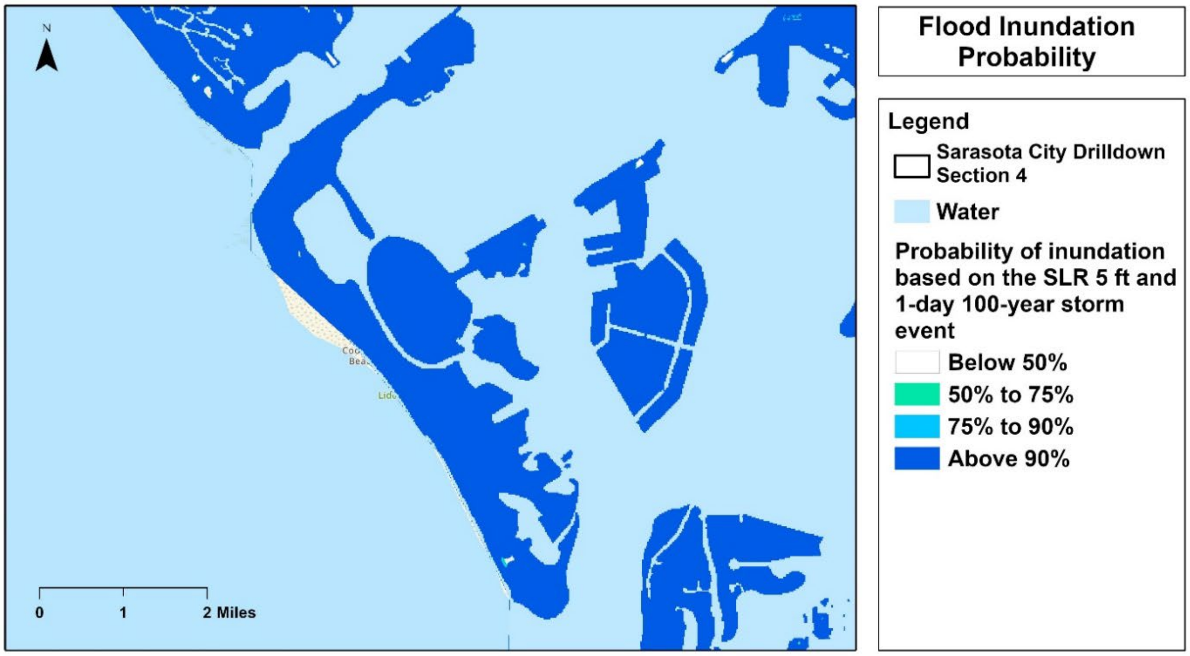


Figure 126. Drilldown of Lido Beach, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 127. Zoomed in image of Lido Beach, based on 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 128 shows the facilities in the tiers from based on land use from the Sarasota County Property Appraiser's office for the Philippi Creek area that is adjacent to the City. Figure 129 shows the aerial of the same area. At 0 ft sea level rise, the creek floods the low-lying areas adjacent to it (see Figure 130). Street flood first along with property close the water. Sea walls are needed, or need to be raised to address coastal flooding and any drains need to have backflow devices installed to that coastal flooding does to create roadway flooding. Note raising roads will conflict with property flood insurance – roadway crowns must be 18" or more below finished floors. Hence Sea wall elevations, a regulatory requirement, should be implemented in the long term. The water also migrates up Philippi Creek. With 5 feet of sea level rise, Figure 131 shows that the water migrates significantly up Philippi Creek.

Figure 132 shows the northern extension of the creek in an aerial view, plus the 1-day 100-year storm event with 0 and 5 ft of sea level rise (Figure 133 and Figure 134). Flooding is extensive. Given the lack of use for seawalls, pumping, and other barriers are suggested.

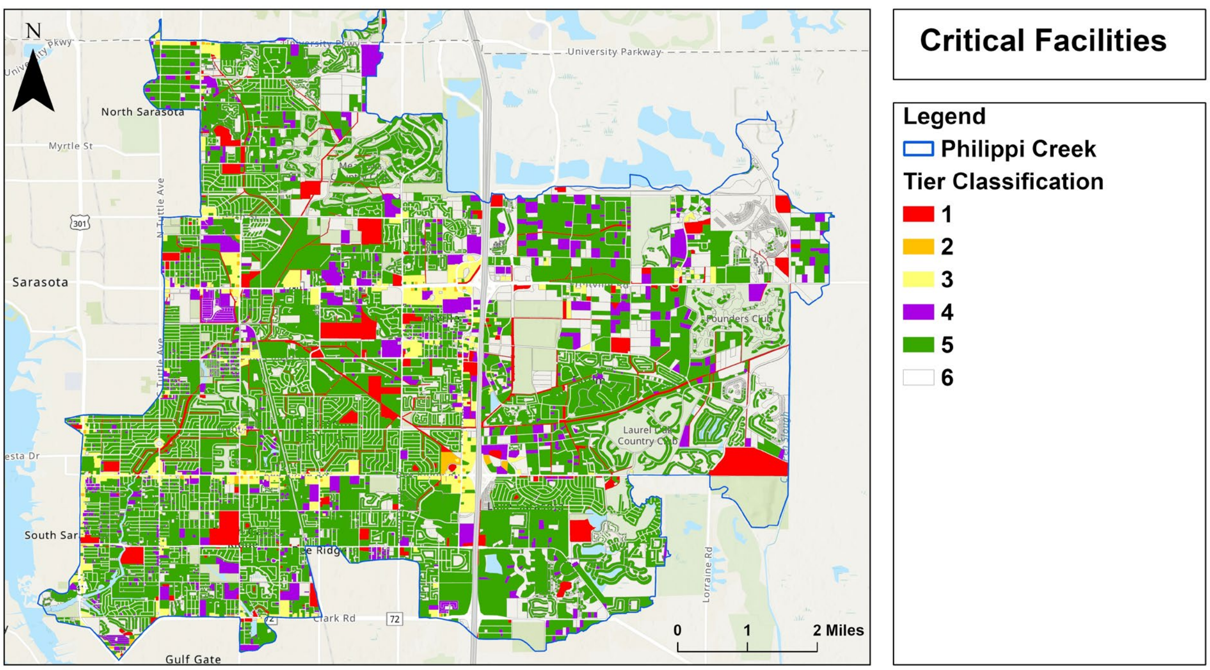


Figure 128. Critical Facilities in Philippi Creek Area, as generated by FAU CWR3

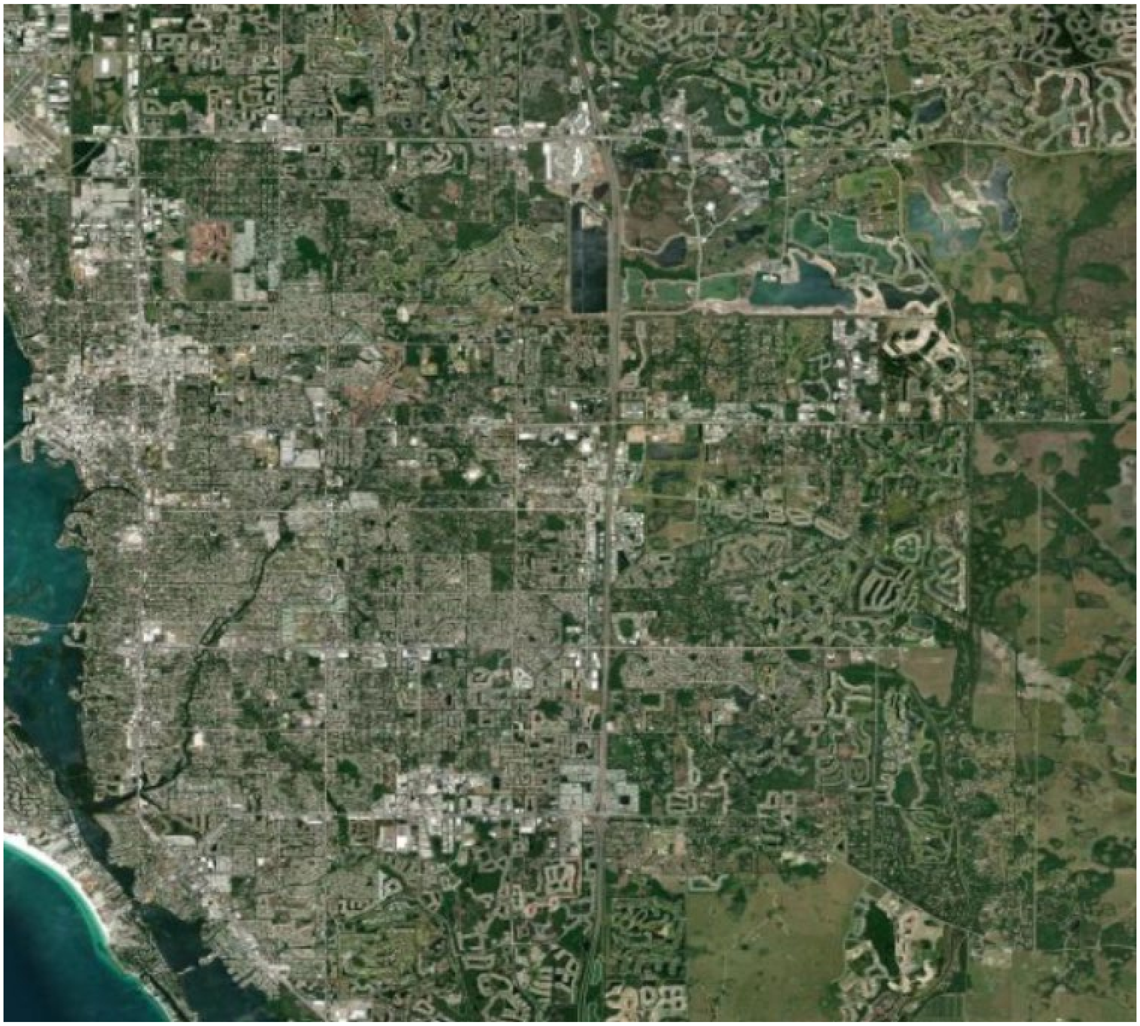


Figure 129. Aerial image for the Philippi Creek Area

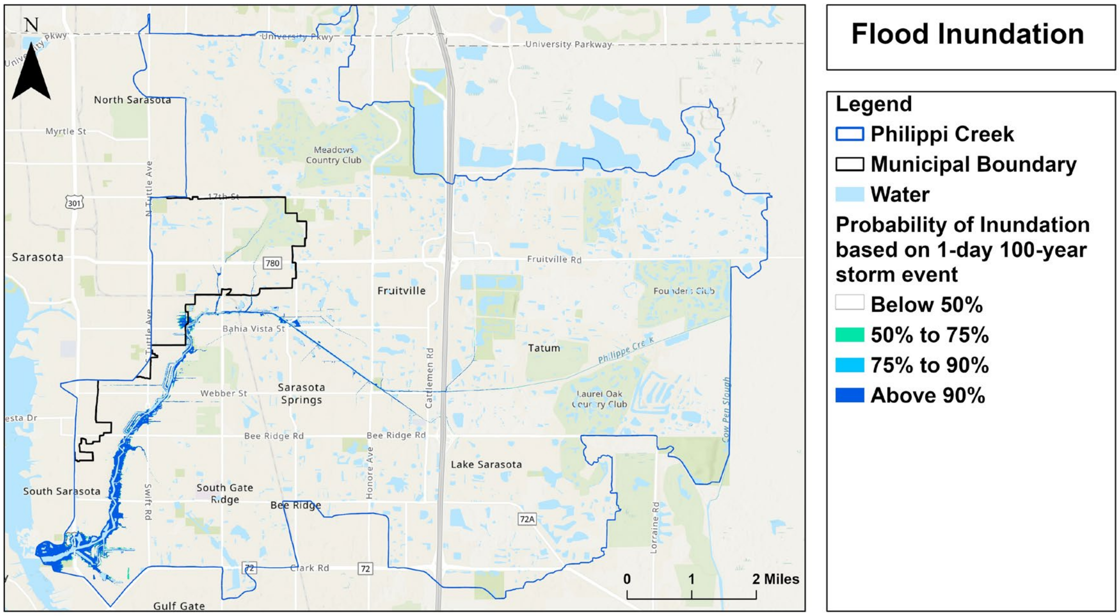


Figure 130. Philippi Creek Area zoomed in, based on 1-day 100-year rainfall event, as generated by FAU CWR3

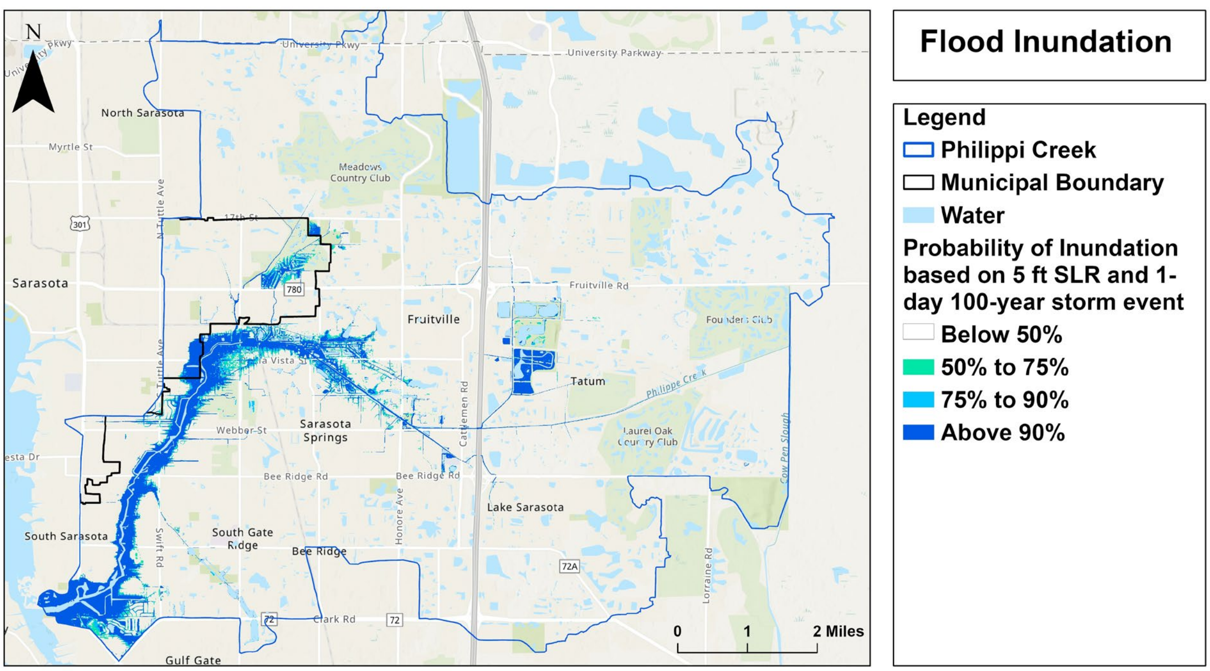


Figure 131. Philippi Creek Area zoomed in, based on 1-day 100-year rainfall event with 5 ft of sea level rise, as generated by FAU CWR3

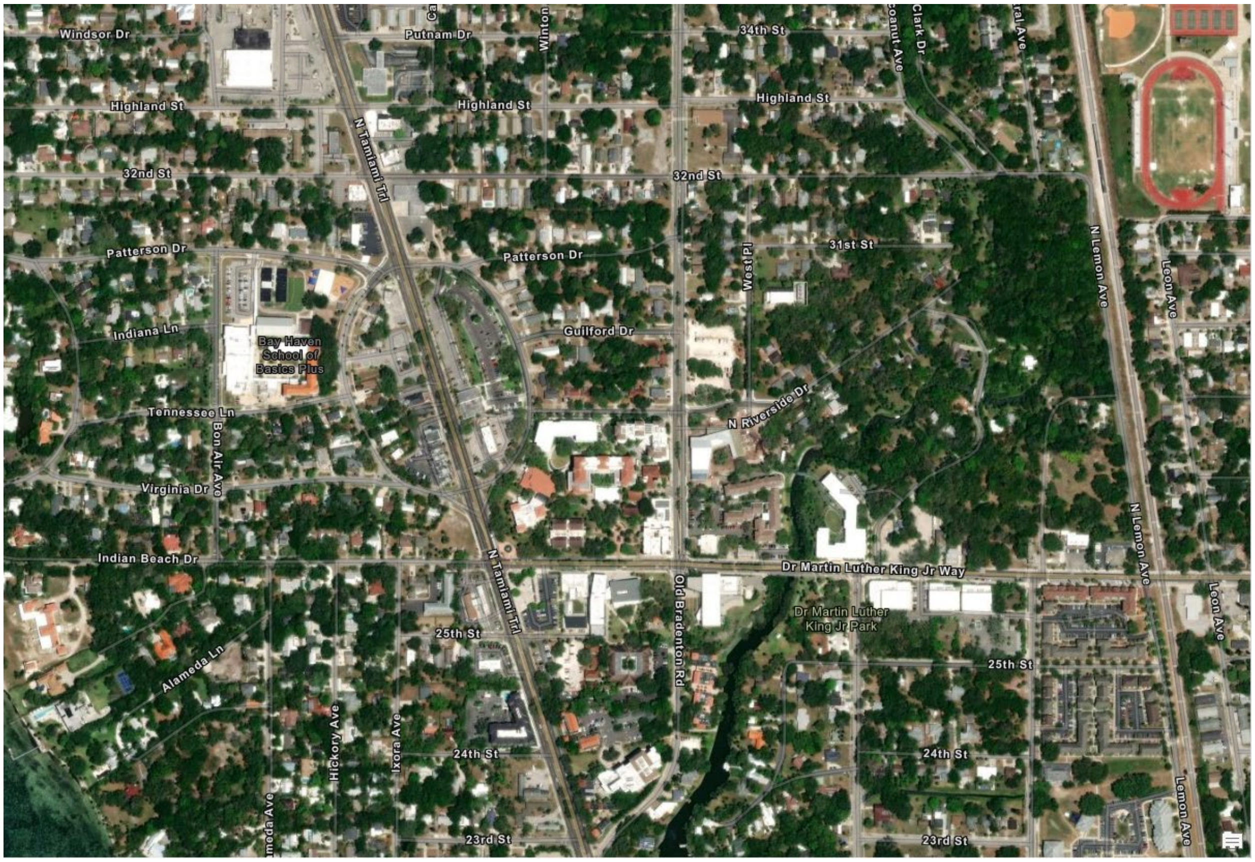


Figure 132. Zoomed image of upper Whitaker Bayou area,

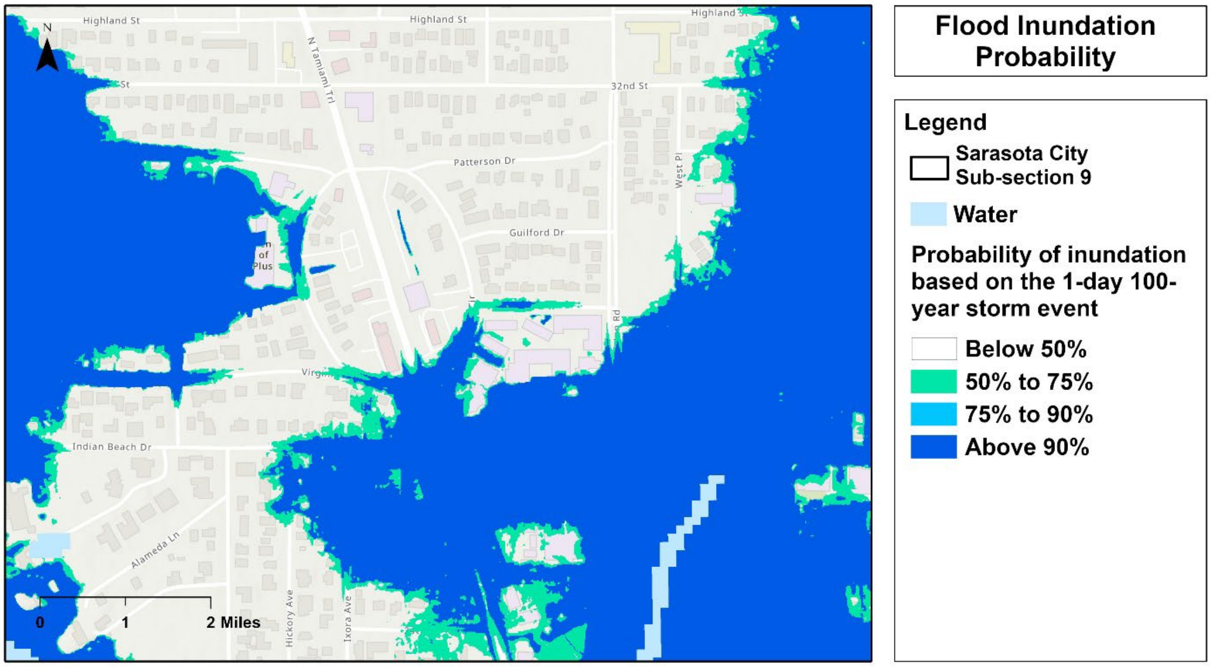


Figure 133. Drilldown of upper Whitaker Bayou area, based on 1-day 100-year rainfall event, as generated by FAU CWR3

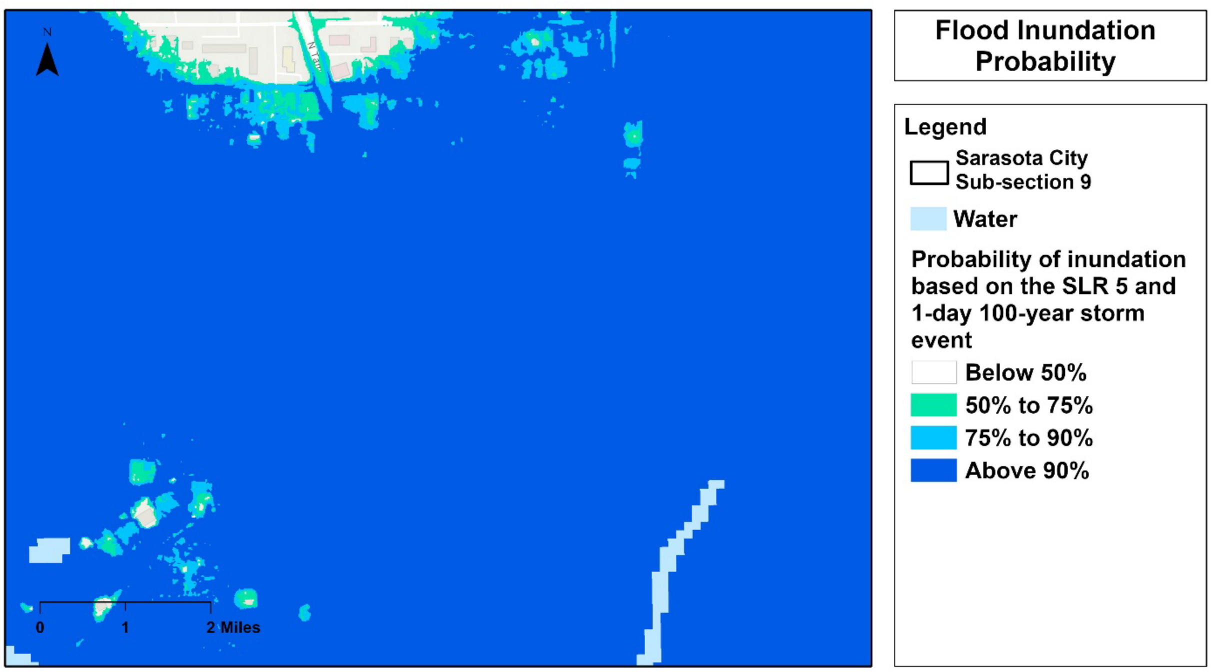


Figure 134. Drill down of upper Whitaker Bayou area,, based on the SLR5 and 100y 1d rainfall event, as generated by FAU CWR3

Nearby there is some flood potential in the vicinity of 19th St and N. Orange Avenue. The aerial is shown in Figure 135. Nuisance flooding occurs with the 1-day 100-year storm (Figure 136), but migration of flooding eastward from US41 occurs with the 5 ft sea level rise scenario and the 1-day 100-year storm event (Figure 137). Downstream efforts to reduce flooding and pumping locally should resolve this issue.

Figure 135. Aerial view of 19th and N. Orange Avenue

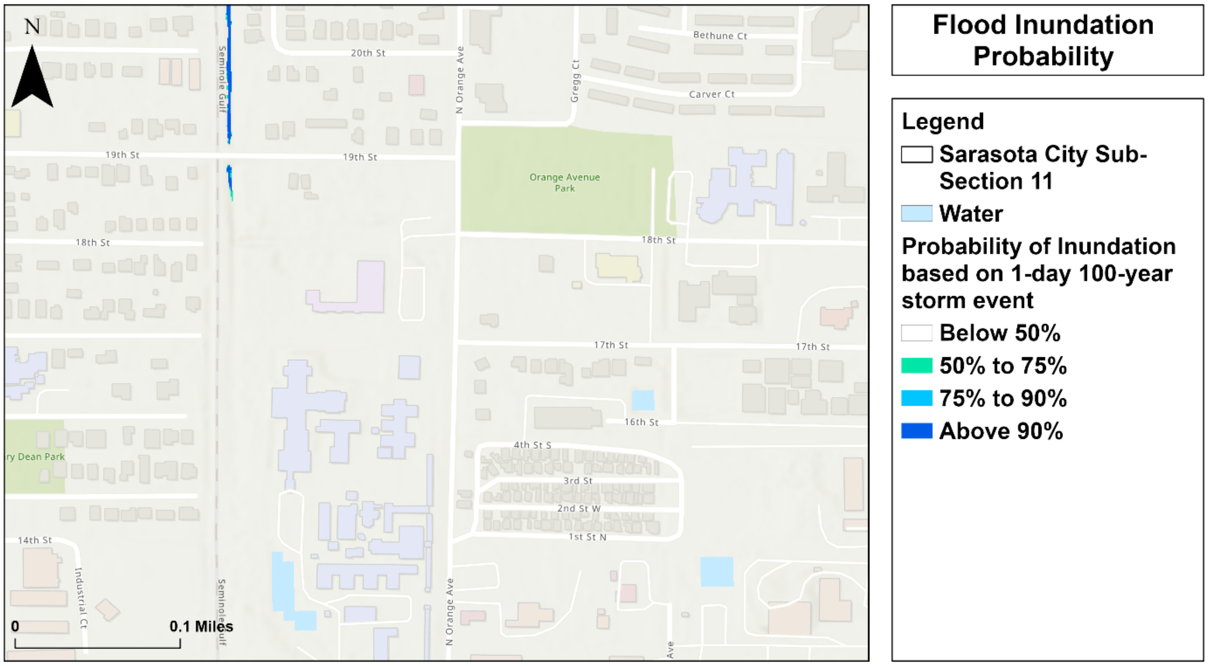


Figure 136. Drilldown of 19th and N. Orange Avenue, based on 1-day 100-year rainfall event – minor nuisance flooding, as generated by FAU CWR3

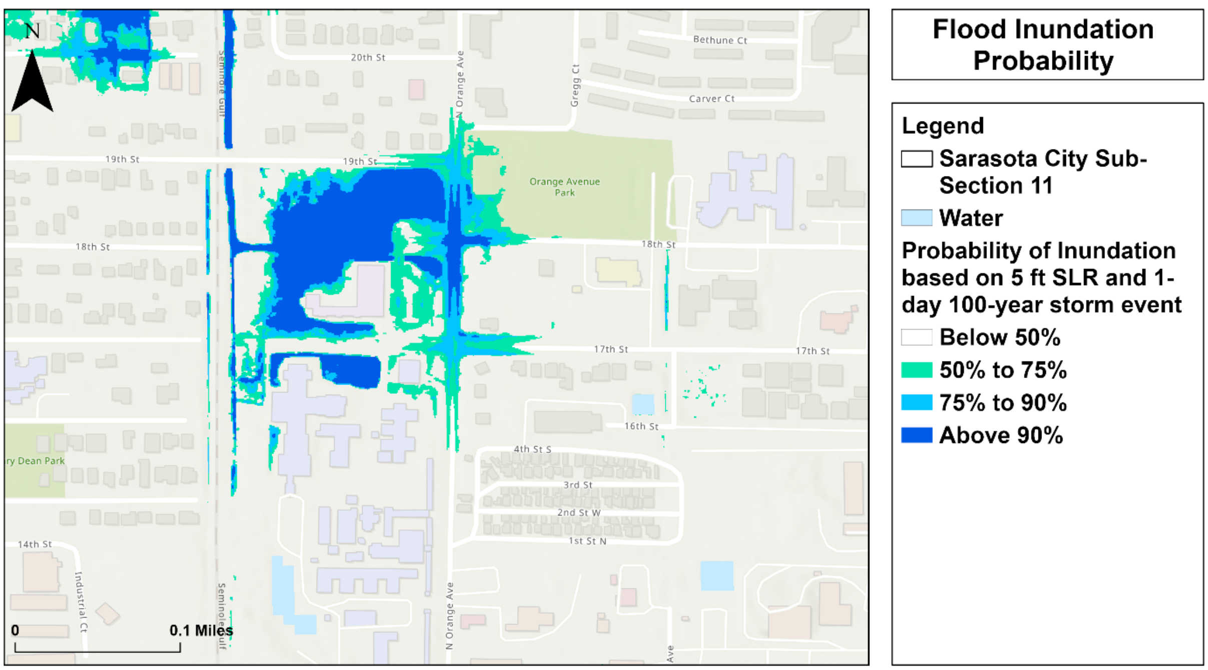


Figure 137. Drilldown of 19th and N. Orange Avenue, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

The final area to model was Whitaker Bayou which enters the bay north of downtown and extends northward nearly to the airport. Figure 138 shows an aerial of the area. Figure 139 shows the critical facilities. Figure 140 shows flooding with the 1-day 100-year storm and Figure 141 shows the same area with the 1 day 100 year storm and 5 feet of sea level rise. Figure 142 to Figure 144 show drilldowns in the basin. The areas near the water flood with the 1-day 100-year storm consistently near the water, but the 5 feet of sea level rise make the flooded area much larger. A means to pump water out of the basin needs further investigation even if the bayou is no longer navigable.

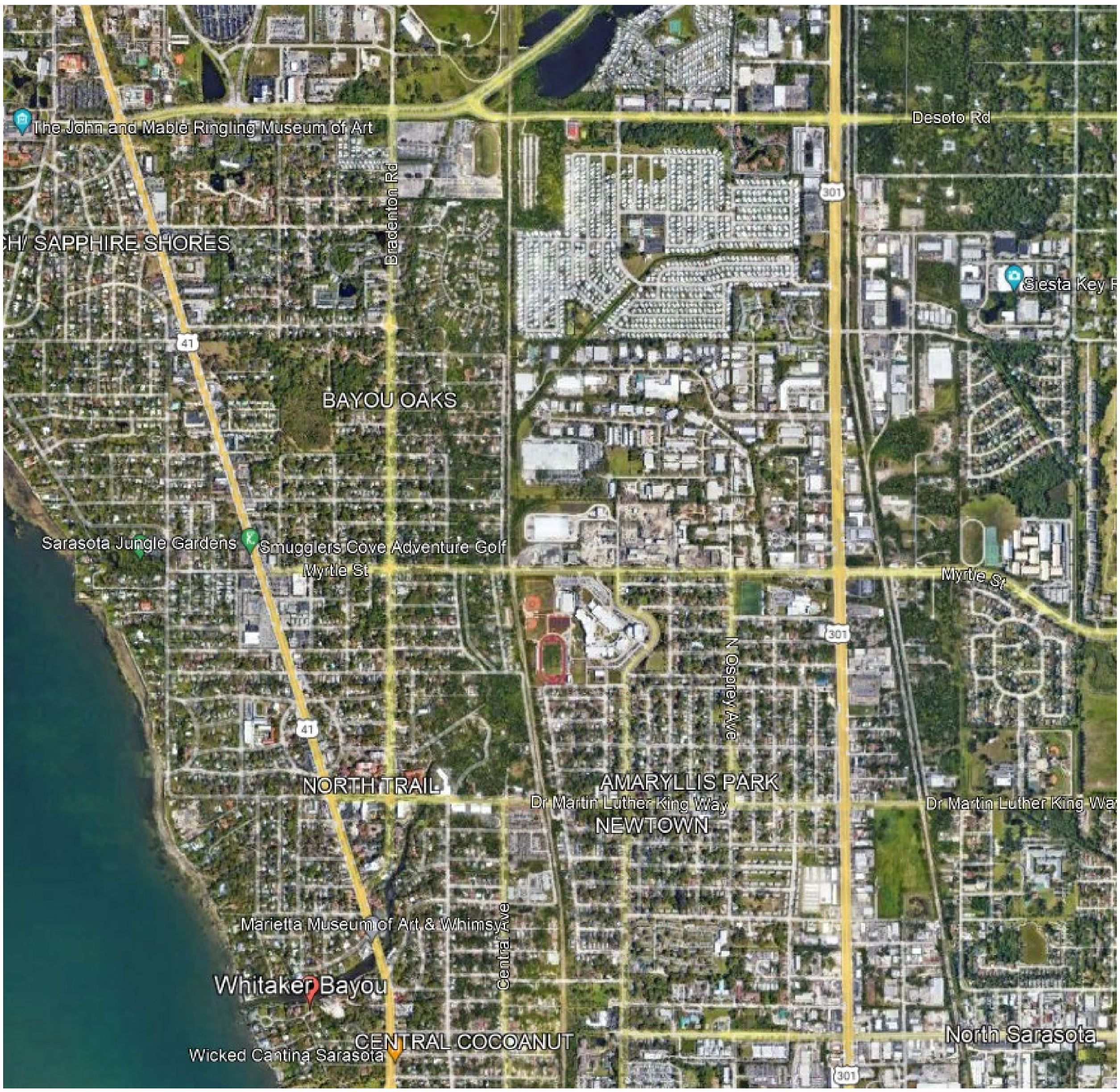


Figure 138. Whitaker Bayou area north of downtown

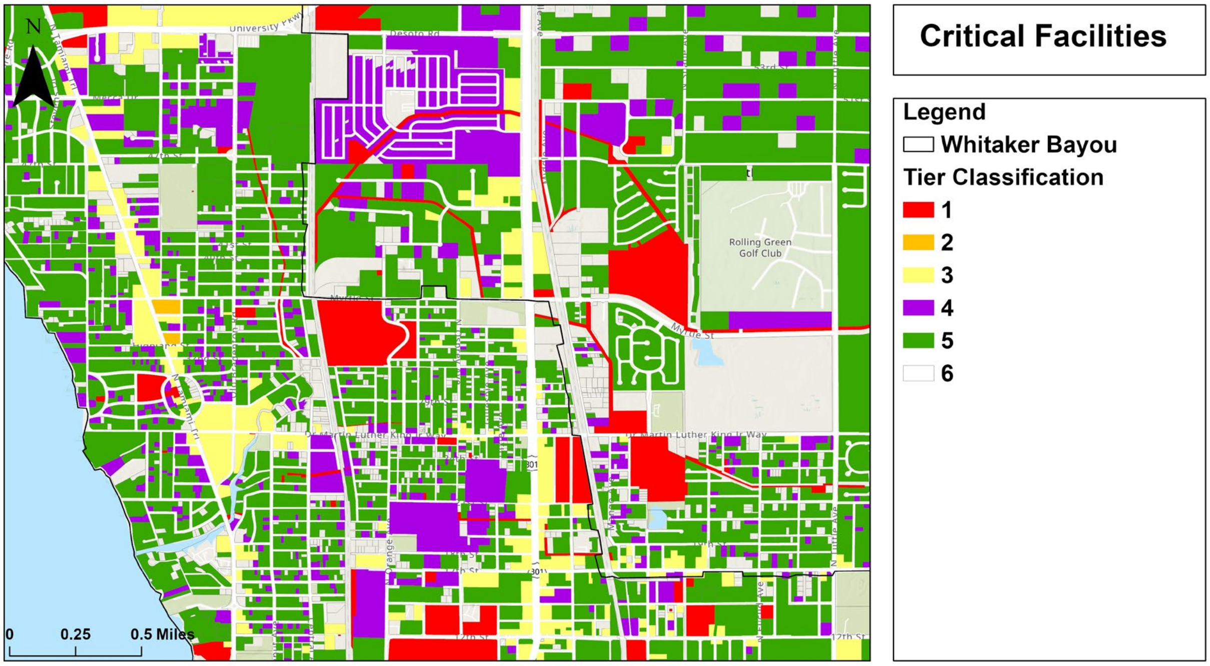


Figure 139. Critical facilities in the Whitaker Bayou area north of downtown, as generated by FAU CWR3

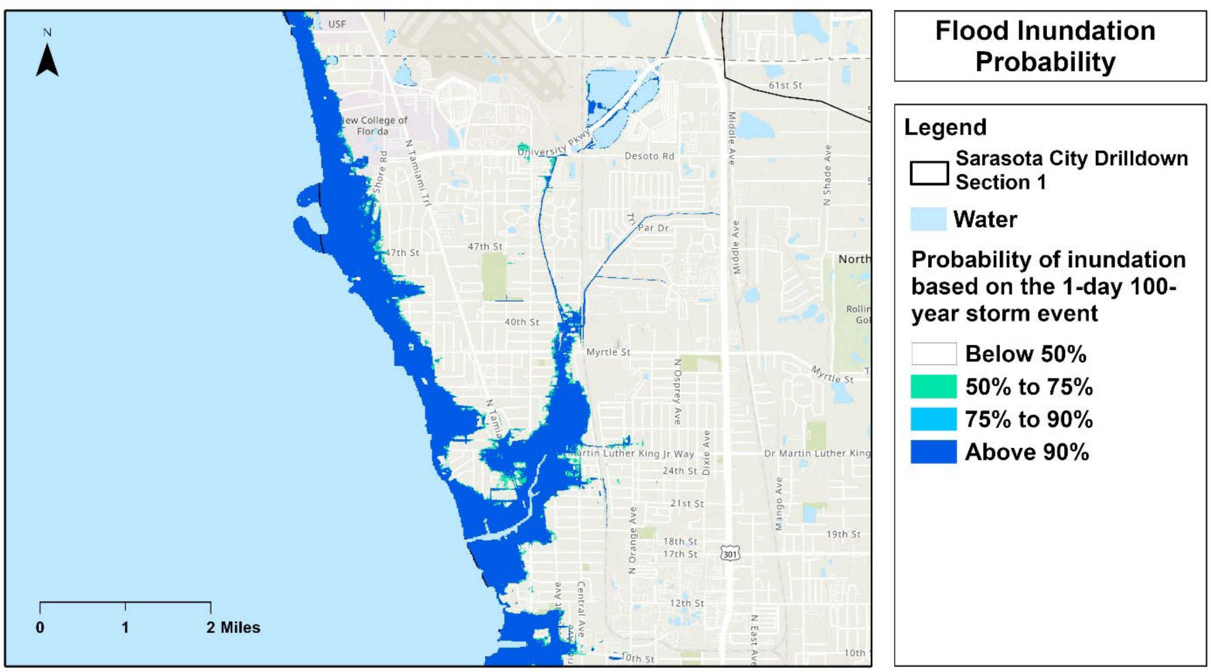


Figure 140. Whitaker Bayou basin with based on 1-day 100-year rainfall event, as generated by FAU CWR3

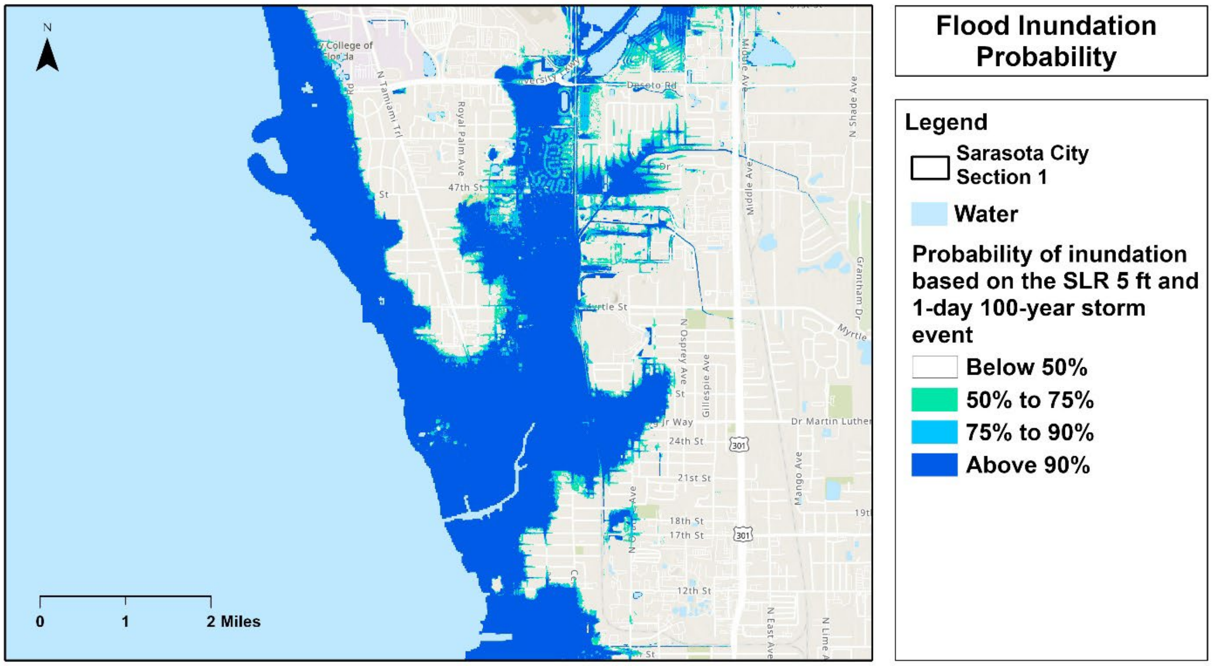


Figure 141. Whitaker Bayou basin with based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 142. Aerial view of Area north of Whitaker Bayou at Old Bradenton Rd

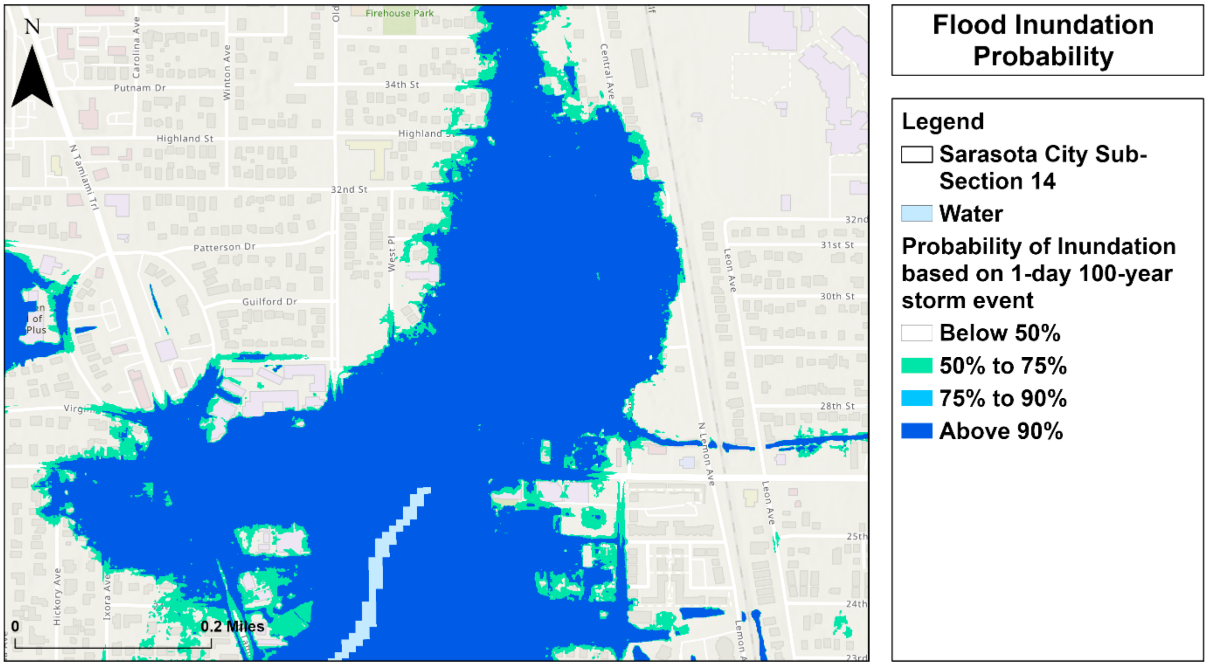


Figure 143. Drilldown of Whitaker Bayou at Old Bradenton Rd, based on 1-day 100-year rainfall even, as generated by FAU CWR3

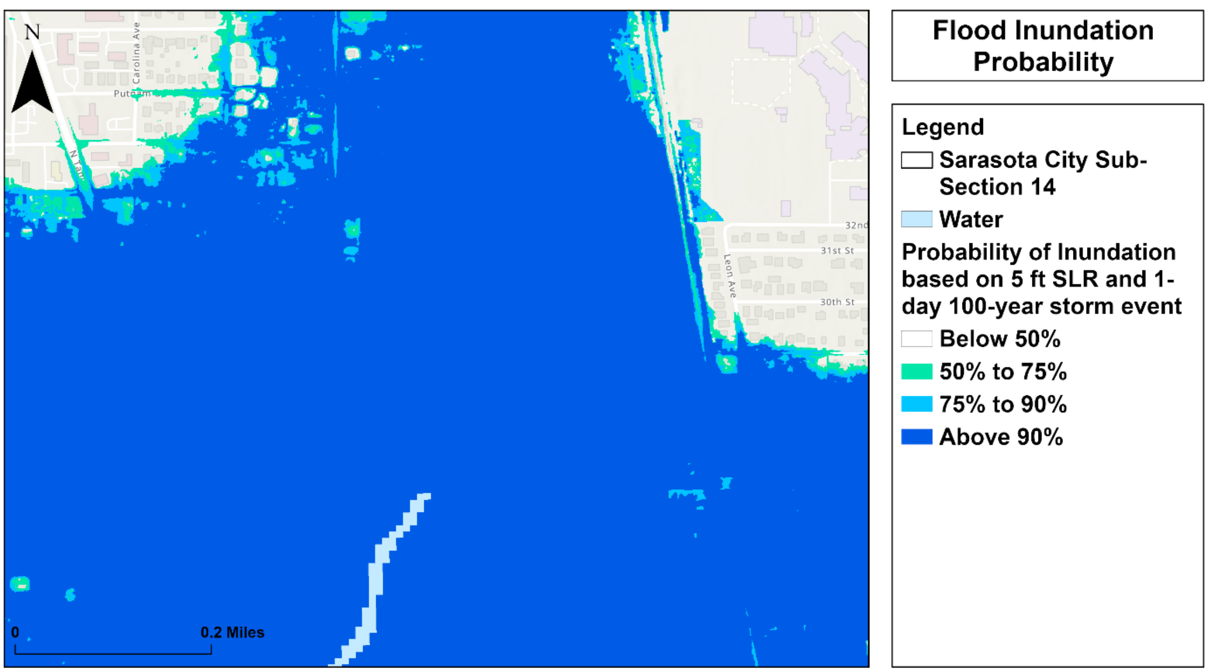


Figure 144. Drilldown of Whitaker Bayou at Old Bradenton Rd, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 145. Aerial view of Whitaker Bayou east of Tamiami Trail

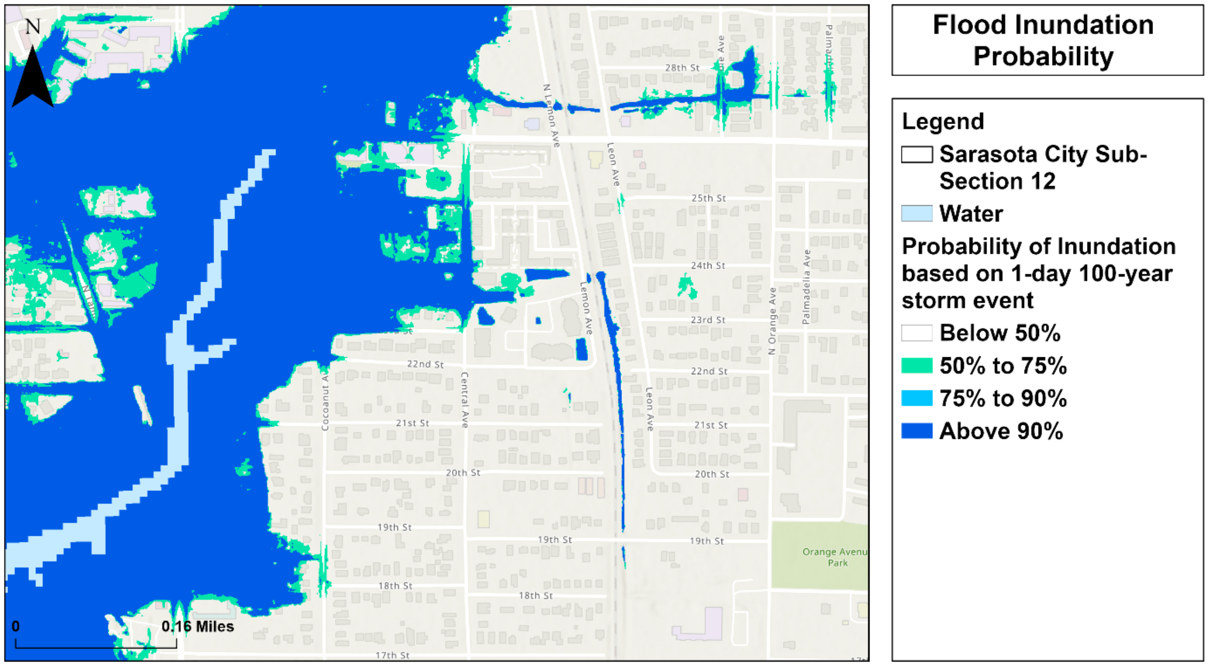


Figure 146. Drilldown of Whitaker Bayou east of Tamiami Trail, based on 1-day 100-year rainfall event, as generated by FAU CWR3

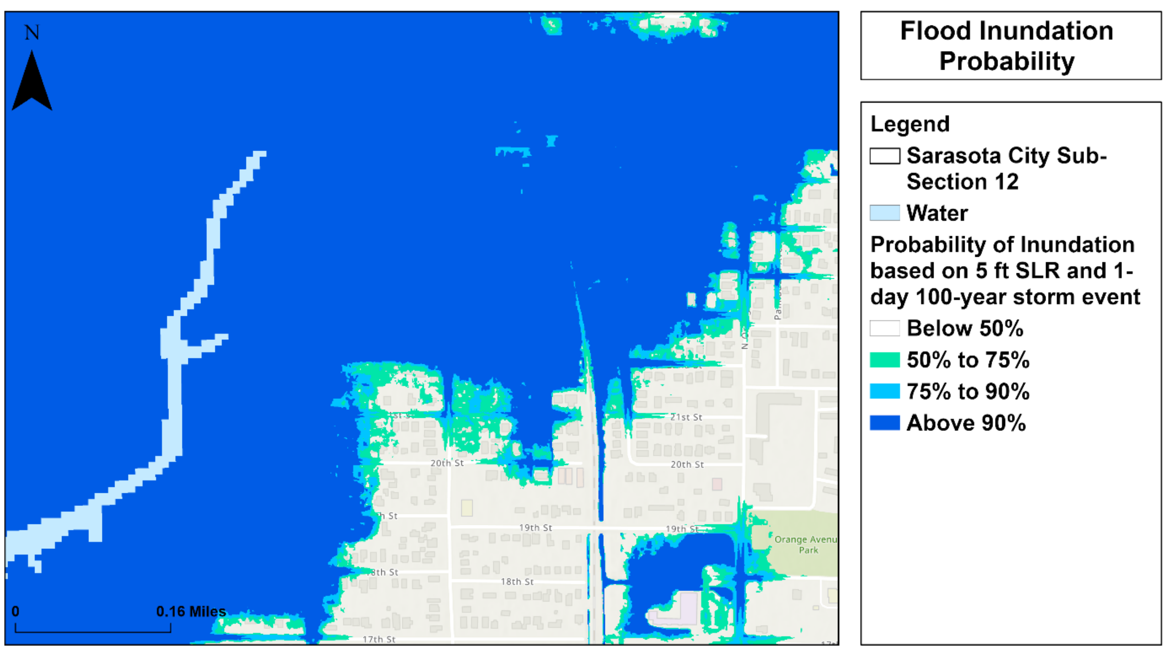


Figure 147. Drilldown of Whitaker Bayou east of Tamiami Trail, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 148. Aerial view of MLK and N. Orange Avenue Area

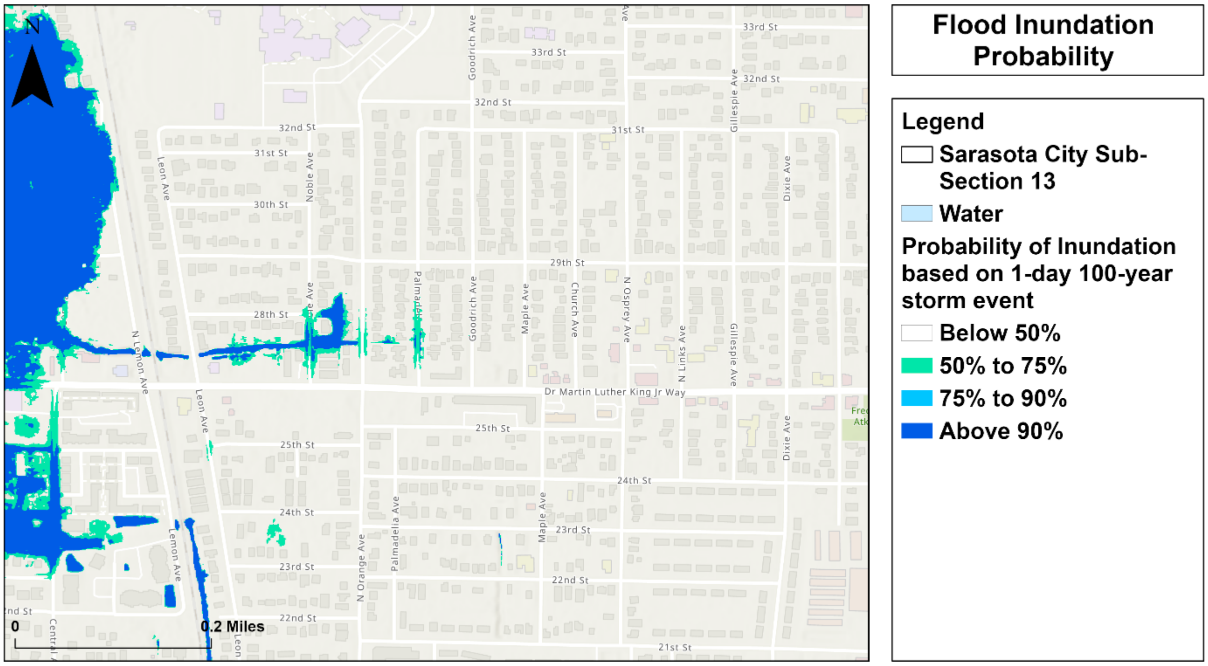


Figure 149. Drilldown of MLK and N. Orange Avenue, based on 1-day 100-year rainfall event, as generated by FAU CWR3

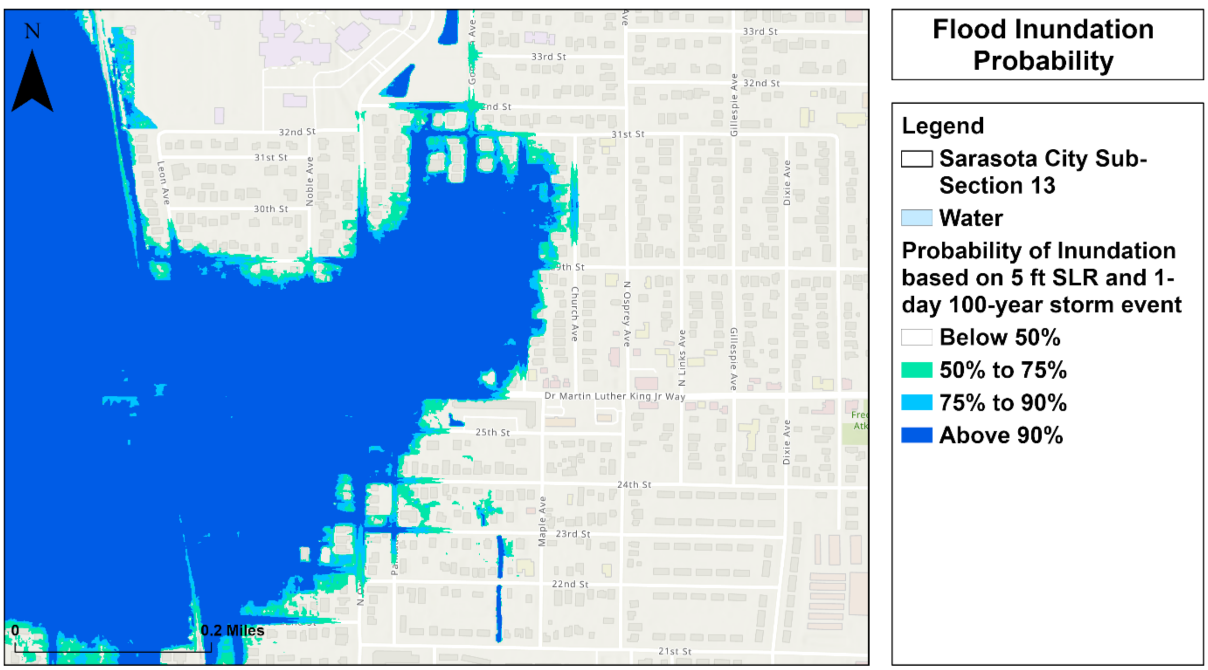


Figure 150. Drilldown of MLK and N. Orange Avenue, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 151. Aerial view of area north of MLK and Railroad tracks

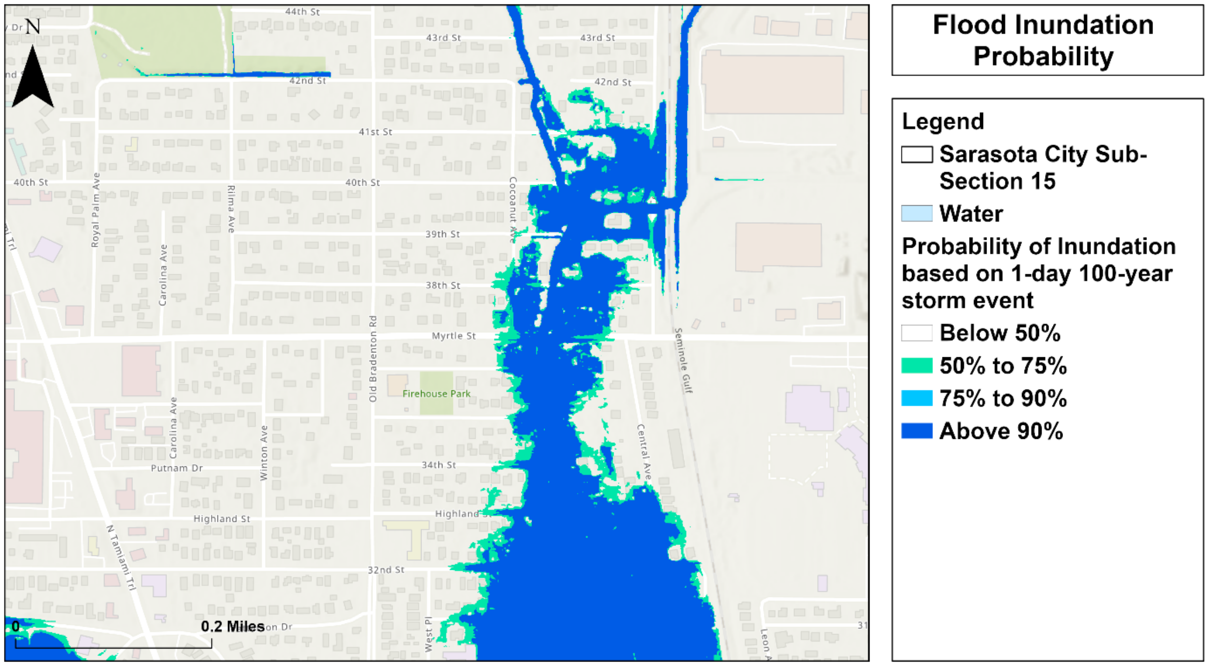


Figure 152. Drilldown of MLK and Railroad tracks, based on 1-day 100-year rainfall event, as generated by FAU CWR3

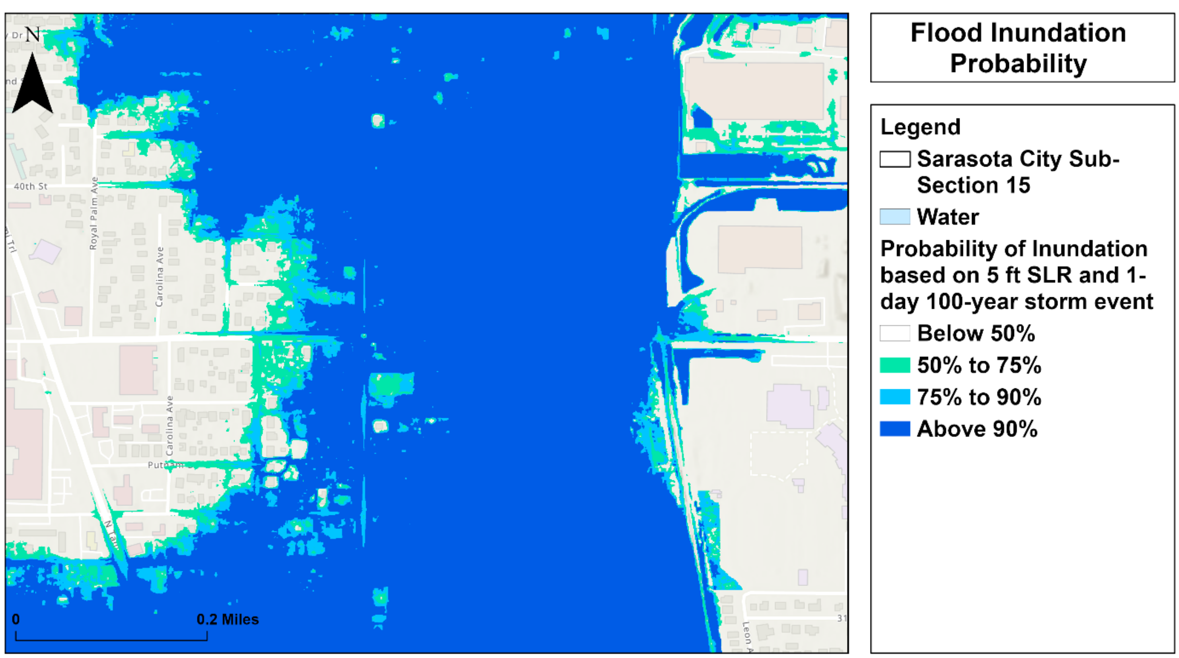


Figure 153. Drilldown of MLK and Railroad tracks, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 154. Aerial view of area east of Tamiami Trail (US41) and railroad, south of airport

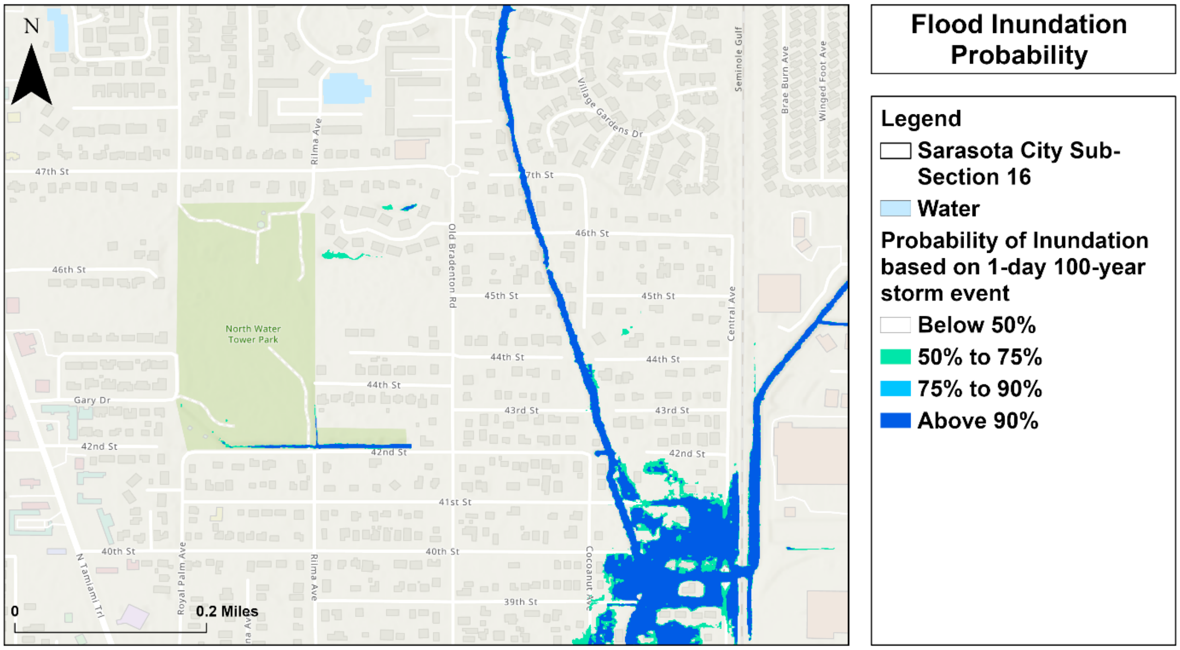


Figure 155. Drilldown of area east of Tamiami Trail (US41) and railroad, south of airport, based on 1-day 100-year rainfall event, as generated by FAU CWR3

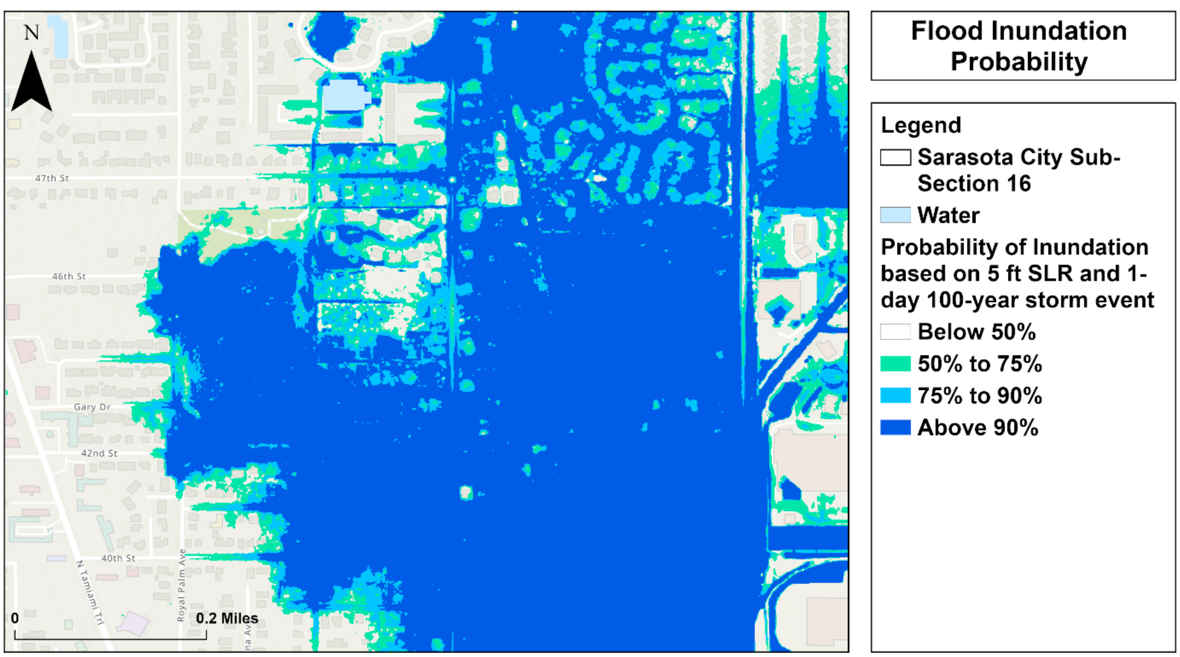


Figure 156. Drilldown of area east of Tamiami Trail (US41) and railroad, south of airport, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 157. Aerial view of area north of Myrtle St and east of Railroad.

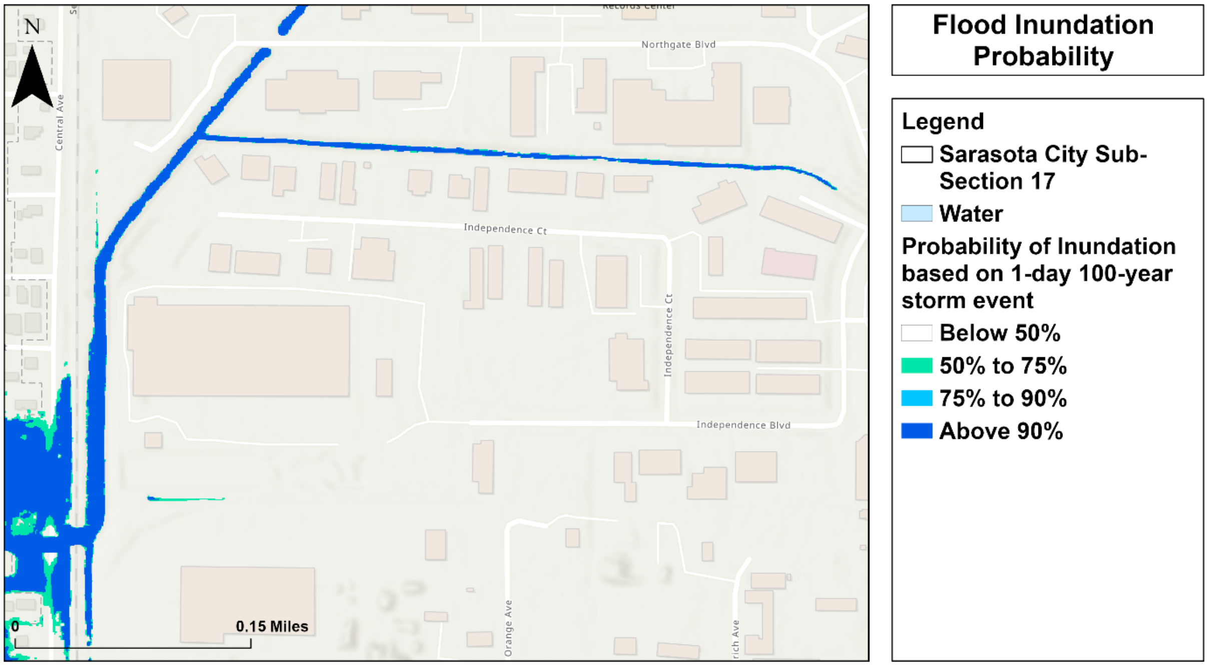


Figure 158. Drilldown of the area north of Myrtle St and east of Railroad, based on 1-day 100-year rainfall event, as generated by FAU CWR3

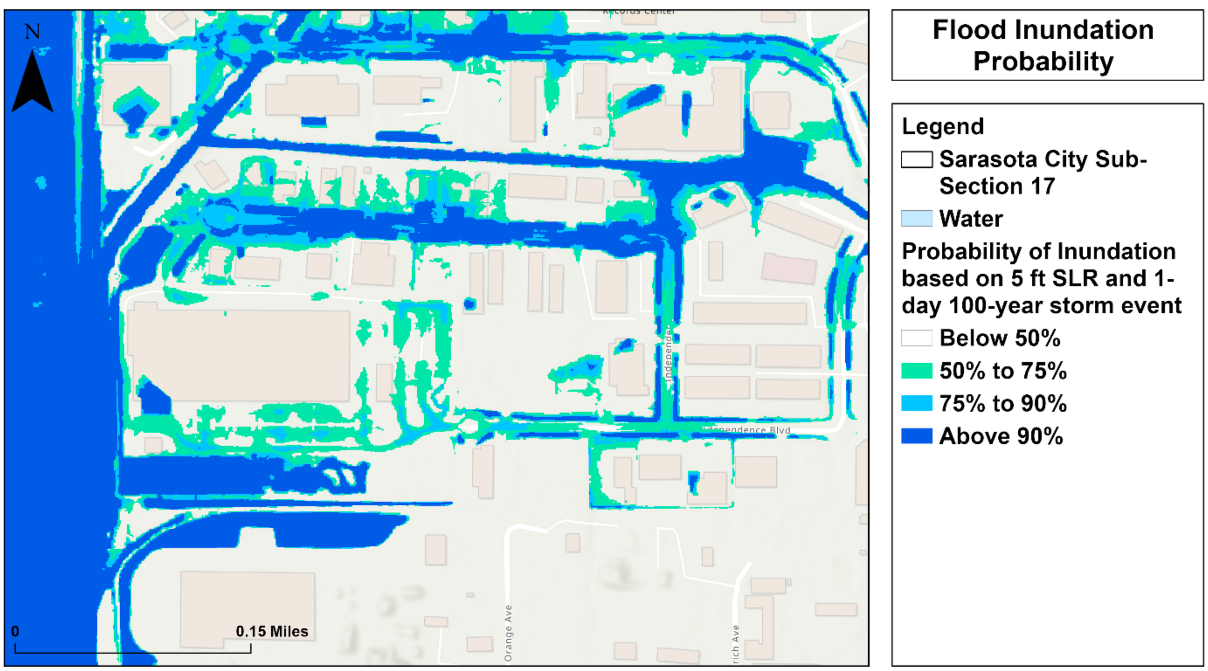


Figure 159. Drilldown of area north of Myrtle St and east of Railroad, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 160. Aerial view of Trailer park south of airport

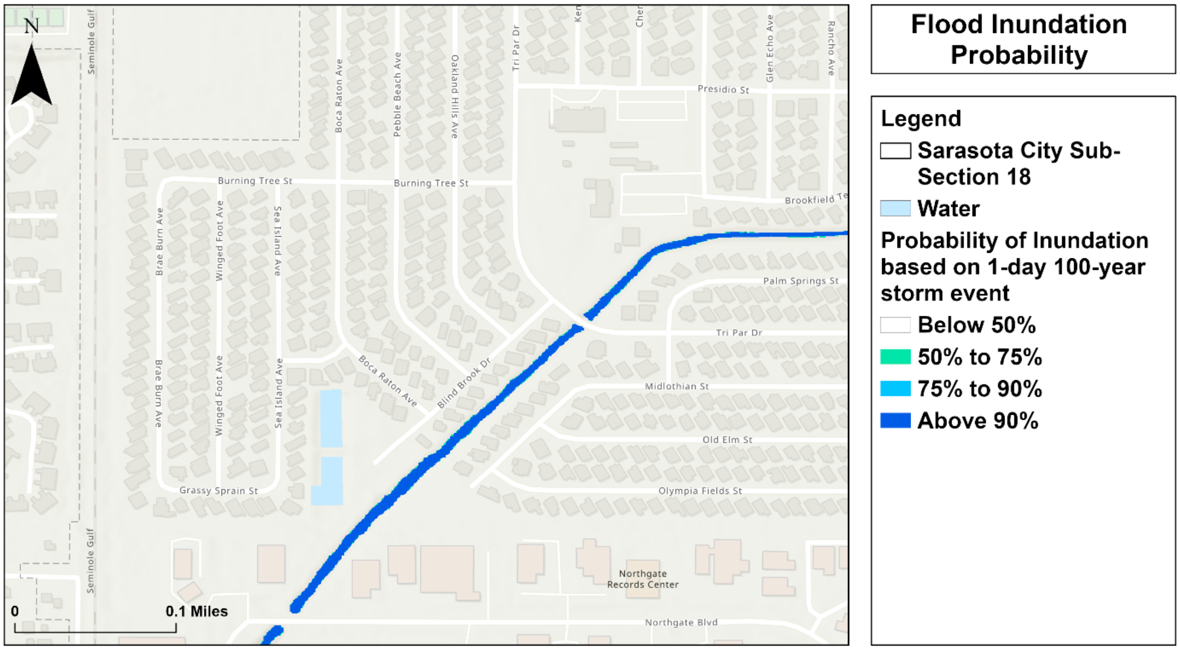


Figure 161. Drilldown of Trailer park south of airport, based on 1-day 100-year rainfall event, as generated by FAU CWR3

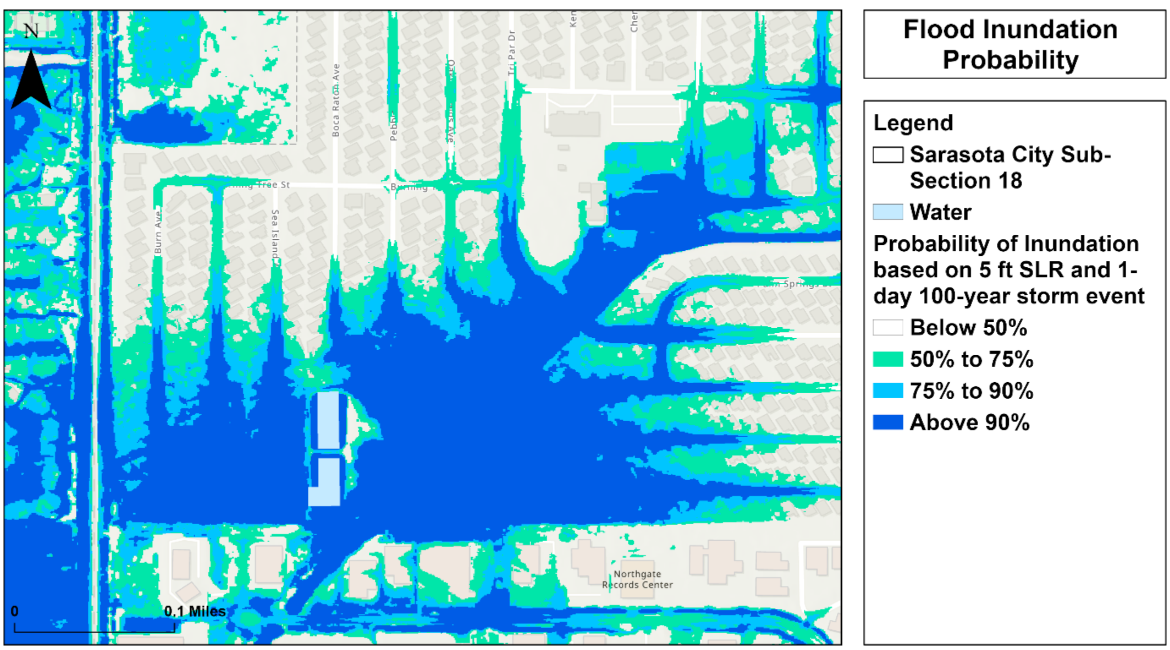


Figure 162. Drill down of Trailer park south of the airport, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 163. Aerial view of the area north of University Parkway, east of the airport

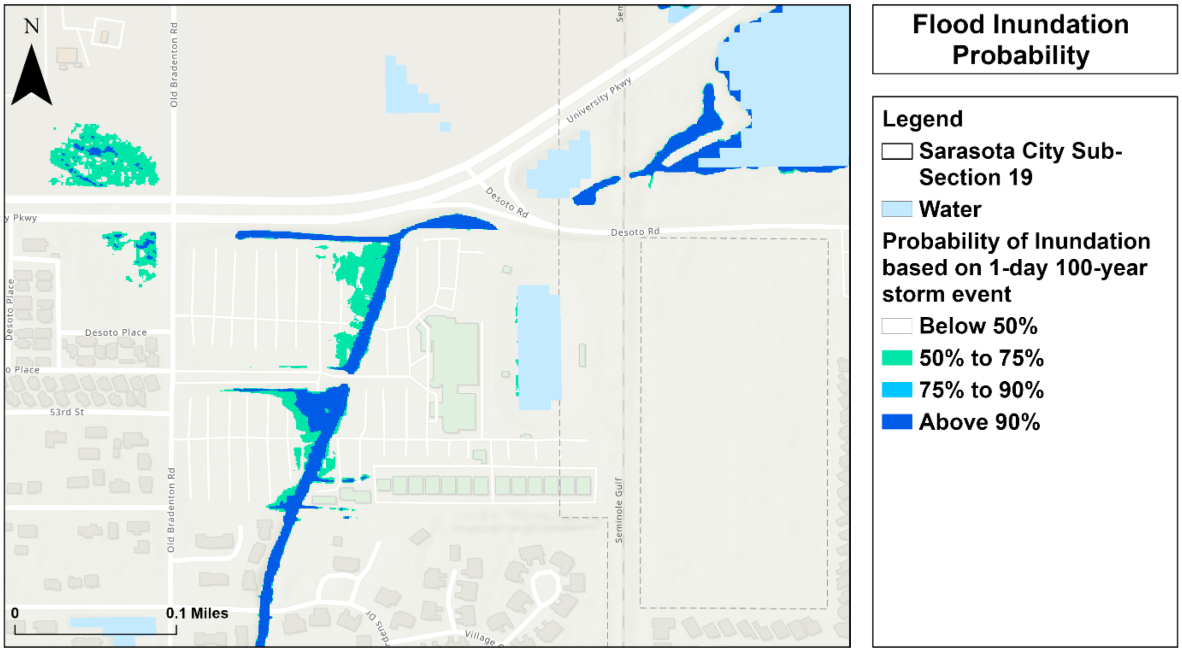


Figure 164. Drilldown of north of University Parkway, east of the airport, based on 1-day 100-year rainfall event, as generated by FAU CWR3

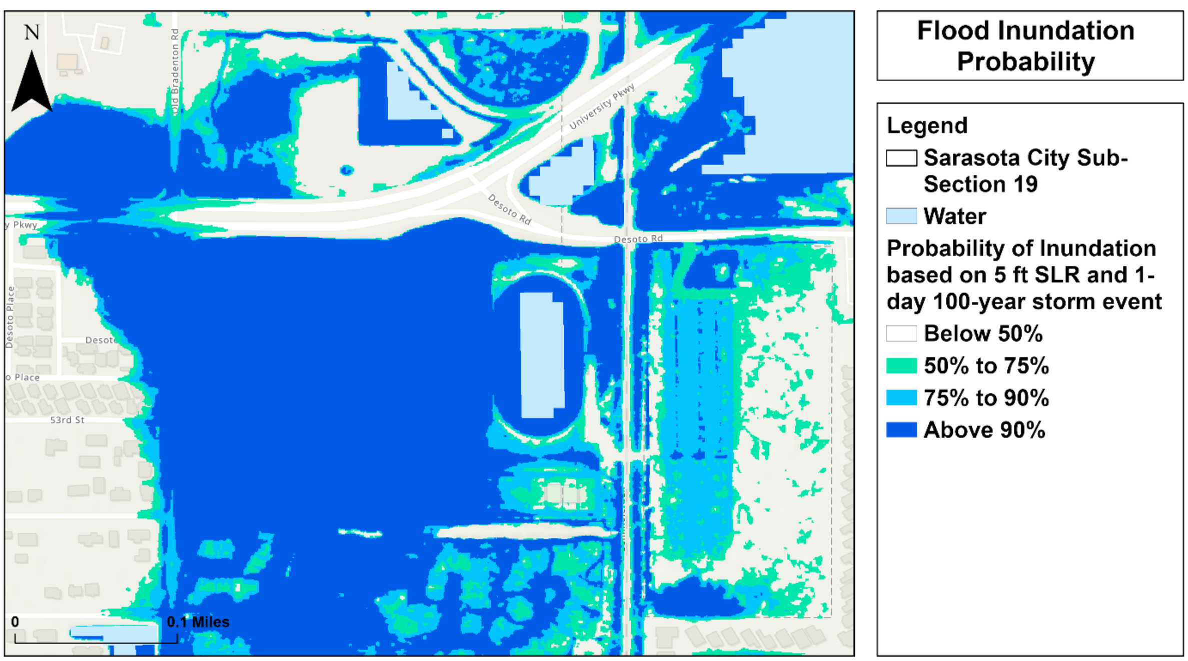


Figure 165. Drilldown of north of University Parkway, east of the airport, based on 5-ft SLR and 1-day 100-year rainfall event, as generated by FAU CWR3

Figure 166. Aerial view of trailer park east of the airport

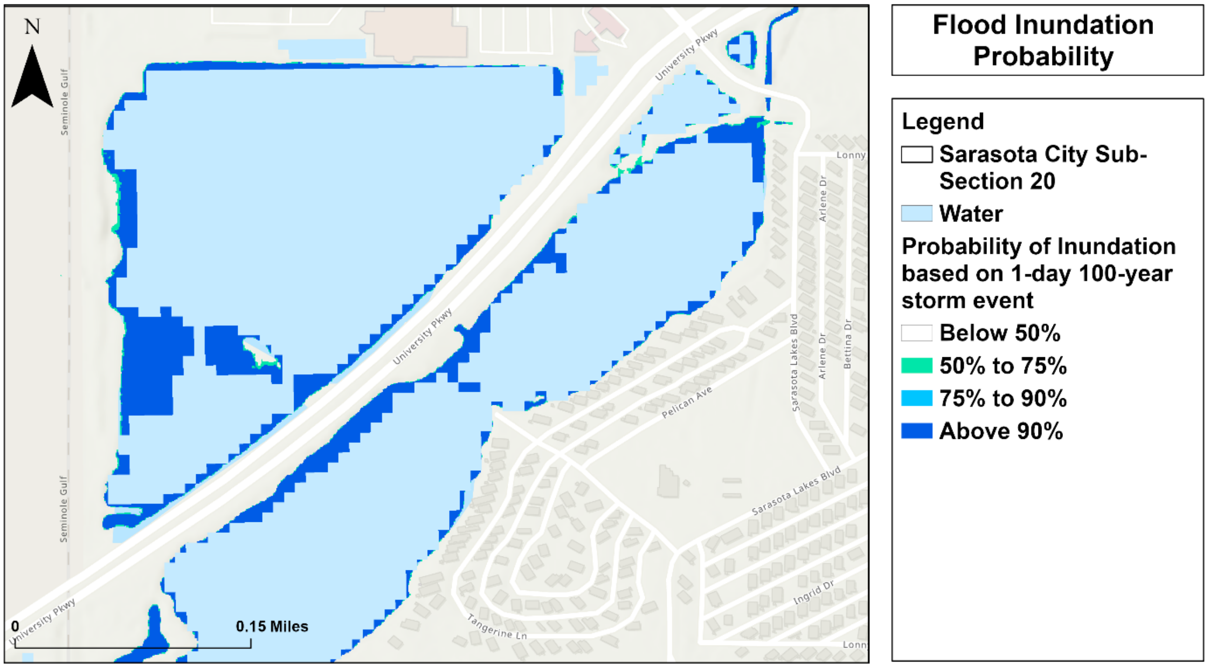


Figure 167. Drilldown of trailer park east of the airport, based on 1-day 100-year rainfall event, as generated by FAU CWR3

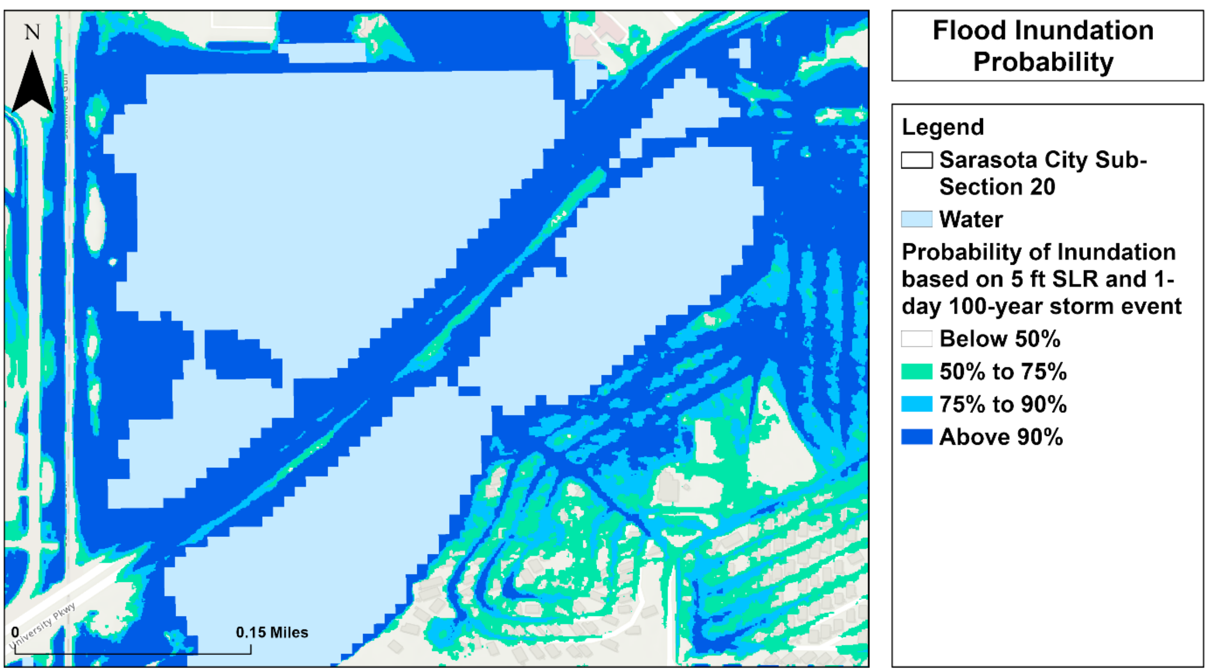


Figure 168. Drilldown of the trailer park east of the airport, based on 5-ft SLR and 1-day 100-year Francisco Reina Francisco Reina rainfall event, as generated by FAU CWR3

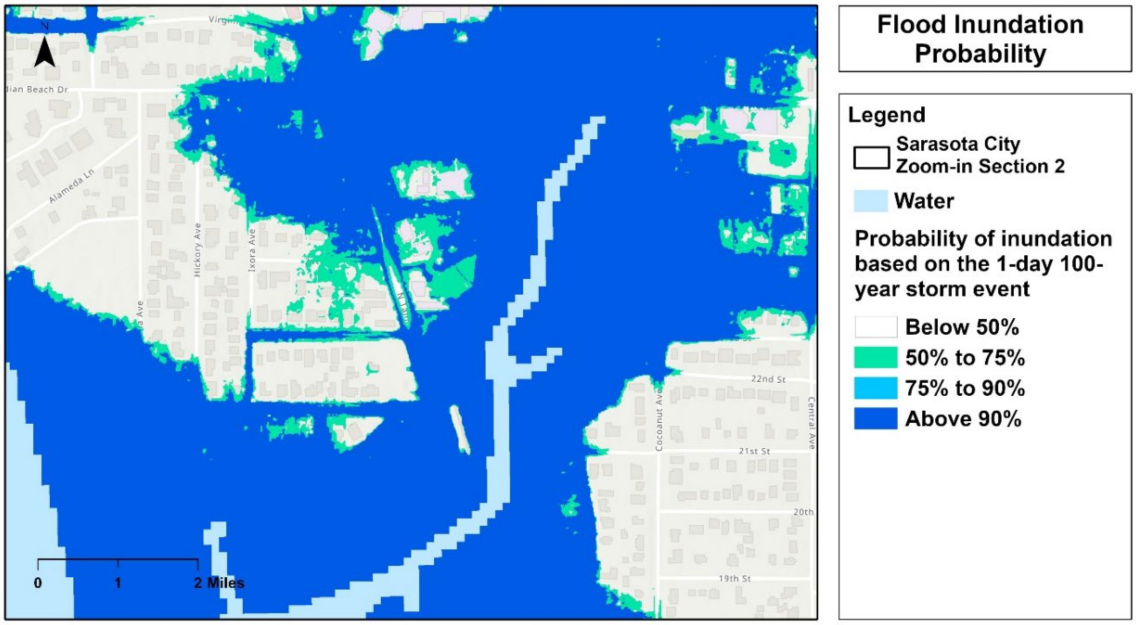


Figure 169. Philippi Creek Area zoomed in, based on 1-day 100-year rainfall event, as generated by FAU CWR3

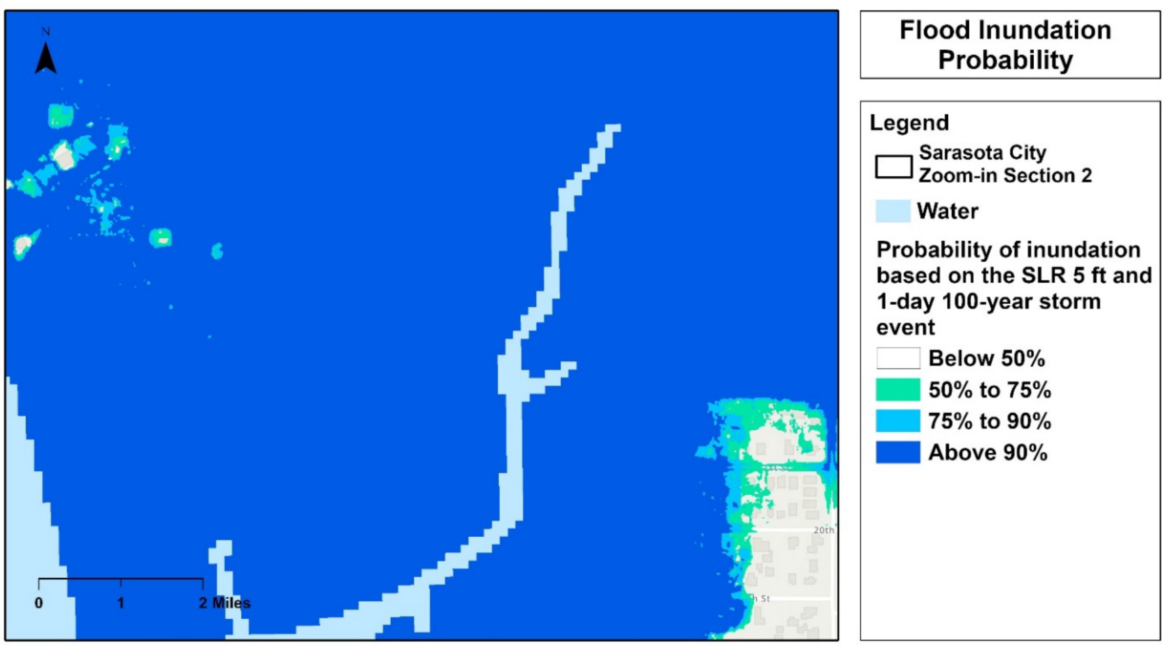


Figure 170. Philippi Creek Area zoomed in, based on 1-day 100-year rainfall event with 5 ft of sea level rise, as generated by FAU CWR3

Overall there are four recurring items:

1. Seawalls are too low. They can be raised as a part of a policy decision through development or redevelopment codes when these sea walls fail or need major repairs.
2. Pipes draining islands to the bay need backflow devices to prevent water from coming back into the streets
3. Localized pump stations will resolve areas on the mainland
4. Means to prevent inland migration of water in Whitaker Bayou and Philippi Creek are needed

These solutions will be discussed in more detail along with other options in Section 5.3.

5.3 Solutions

For the Phase 1 guidance document, 35 solutions are referred to as the "Periodic Table" menu of green and grey infrastructure technologies (Figure 171). The ones that apply to the City are highlighted and discussed in more detail in the following sections. The yellow highlighted items are ideas that are easily implementable or are part of current permitting. They will provide help for regular storm events and nuisance flooding.

The orange items are tangential to stormwater – they address the sanitary sewer system. Septic tanks on an island will fail with high water tables, creating water quality impacts on the adjacent canals and water bodies. They also do not work when flooded. Sanitary sewer will if protected and sealed. While the City has been converting to sanitary sewer, continuing that effort will improve the long-term water quality and sewer sustainability.

The red items are those that are longer term. As noted in the prior section, road bases are already failing. That will continue at an accelerated rate as the base remains wet. Raising roads has the major challenge of impacting flood insurance. The crown of the road must remain 18 inches below the finished floor or the structure cannot obtain flood insurance (it is considered a basement which is not insurable in Florida).

Likewise, sea walls, identified as an issue in the prior section have two challenges they need to be increased in height which may not be able to be done easily given the current condition or structure of the sea walls and the opening for street drains through the seawalls permits water to backflow into the streets. That needs to be stopped.

Policy issues include altering zoning or property acquisitions to remove flood-prone areas from development. These are much longer-term challenges.

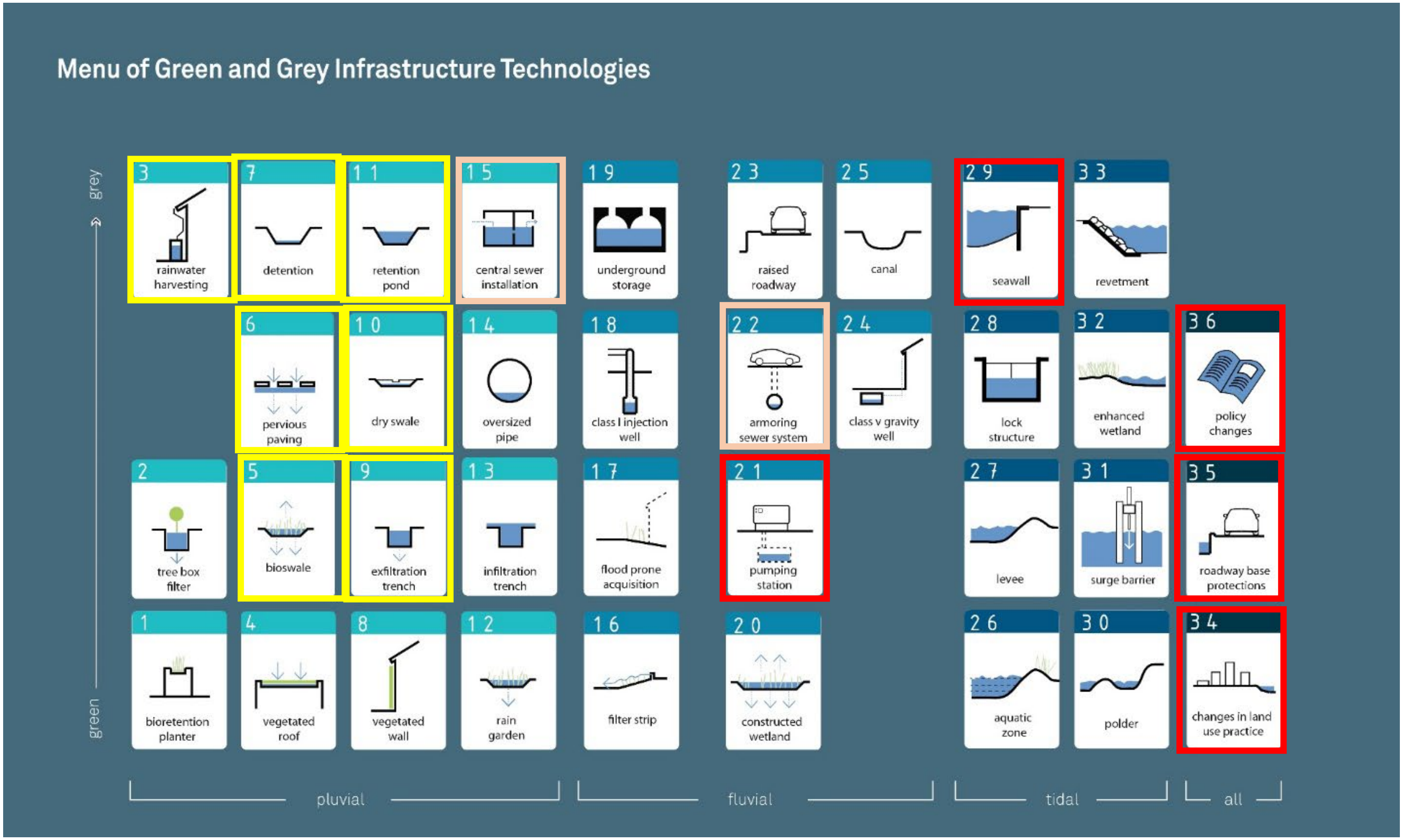


Figure 171.“Periodic table” menu of green and grey infrastructure technology options. The menu is organized to address various flooding types, from pluvial (rainfall and runoff mitigation in upland areas), fluvial (runoff, high groundwater, and surface water management in low-lying flood-prone areas), tidal (flooding associated with storm surge, high groundwater, and tidally influenced), and all (applies across the spectrum).

5.3.1 Rainwater Harvesting

Rainwater harvesting is the collection and storage of rain on a site in some form of container, rather than allowing it to run off. Typically, the rainwater is collected from a roof-like surface and redirected to a tank, cistern (Figure 172), or pond for later use for irrigation or other non-potable purpose. This option can be used in areas where some irrigation is needed for daily rain events. Limited use for large-scale events since the container will overflow.

Figure 172. Rainwater harvesting cistern (used for irrigation) at the Pine Jog Environmental Center in West Palm Beach, FL

A common location for rainwater harvesting is at the terminal end of downspouts for buildings. In areas with highly variable rainfall, the ability to store water for non-potable purposes is a well-understood means of water conservation. Note because the cistern will only hold a certain volume of water, a means to address cistern overflows is needed. The costs for these systems are low, and maintenance is limited to periodic cleaning to remove roof debris/sediment. Rainwater harvesting can also help a development acquire LEED® credits. Design considerations are summarized in Figure 173.

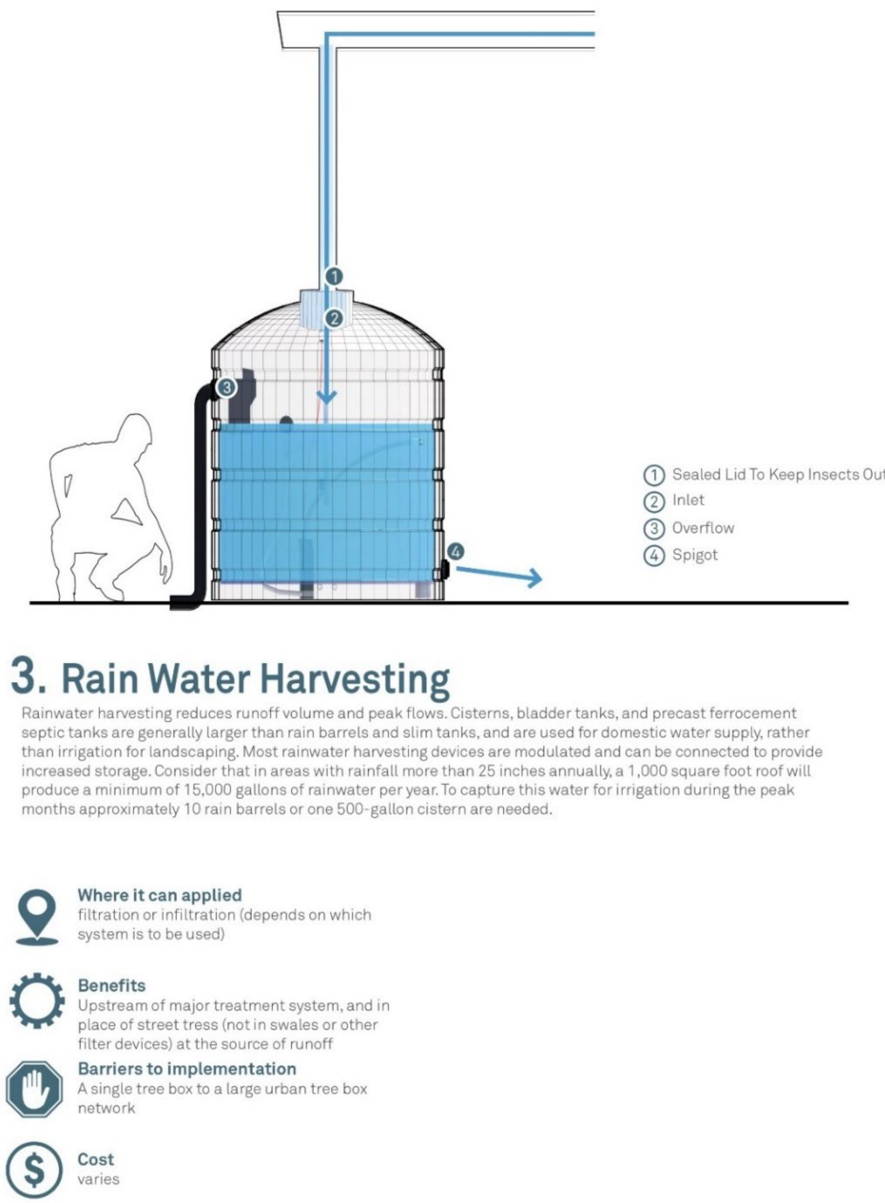


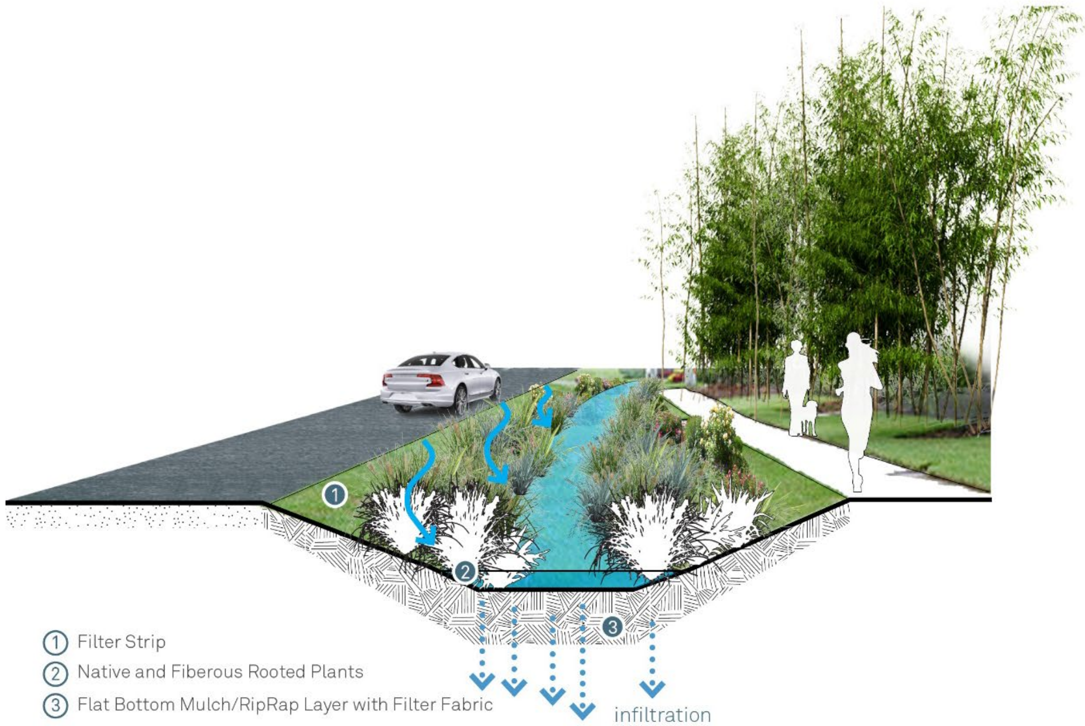
Figure 173. Design considerations, benefits, barriers, and costs for a rainwater harvesting system

5.3.2 Bioswales

Bioswales are vegetated drainage ways that function by slowing runoff as it comes off an impervious surface, such as parking areas (Figure 174). Bioswales remove sediments and other pollutants and provide infiltration into the soil during small-scale rain events.

Figure 174. Photo of a bioswale pilot installation in Hallandale Beach, FL (https://www.hallandalebeachfl.gov/)

To prevent overflows, construction typically includes a perforated pipe beneath the bioswale that will allow excess water to be diverted to a stormwater system of some type (retention ponds are normally the discharge points). Design considerations are illustrated in Figure 175, and Figure 176 shows the detail of construction.



5. Bioswale

Bioswales are a bioretention device in which pollutant mitigation occurs through phytoremediation by facultative vegetation. Bioswales combine treatment and conveyance services, reducing land development costs by eliminating the need for costly conventional conveyance systems. The main function of a bioswale is to treat stormwater runoff as it is conveyed, whereas the main function of a rain garden is to treat stormwater runoff as it is infiltrated. Bioswales are usually located along roads, drives, or parking lots where the contributing acreage is less than five acres Bioswales can also be sized to improve water quality as the plants are effective at removing many contaminants, especially petroleum-based contaminants. The solution is also cost effective, while also providing a landscaping feature that is often required for new developments, helps reduce urban heat island effects, and increases aesthetics when maintained. The use of native plants that require minimal irrigation is appropriate. LEED® credits can also be gained by using bioswales.

Where it can applied
Parking lots, runoff from development - primarily treatment for discharge to another system

Benefits
Protects Property, treats runoff

Barriers to implementation
maintenance, limited volume disposed of, mostly for treatment

Cost
$20k-$200k/acre

Figure 175. Design considerations, benefits, barriers, and costs for a bioswale

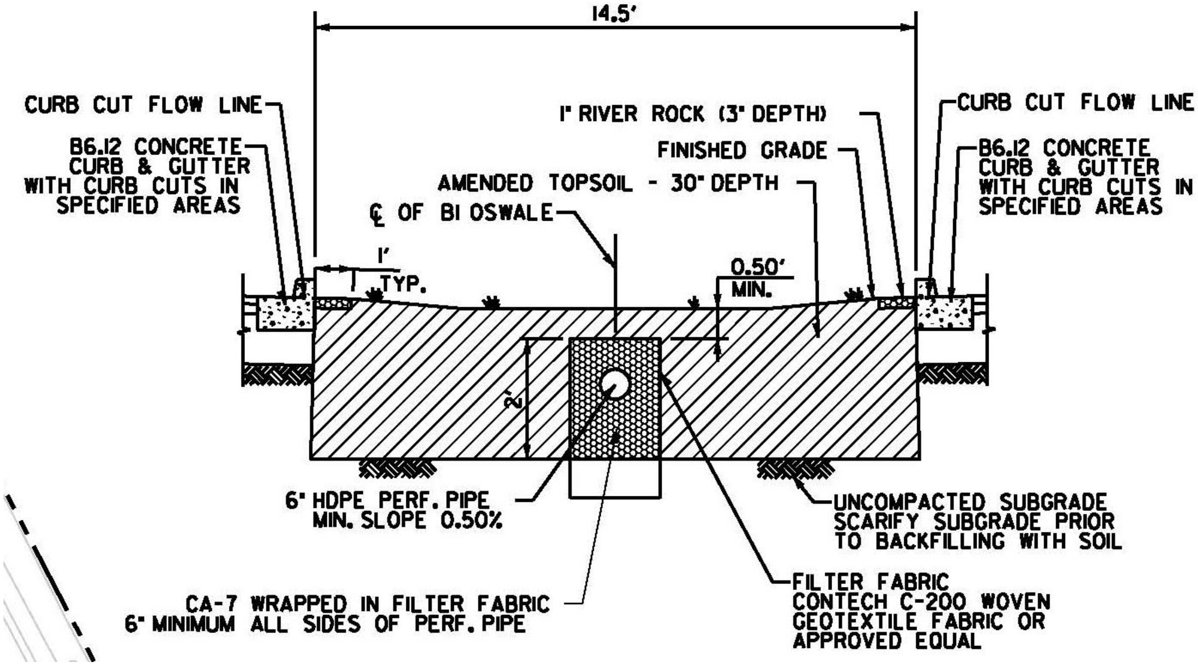


Figure 176. Construction detail of a bioswale (https://www.warrenville.il.us/456/Bioswales)

5.3.3 Pervious Paving

Transportation surfaces (roads, parking lots, and driveways) account for over 60% of impervious urban surfaces. Permeable pavement allows rainfall to infiltrate down from these surfaces rather than running off into storm sewers. Rainfall moves into a rock chamber below the pavement. Water in the pore space between the aggregate either percolates out and down through surrounding soils or moves to a perforated drainpipe installed in the rock chamber. Water is slowly released to become ground flow or enter surface waters after it has been cleaned and cooled by moving through the pavement and underground rock chamber. Since impervious pavement is the primary source of stormwater runoff, low-impact development (LID) strategies recommend permeable paving for parking areas and other light-duty hard surfaces. The benefits of pervious surfacing include: 1) lower surface temperature, 2) less flash flooding and standing water, 3) fewer surface pollutants entering downstream waterbodies, 4) less stormwater runoff, 5) less need for detention ponds and other stormwater management practices, and 6) more recharge to water table aquifers.

Permeable paving techniques include pavement (Figure 177) and pavers (Figure 178). All permeable paving systems consist of a durable, load bearing, pervious surface overlying a crushed stone base that stores rainwater before it infiltrates into the underlying soil. Pervious pavements require maintenance. The holes that make the pavement pervious can become clogged with organics, plants, or sediments. Periodic removal of sediment is required, or the pavement will no longer be permeable. In Florida, because of the potential for plugging, pervious pavements are considered impervious when permitting and designing stormwater systems. Design considerations are summarized in Figure 179.

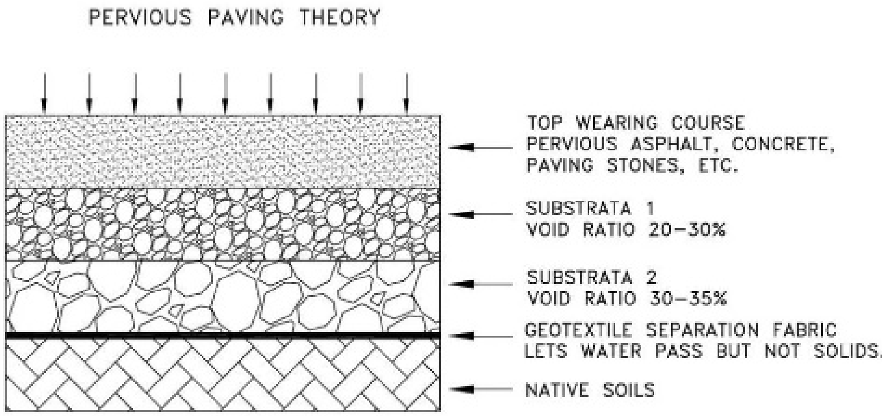
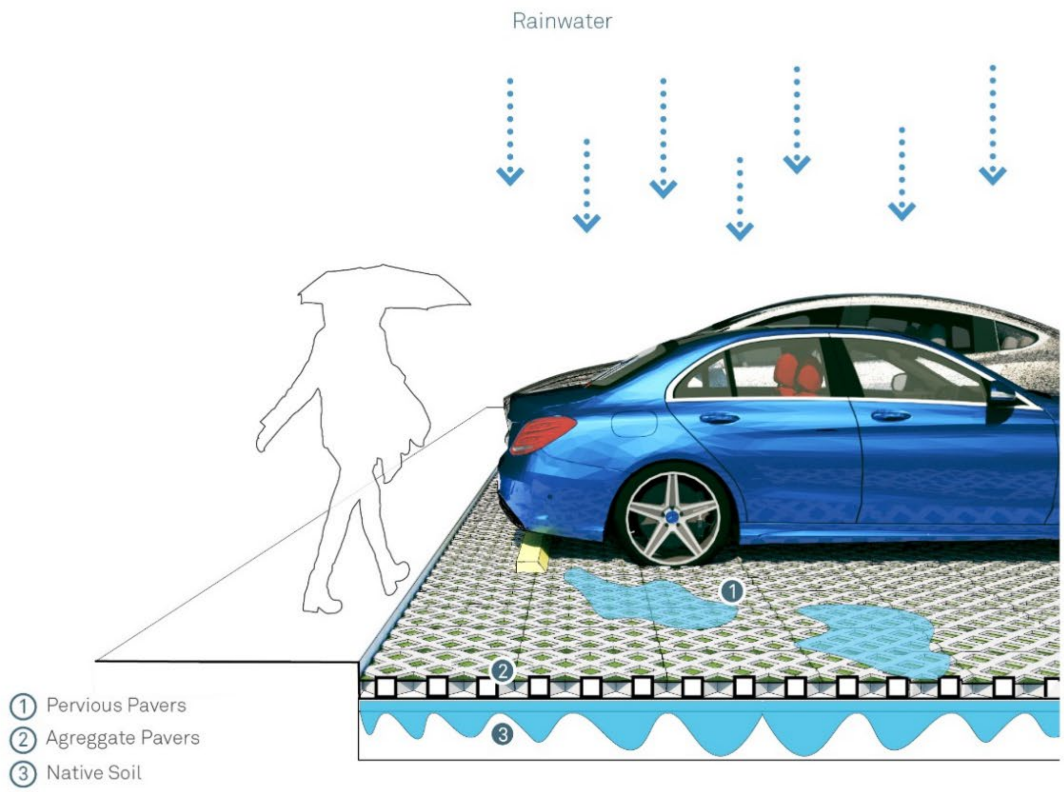


Figure 177. Pervious pavement detail (https://www.grantspassoregon.gov/280/Pervious-Pavement-Alternative)

Figure 178. Example of a pervious paver driveway



6. Pervious Paving

A pervious paving system includes a subsurface base made of course aggregate for stormwater storage. In some designs, pervious pavement is supported by underground layers of soil, gravel and sand to increase storage and maximize infiltration rates. Pervious paving removes sediment and other pollutants. It acts to reduce and distribute stormwater volume, encouraging groundwater infiltration. Multiple types of pervious paving, including modulated precast pavers, poured in place systems, porous asphalt, porous concrete, and gravel, offer varying levels of service. Reduction of the urban heat island effect is possible when using high-albedo, lightly colored systems.

Where it can applied
parking lots, patios, anything except paved roads due to traffic loading

Benefits
reduces roadway and parking lot flooding

Barriers to implementation
must be maintained via vacuuming or the perviousness fades after 2-3 years

Cost
$10-20/sf, requires bumpers and sub-base to maintain paver integrity

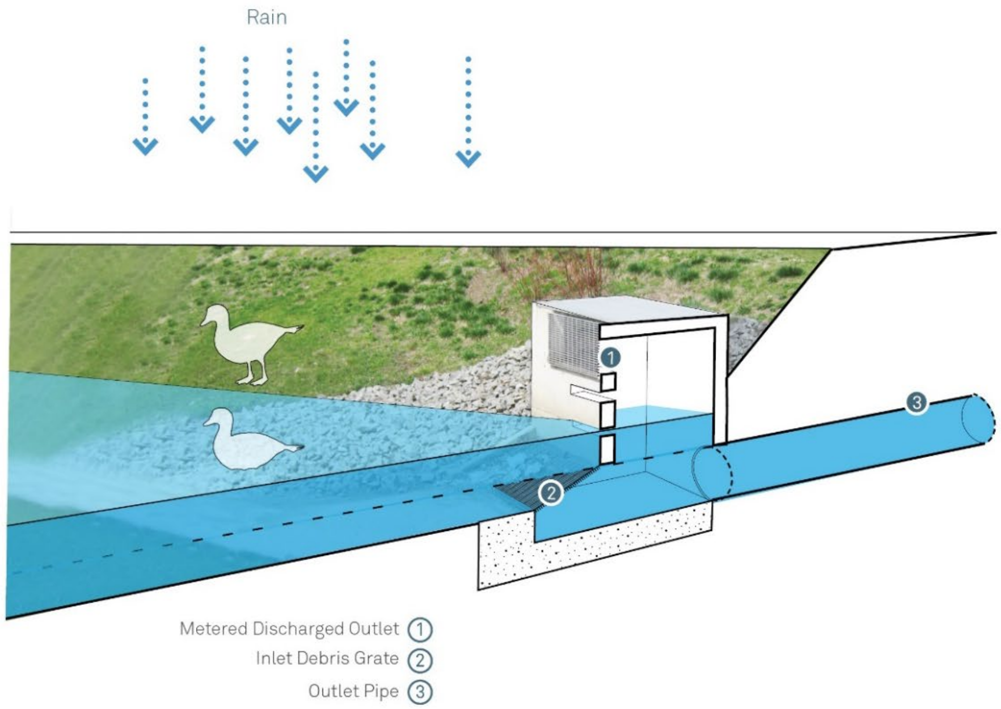
Figure 179. Design considerations, benefits, barriers, and costs for pervious paving

5.3.4 Detention

Already a requirement of the SFWMD, detention ponds are widely used and designed for stormwater management applications. Detention is distinctly different from retention, which keeps the water on site, while detention releases it slowly with time to mimic the natural system or has an overflow (Figure 180). Effective detention designs dramatically reduce runoff rates, prevent most increases in flooding associated with new development, reduce run-off pollutants, and prevent erosion. A detention basin will have an overflow that will go to an offsite stormwater system. The concept is to hold the water for a period of time and release it slowly back into the natural system.

Figure 180. Detention basin with overflow

Detention basins are well developed from a technology perspective, widely used, and well understood. They are inexpensive to construct as long as land is available. They will remove pollutants with limited added features. They do have two issues: 1) they tend to plug when not maintained, so to reduce maintenance, mowing, aeration, and other maintenance needs are required 2) if the area is densely built with limited pervious available, the volume of runoff may rapidly overwhelm the amount of water the basin can handle. Design considerations are summarized in Figure 181.



7. Detention

Detention ponds are designed to completely evacuate water from storm events, usually within 24 hours. They primarily provide runoff volume control reducing peak flows that cause downstream scouring and loss of aquatic habitat. As a general rule, detention ponds should be implemented for drainage areas greater than 10 acres. On smaller sites it may be difficult to provide control since outlet diameter specifications needed to control small storm events are small and thus prone to clogging. Also, treatment costs per acre are reduced when implemented at larger scales.

Where it can applied
Common for new development, but difficult to retrofit; developer resist because it consumes land they could otherwise develop; limited to open areas

Benefits
Removes water from streets, reduces flooding

Barriers to implementation
Land availability, maintenance of pond, discharge location

Cost
$200k/acre

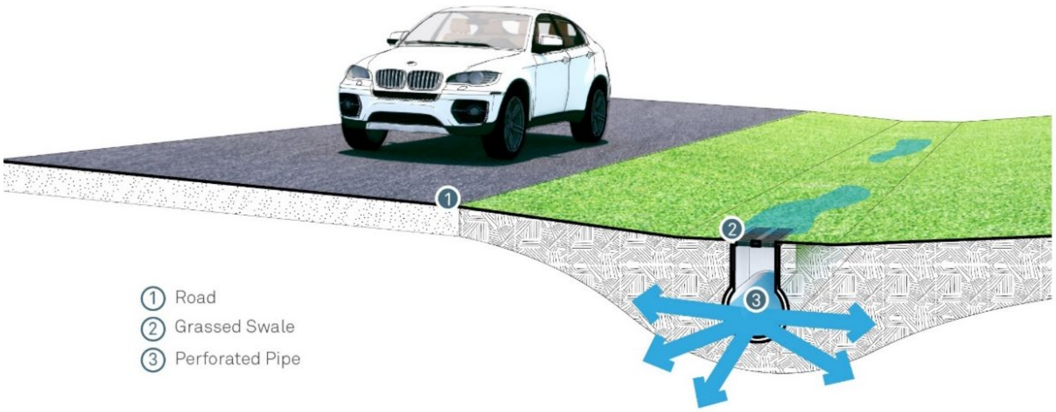
Figure 181. Design considerations, benefits, barriers, and costs for detention

5.3.5 Exfiltration Trench

As a requirement of the SFWMD, the Florida Department of Transportation (FDOT) and most municipalities rely heavily on exfiltration trenches or French drains. These systems work because the perforated piping is located above the water table, thereby allowing water to leak out; however, they cease to function if they are located below the water table. As the water table rises, exfiltration systems in low-lying areas will cease to work as they become submerged. Exfiltration trenches, or French drains, are commonly used in Florida. Exfiltration is a preferred strategy behind retention areas by SFWMD. The concept is simple: install a perforated pipe beneath the surface of a road, parking area, or swale and have the drainage system empty to it. The difference in head between the surface of the drainage system and the water table, combined with the hydraulic conductivity of the soil, provides an indication of the amount of water that can be disposed of. The assumption is typically a 24-inch perforated pipe placed in a 4 ft gravel trench, laid fully above the water table to maximize the potential for water to exit the pipe and filter into the soil. The results of engineering calculations generally are characterized by the length of the trench required to dispose of a given volume of water.

Benefits of exfiltration trenches include that they are well developed from a technology perspective, widely used, well understood, and generally can dispose of large volumes of water, especially when large parts of the drainage system on-site are exfiltration trenches. They do have two issues – they tend to plug when not maintained, so to reduce maintenance, baffling is needed to prevent leaves and fines from entering the trench pipe. Unfortunately, this is only partially successful, so regular vacuum service is needed, which is difficult to implement. Second, if the area is densely built with limited pervious area, the volume of runoff may overwhelm the amount of water the soil can take. Recent rainfall and heightened water tables complicate exfiltration trench operation because the higher water tables cause them to work least efficiently when you need them most – rainfall at the end of the wet season. But they have value and function well.

The cost to install exfiltration trenches varies depending on the pipe trench width and depth. Typical costs are $150 per linear foot. Developers routinely install them to reduce the amount of land required for retention ponds. They also will pull contaminants into the trench as opposed to allowing them to runoff to surface water bodies. That can also be an issue unless additional treatment is otherwise provided. Trenches do not work if not well maintained, in muck soils and when the groundwater level inundates the trenches. In these circumstances, a better option is required. Design considerations are summarized in Figure 182.



9. Exfiltration Trench

Exfiltration trenches are particularly useful for sites with poorly-drained soils. Runoff gradually percolates through an engineered trench with amended soil over a period of days. Exfiltration trenches filter particulates as stormwater runoff moves through the media. Exfiltration trenches require less maintenance if upstream pre-treatment facilities like filter strips are used. Trees should not be planted near exfiltration trenches. These two actions reduce the potential for clogging the trench. Annual inspection is recommended to remove large debris and/or trash.

Where it can applied
Any low lying area where stormwater collects, and the water table is more than 3 ft below the surface; densely developed areas where retention is not available, roadways

Benefits
Excess water drains to aquifer, some treatment provided

Barriers to implementation
Significant damage to roadways for installation, maintenance needed, clogging issues reduce benefits

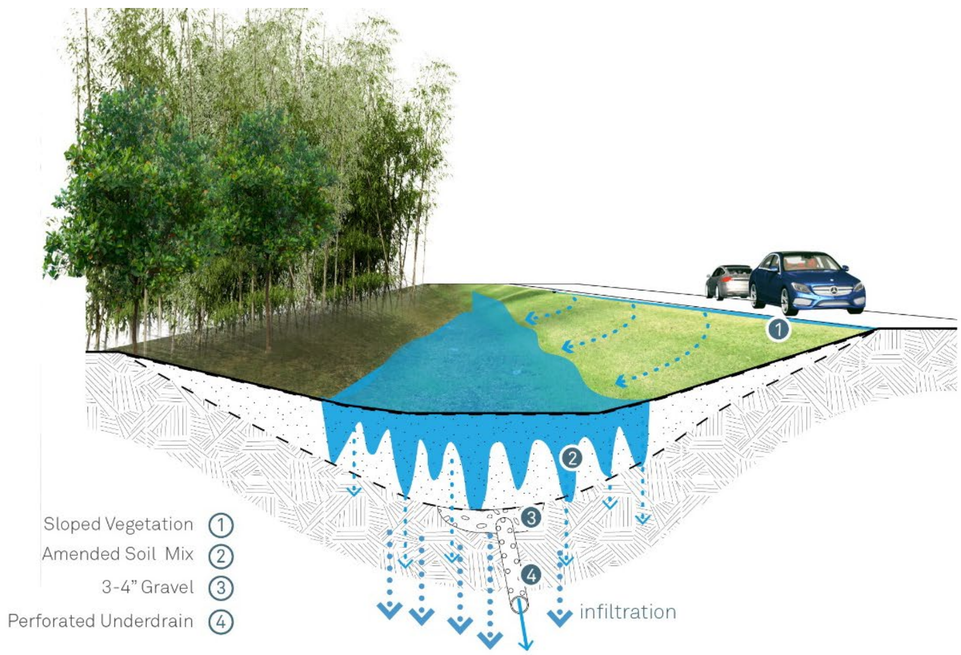
Cost
$250/lf

Figure 182. Design considerations, benefits, barriers, and costs for an exfiltration trench

5.3.6 Dry Swale

A dry swale is similar to a bioswale except that there is no planted vegetation. The most common place to find them is adjacent to roads (Figure 183) or parking lots where the buried pipe will be in place to prevent overflows. Design considerations are summarized in Figure 184. In all cases, the dry swale has both quantity and water quality benefits.

Figure 183. Roadway dry swale



10. Dry Swale

In place of hard-engineered concrete channels, dry swales offer services beyond peak flow reduction that include runoff detention and sedimentation. Dry swales, when combined with check dams and underdrains, detain stormwater, and increase infiltration. Often located in drainage easements, they are a cost effective way to convey water between buildings, land uses, and along roadsides. Water quality is optimized when the channel profile is two to eight foot maximum in bottom width, holding a four inch water volume depth. During the establishment newly seeded banks should be stabilized with erosion control devices.

Where it can applied
Parking lots, runoff from development - primarily treatment for discharge to another system

Benefits
Protects Property, treats runoff

Barriers to implementation
maintenance, limited volume disposed of, mostly for treatment

Cost
$200k/mile

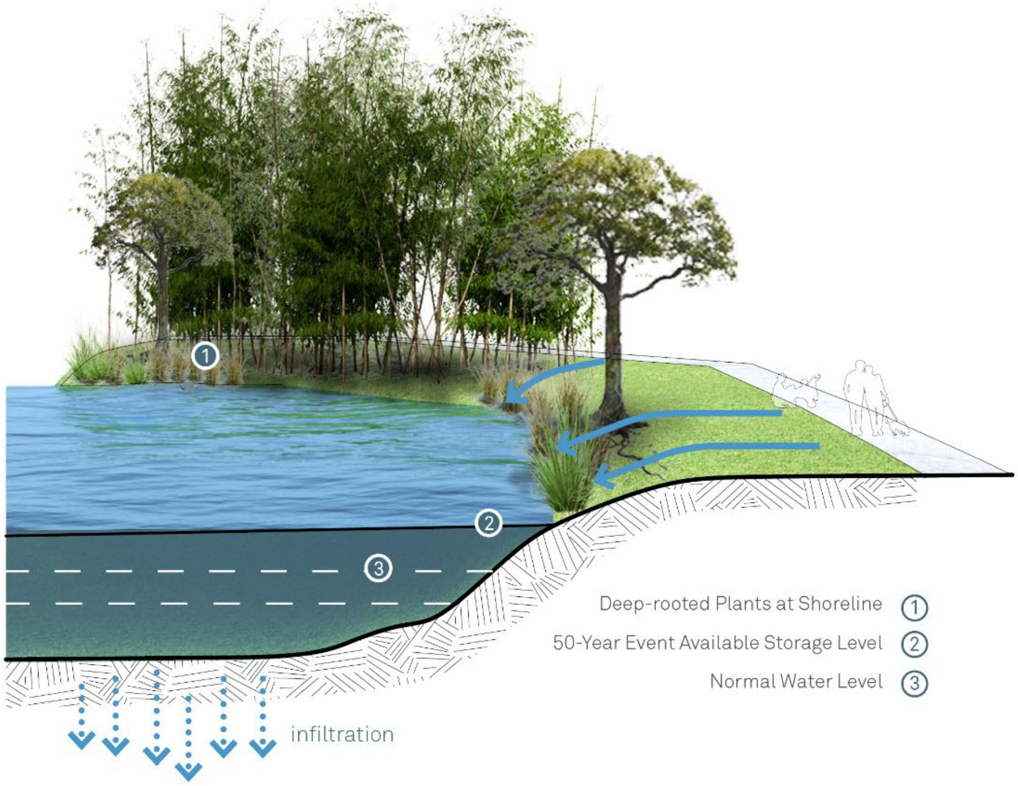
Figure 184. Design considerations, benefits, barriers, and costs for a dry swale

5.3.7 Retention Pond

Development causes the ground surface to become more impervious, which results in greater runoff of rainfall and a loss of infiltration. The heightened runoff patterns increase the likelihood that older infrastructure (piping) will be insufficient to move water from developed areas, resulting in increased funding. The loss of wetlands, mangroves, and other coastal ecosystems diminishes the ability to store water or to provide areas to direct excess precipitation to avoid flooding. Storage areas to delay the movement of water until a lower tide and increased infiltration capacity are priorities. Prevention of the conversion of land over areas where stormwater may collect, in floodplains and low areas to development should also be a land use priority. For redevelopment areas, reduced development, and the migration of development in these areas should be a priority in local communities. The use of low-impact development (LID) techniques to delay peak and reduce stormwater runoff can be a cost-effective option to consider from a land use perspective. Costs for changes in development patterns and protection of low-lying areas will be costly and highly controversial.

Benefits of retention ponds include that they are well developed from a technology perspective, widely used, well understood. Retention keeps the water on a site, as opposed to detention ponds, which release the water slowly with time to mimic the natural system. Retention ponds (Figure 185) are inexpensive to construct as long as land is available (something developers prefer not to do). They will remove pollutants with limited added features. They do tend to have issues with maintenance, mowing, aeration, and other requirements. Second, if the area is densely built with limited pervious area, the volume of runoff may overwhelm the amount of water the basin can take. Recent rain can cause the pond to be full, and unavailable when you need them for the next rain event. Ponds do not work if not well maintained, in muck soils and when the groundwater levels are high. Another issue might be eutrophication from overfertilization and nutrient runoff. In these circumstances, a better option is required. Figure 186 shows the typical design parameters of retention ponds.

Figure 185. Aerated retention pond



11. Retention Pond

Retention ponds remove pollutants through biological uptake processes and sedimentation. The amount of pollutants that are removed from stormwater runoff is proportionate to the length of time runoff remains in the pond, as well as the relation of runoff to retention pond volume. Since retention ponds must maintain a permanent pool, they cannot be constructed in areas with insufficient precipitation or highly permeable soils, unless the soil is compacted or overlain with clay. Generally, continual drainage inputs are required to maintain permanent pond levels.

Where it can applied
Common for new development, but difficult to retrofit; developer resist because it consumes land they could otherwise develop; limited to open areas

Benefits
Removes water from streets, reduces flooding

Barriers to implementation
Land availability, maintenance of pond, discharge location

Cost
$200k/acre

Figure 186. Design considerations, benefits, barriers, and costs for a retention pond

5.3.8 Central Sewer Installation

As noted previously, less a stormwater issue than an operational solution for addressing septic tanks that will not function when flooded, central sewers are regulated, and programs are in place to monitor them for breaks, leaks, and at the end of the pipe, treatment. The concept is to use gravity lines to collect sewage from households and convey it to a central treatment facility. Disposal can include many options including reuse for irrigation.

Installation of central sanitary sewers has been a standard practice for over 100 years, but many older developments in remote areas are still on septic tanks. In Florida, there are about 2.8 million septic tanks (FDOH, 2020). The challenge is that on-site treatment and disposal systems such as septic tanks may only work when the drainfield is above water, thereby permitting soil treatment of the discharged water in the vadose zone. These systems do not function properly when the water table is high, and the discharge is essentially injected into the near-surface aquifer without treatment and often finds its way into local surface water bodies. Results from observing septic and sewer areas by FAU in south Florida and Taylor County, demonstrate that there is an ongoing release of contaminants during the seasonal high water table elevation event (Meeroff and Morin, 2005; Meeroff, Morin and Bloetscher, 2007; Bocca, Meeroff and Bloetscher, 2007; Meeroff, Bloetscher, Bocca and Morin, 2008; Meeroff, Bloetscher, Long and Bocca, 2014). As a result, septic systems have the potential to contaminate certain stormwater infrastructure (exfiltration, infiltration pipelines), thereby making water quality permitting options more difficult.

Replacement of septic tanks with central sewer is problematic given that it costs $10,000-$15,000 per residential connection to install sewers and remove the old septic tank (not including sewer connection charges), which creates a challenge for residents and a difficult decision for public officials. Design considerations are summarized in Figure 187.

Figure 187. Design considerations, benefits, barriers, and costs for central sewer installation

5.3.9 Armored Sewer Systems

A companion to central sewers, increased infiltration/inflow (I/I) due to saturated soil conditions and infrastructure structural issues (e.g., broken pipes, deteriorating pipes) will need to be addressed. Infiltration (Figure 188) is a direct result of groundwater that migrates into the pipes due to the pipes being underwater, which is the normal situation for most of coastal Florida. Most utilities have peaks, which are likely to become larger if climate change results in increased rainfall volume. Peaks are caused by inflow during rain events – generally surface connections. Reducing infiltration and inflow reduces the demands on wastewater plants, frees capacity, and limits chlorides, which can make reuse disposal options a challenge. It will also reduce the pump run times on lift stations due to lower flows.

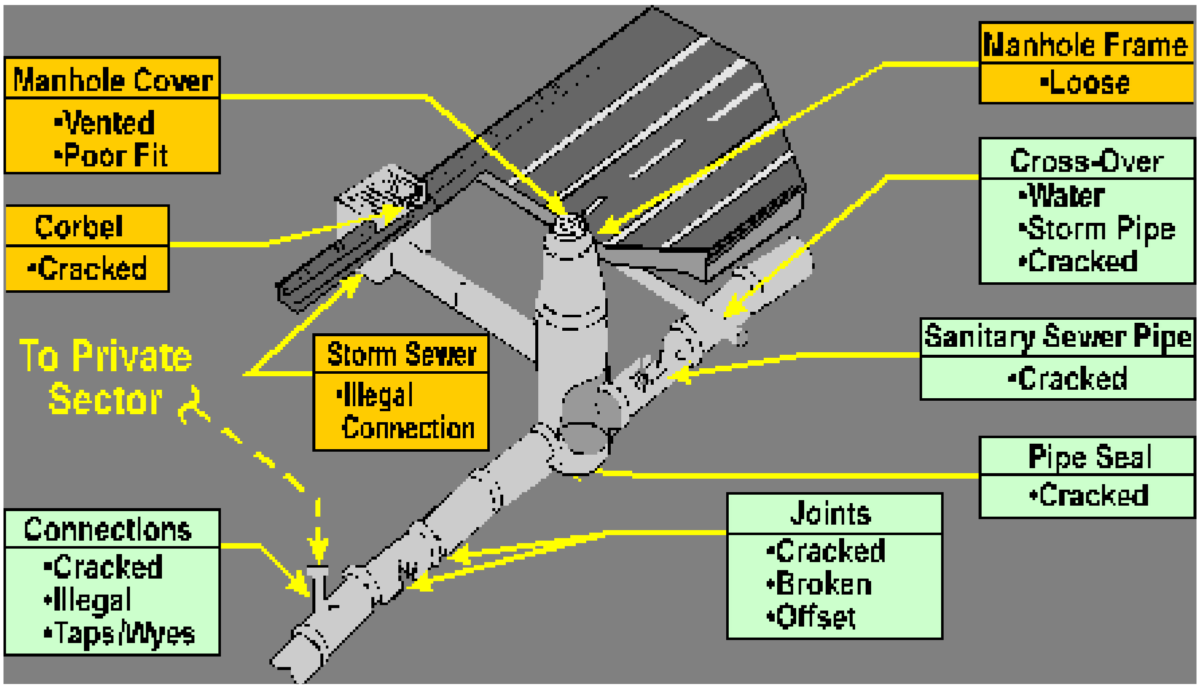


Figure 188. Potential infiltration and inflow areas (Bloetscher, 2008)

It is estimated that there are over 1 million manholes in Florida, nearly all of which are located in areas vulnerable to flooding. New sanitary sewer systems will need to be designed and installed to meet predicted future conditions that could include increased infiltration potential resulting from either changes in rainfall patterns or sea level rise. New and existing systems will need to adapt to these different hydrologic conditions.

Over 10% of sewer service lines are believed to be damaged based on South Florida experience causing about half of the infiltration issues that will be found in a low flow inspection. There are no limits to implementation other than costs. The cost to seal manholes is estimated at $100/manhole with other improvements such as chimney seals (Figure 189), LDL plugs (Figure 190), rain dishes (Figure 191), and ancillary corrections to service lines on both public and private property. A full inflow removal program is on the order of $500/ manhole, which will reduce costs associated with infiltration and generally pays for itself. The improvements will function until the area is fully inundated, and development moves elsewhere. It is a robust improvement that will last for years but does require ongoing upkeep as the system deteriorates with time. Design considerations are summarized in Figure 192.

Figure 189. Chimney seal installed (Courtesy USSI)

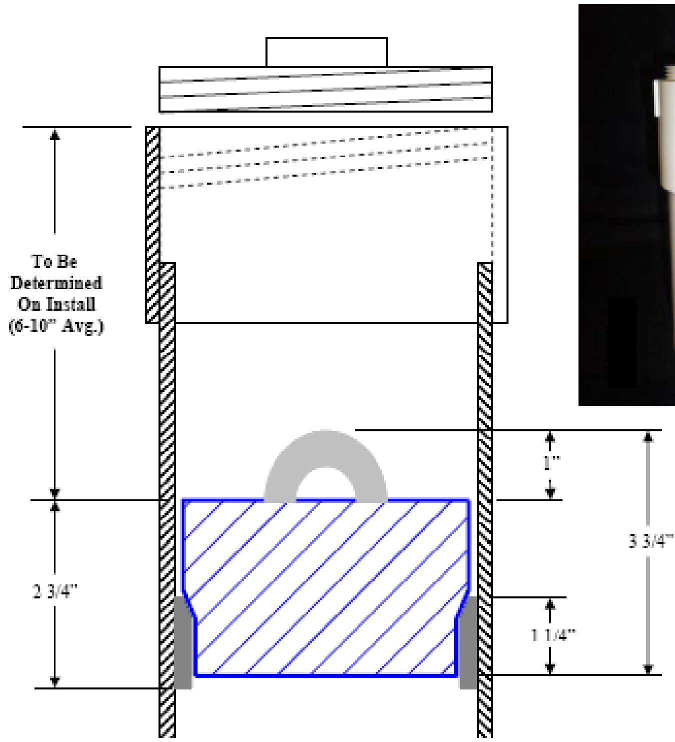
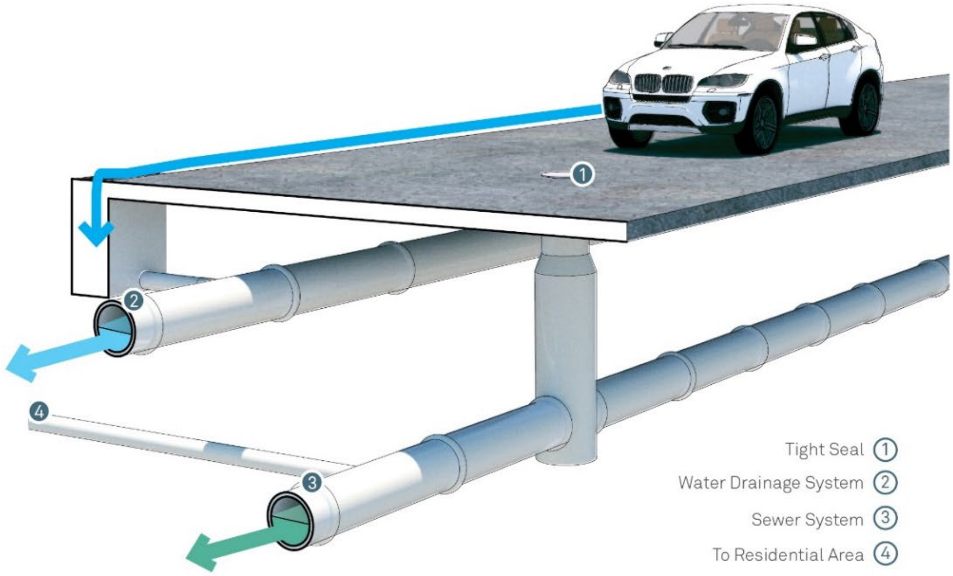


Figure 190. LDL plug design (Courtesy USSI)

Figure 191. Inflow defender manhole rain dish (Courtesy USSI)



22. Armoring Sewer System

Increased infiltration/inflow (I/I) due to saturated soil conditions and infrastructure structural issues (e.g., broken pipes, deteriorating pipes) will need to be addressed. Infiltration is a direct result of groundwater that migrates into the pipes due the pipes being under water, which is the normal situation for most of coastal Florida. Most utilities have peaks, which are likely to become larger if climate change results in increased rainfall volume. Peaks are caused by inflow during rain events – generally surface connections. Reducing infiltration and inflow reduces the demands on wastewater plants, frees capacity, and limits chlorides, which can make reuse disposal options a challenge. It will also reduce the pump run times on lift stations due to lower flows.

Where it can applied
Any area where gravity sanitary sewers are installed, which is most of the City

Benefits
Keeps stormwater out of sanitary sewer system and reduces potential for disease spread from sewage overflows. Major public health solution

Barriers to implementation
limited expense beyond capital cost

Cost
$500/manhole

Figure 192. Design considerations, benefits, barriers, and costs for armoring sewer systems

The protocol for identifying breaches in the system that lead to infiltration/inflow include:

- Inspection of all sanitary sewer manholes for damage, leakage, or other problems all documented in a report that identifies the problem type, location, and recommended repair
- Repair the flow path in the bottom of the manhole (bench) in poor condition or exhibiting substantial leakage
- Repair manhole walls in poor condition or exhibiting substantial leakage

- Repair/seal chimneys in all manholes to reduce infiltration from the street during flooding events
- Install dishes in all manholes to prevent infiltration
- Install LDL™ plugs where manholes in the public right-of-way or other portion of the utility's system are damaged
- Identify sewer system leaks, including those on private property (via location of smoke on private property)
- Perform a low-flow inspection

5.3.10 Pump Stations

In urban areas, stormwater collection and management systems may need to be redesigned and expanded to increase capacity since the current capacity is not likely to address new peaking factors associated with climate change. In low-lying areas, exfiltration trenches and other pipes are already inundated. As a result, a more consistent solution is required, which usually involves pumping. The concept is simple: drain the stormwater to a central area, install a pump, and move the water to another place (or waterbody). Pump stations are commonly used, are reliable, and can protect property. Emergency generators are often required to ensure operation during electrical power disruptions.

Pumping is a preferred strategy when retention areas and exfiltration are not feasible. The difference in head between the surface of the drainage system and the water table is not relevant as the only issue is that the receiving waterbody is lower than the pump to prevent backflow. The amount of pumping is proportional to the area served and the design storm of concern. The pump station demand will increase with time as groundwater levels rise, precipitation becomes more intense, or water crosses the sea walls. Hence pumping stations must be designed to be expanded or they will have to be replaced.

The cost of pump stations starts at $250,000 and increases with demands and area served. Very large ones may cost upwards of $100 million. Developers routinely install them when retention ponds cannot be constructed. Pump stations do not remove contaminants in and of themselves. Treatment can be added at the station with increased cost and maintenance. A bigger issue is water quality impacts to the receiving waterbody. It should be noted that water quality is sensitive to increased water temperatures, changes in patterns of precipitation, and changes in pollutant loadings. If a waterbody, such as the Intracoastal Waterway, receives more water from the land, nutrients, carbon, and other contaminants will increase, while salinity will be reduced. All have poor impacts on native biota in the estuary. Temperatures increase due to runoff, so there will be both direct and indirect effects on aquatic ecosystems, especially during low-flow periods. Water quality impacts to surface waters are currently difficult to quantify. There are no current hydrologic observing systems for purposes of detecting effects on water resources, and limited studies of hydrologic trends in the southeast of Florida have been completed. Lower flows in streams during the summer and fall could substantially reduce available dilution in those streams, thereby concentrating salts and other pollutants. Temperature and nutrients will reduce dissolved oxygen (by increasing temperature and increasing metabolism). As a result, it may become more difficult to meet or maintain current surface water quality standards for receiving water bodies.

Pumping is one of the more robust solutions for dealing with runoff and sea level rise. Larger stations will be needed, employing more power, and requiring more maintenance. Studies for individual neighborhoods will be required to identify such needs. At some point, pump stations will cease to work when an area is completely inundated by coastal water bodies. Design considerations are summarized in Figure 193.

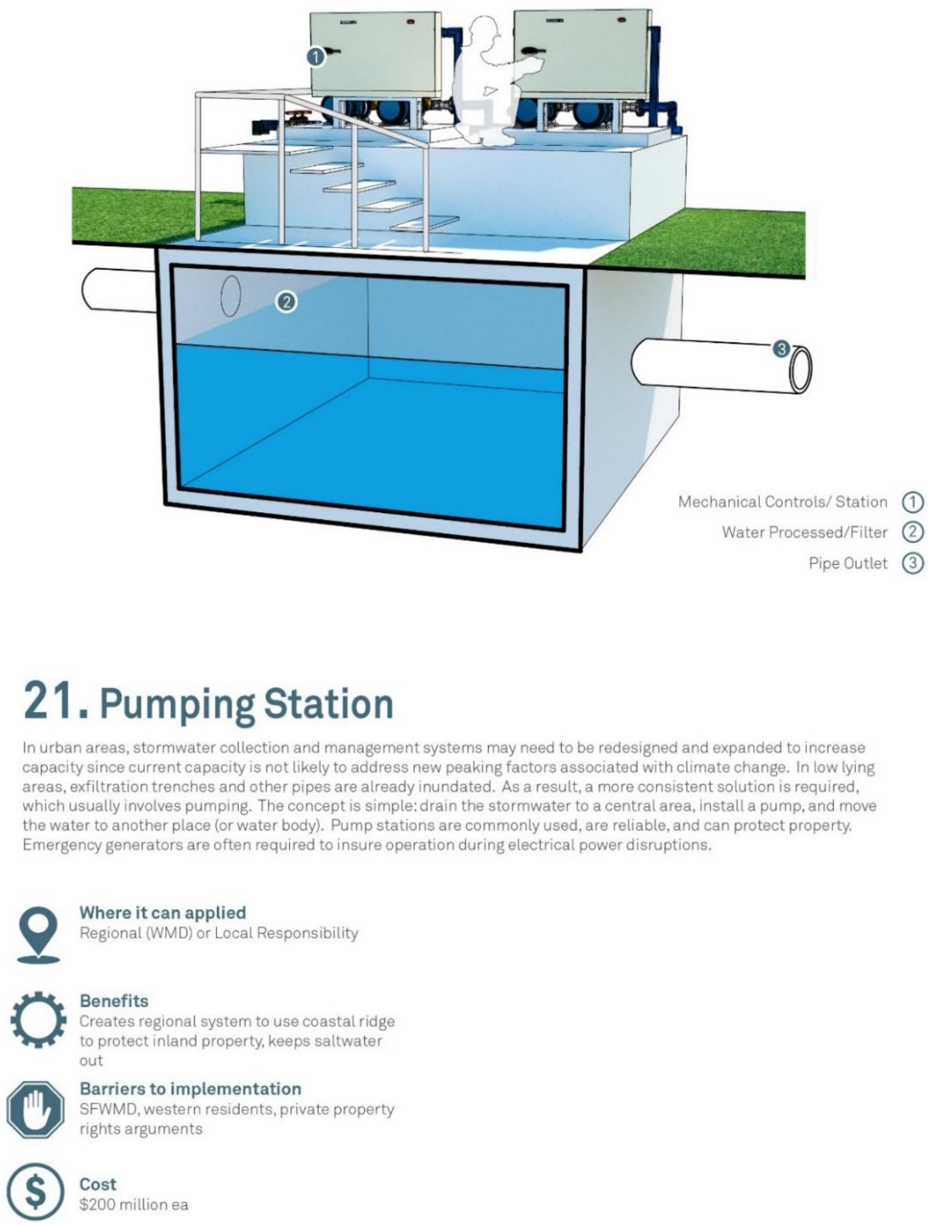


Figure 193. Design considerations, benefits, barriers, and costs for pump stations

5.3.11 Sea Walls

Sea walls have been successfully used as a means to protect areas of human habitation, conservation, and leisure activities from the action of tides, waves, or tsunamis. Historically they have been made of many different materials, from monolithic concrete barriers, brick or block walls, rubble mound structures, or steel sheet pile walls. They are naturally, heavily engineered, permanent structures that are costly to design but are a common site along the Florida coastline. The physical design of sea walls is highly variable; they can either be sloping or vertical and made from a wide range of materials. The design and the texture of the walls also have a significant impact on its performance. For example, while a smooth surface reflects wave energy better, irregular surfaces, on the other hand, disperse the direction of the waves better. Typically, the seawalls must have a deep foundation to enhance its stability. Also, earthen anchors are mostly buried deep into the land and connected by rods to the wall to help it overcome pressure from the landward side. Design considerations are summarized in Figure 194. The anchors are not appropriate for fill which is the case on most island and coastal communities. Deeper foundations are needed which cost more.

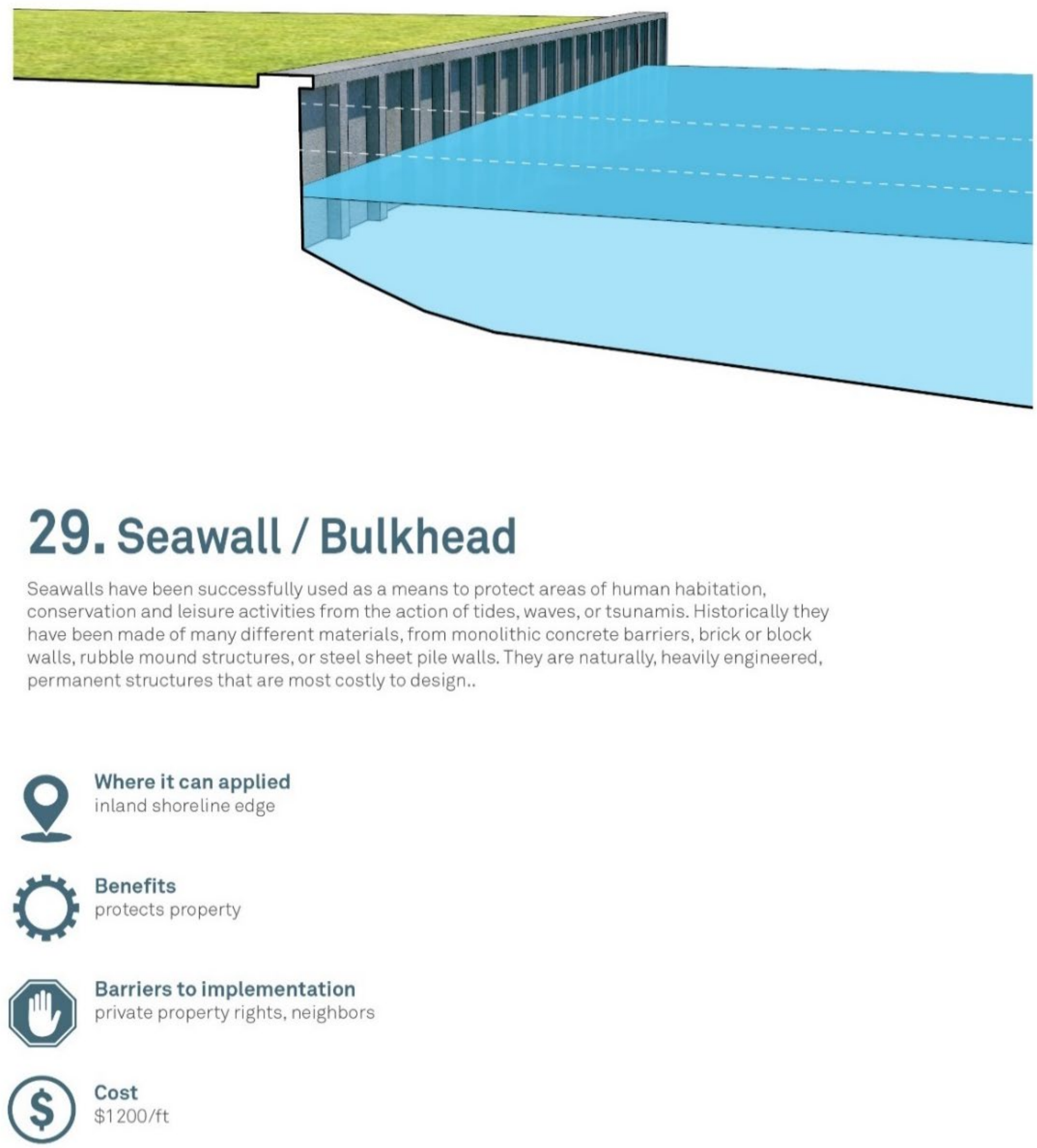


Figure 194. Design considerations, benefits, barriers, and costs for seawalls

The concept of sea walls is to prevent property from flooding (see Figure 195). Figure 196 shows the concept. However, as the sea rises, these walls may get overtopped. 8 ft is the minimum elevation suggested for the 2100 timeframe.

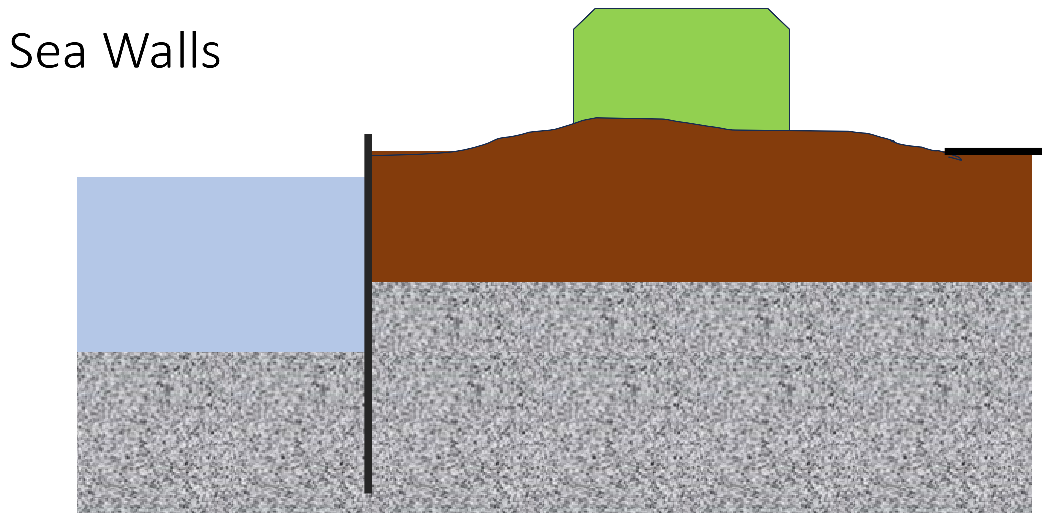


Figure 195. Sea Walls protect adjacent property

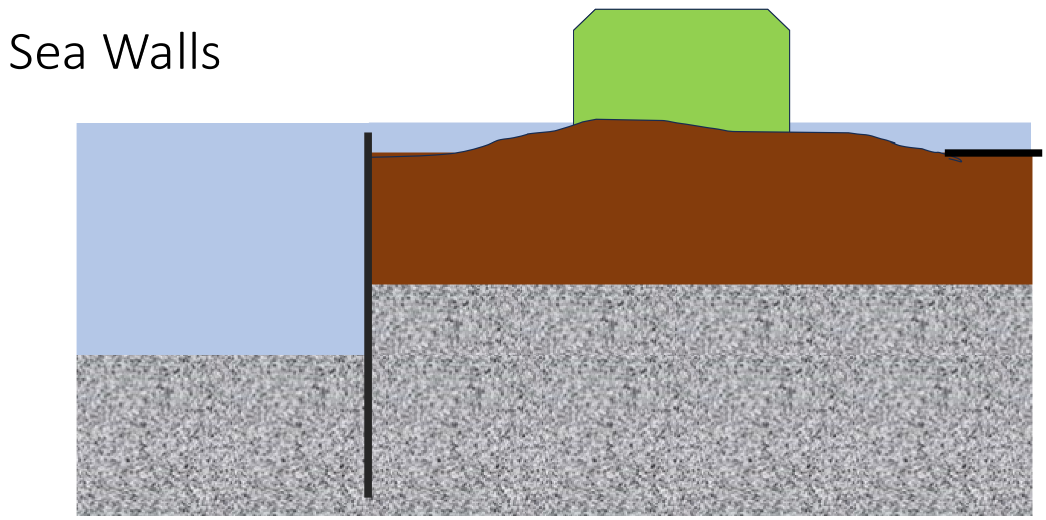


Figure 196. Sea walls will create flooding that cannot easily be removed if topped.

There are sea wall challenges. Many sea walls are structurally deficient. As a result, they will not suffice for current conditions let alone future ones. Increasing sea wall height is needed, but requires policy adjustments and many current sea walls will not be structurally sufficient to add height. Failure of any sea walls invalidates all others on the same water body.

Drainage pipes go through the sea walls to drain roads (see Figure 197). As the sea level rises, the water backflows into the street (see Figure 198). Hence the apparent flooding may be sea level or king tide induced. Tideflex and other companies have options to prevent backflow (see Figure 199). All require periodic maintenance, especially in marine environments. Where sea walls may not be adequate to connect the valve inserts (Figure 200) are required – see final installation in Figure 201). Road-based failures result from the failure to install backflow devices.

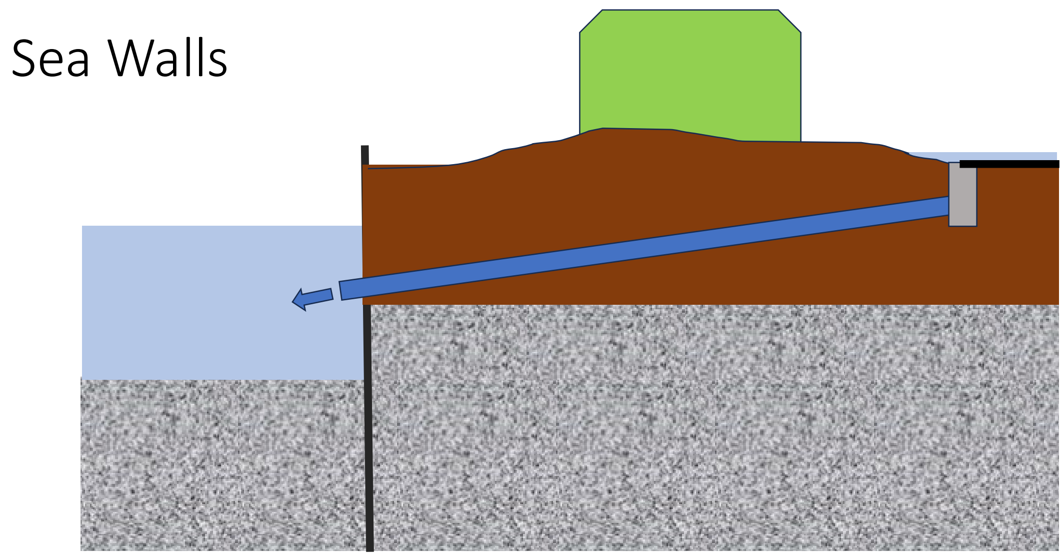


Figure 197. Storm Drains from Roads through Sea walls

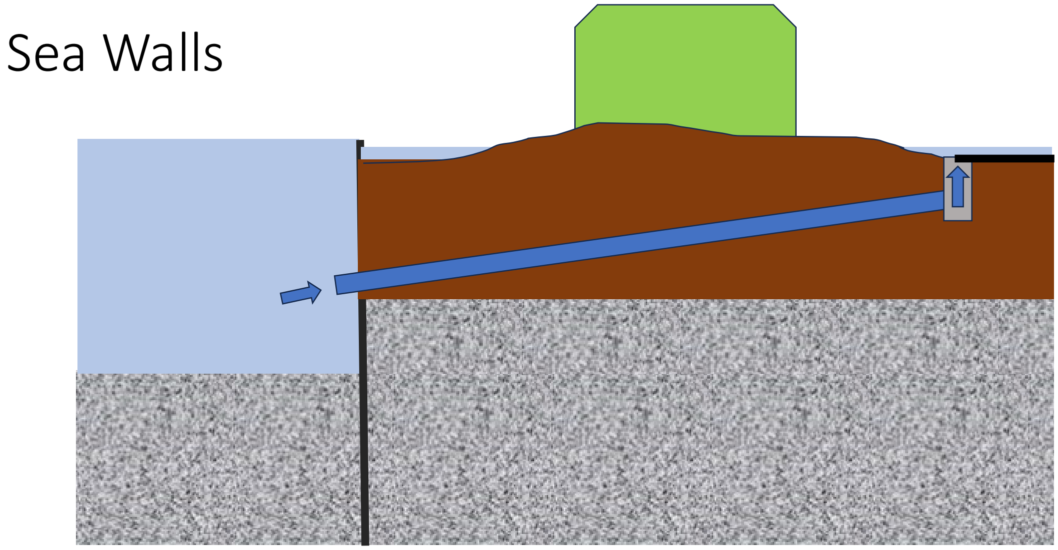


Figure 198. Storm Drains flow backward in coastal areas when tides or sea level rise.

Figure 199. Backflow valves

Figure 200. Sea wall insert for Tideflex valve

Figure 201. Completed Tideflex installation with insert

5.3.12 Roadway Base Protection

A major reason is that many wastewater treatment plants originated as small developer-owned systems designed to serve their development, and later were deeded to local governments. Figure 202shows the road base as intended to be developed with the water table below the base. Then the water tale rises (Figure 203), and the fines within the base material move, causing the base to shift which then causes the pavement to flex as traffic moves on it. Cracks in the crown will develop- the first major indication that the base, not the pavement has failed. Geotextile and other means to prevent the movement of fines or intrusion of water are necessary.

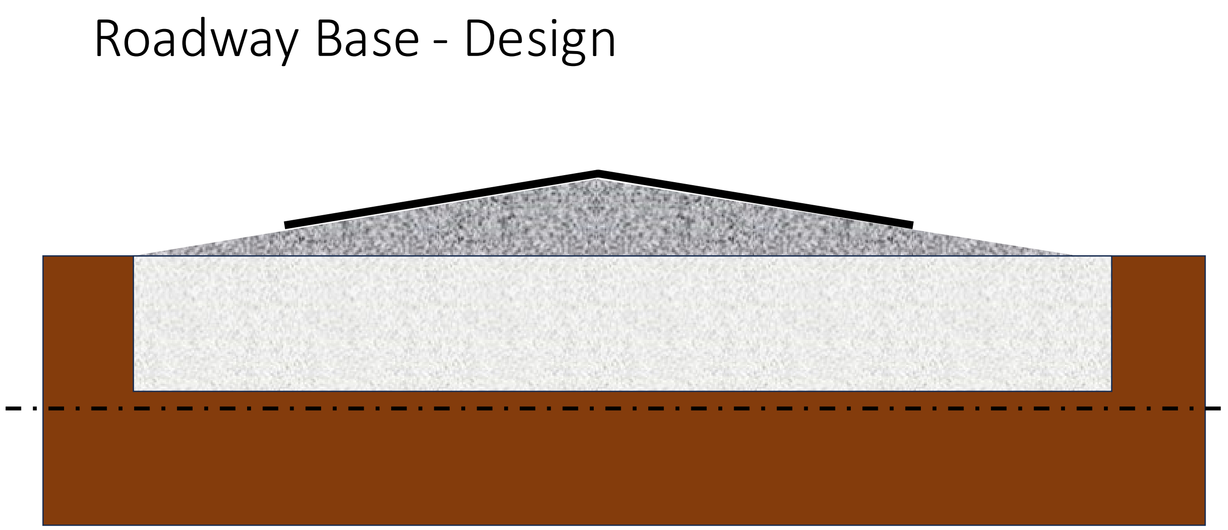


Figure 202. Roadways as intended to be constructed

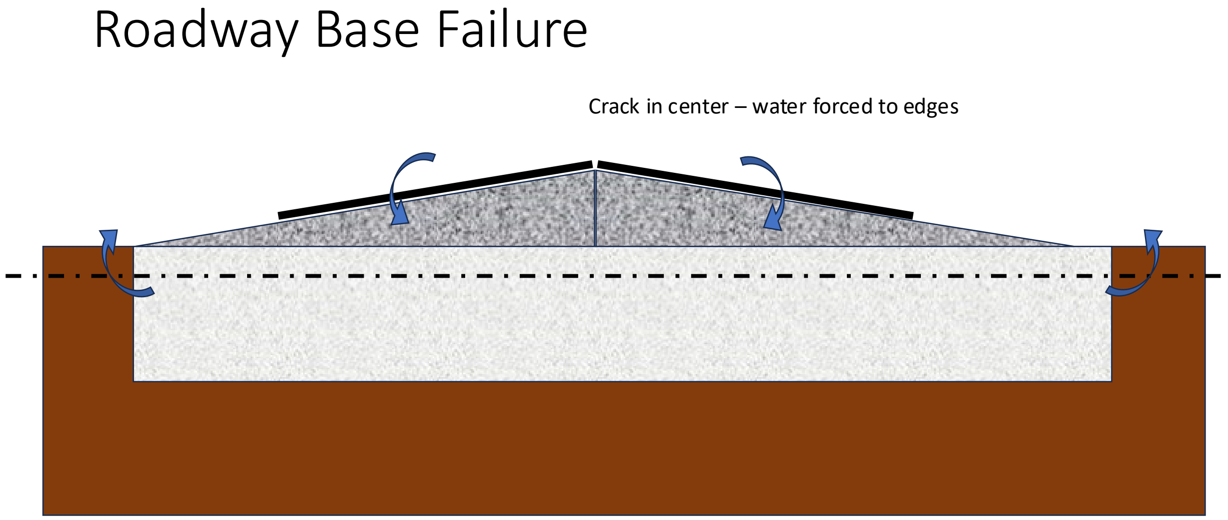


Figure 203. Roadways once the base gets wet and longitudinal cracks develop at the crown

Conventional disposal methods (e.g., stream discharges or ocean outfalls) are not easily permitted or have proven to not be sustainable. The costs of injection wells for small systems cannot be justified either, so the reuse (usually by percolation ponds) of small quantities of wastewater was the chosen alternative for disposal. Because it is critical to protect the roadway base, all efforts should begin with providing the base with adequate drainage systems to meet future conditions. At present, most base courses are installed above the water table. As long as the base stays dry, the roadway surface will remain stable. The costs for roadway base protection systems could exceed $1 million per lane-mile. Design considerations are summarized in Figure 204.

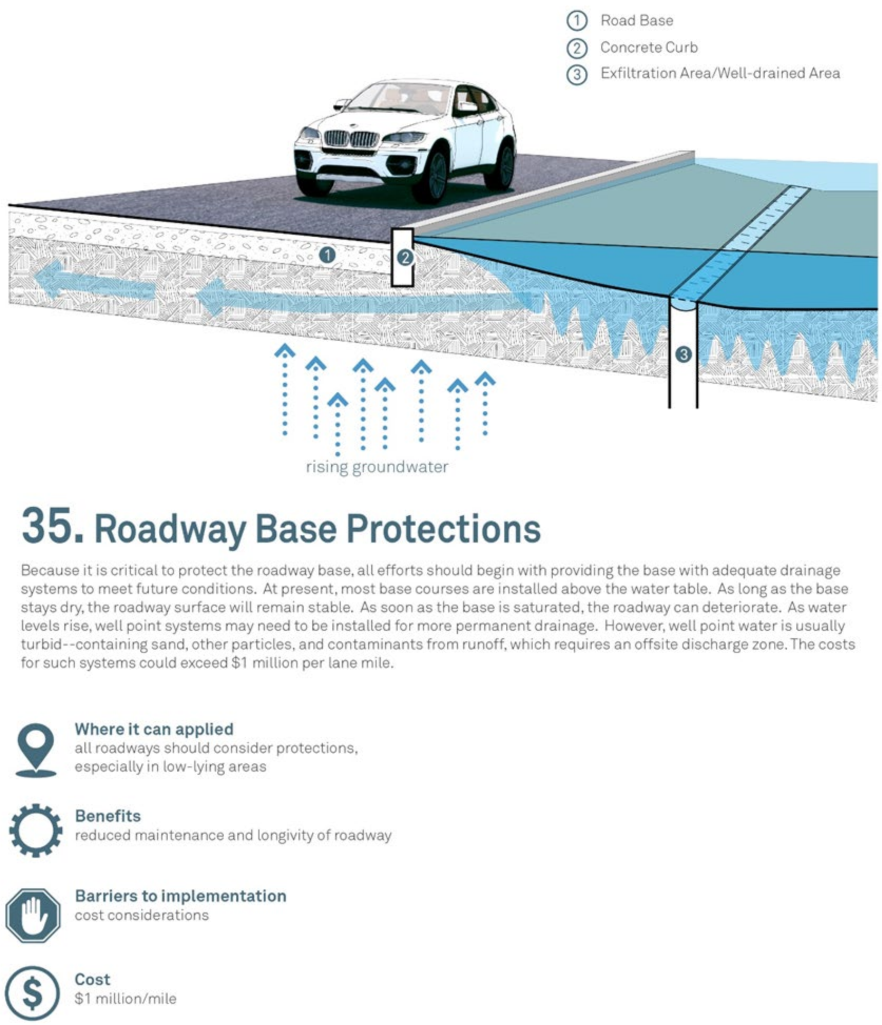


Figure 204. Design considerations, benefits, barriers, and costs for roadway base protections

5.3.13 Changes in Land Use Practices

Reduced development and the migration of development in these areas should be a priority in local communities. The use of low-impact development (LID) techniques to delay peak and reduce stormwater runoff can be a cost-effective option to consider from a land use perspective (see Figure 205). In the long term, development policies will need to include the 50- and 100-year vision of development and require developers to include hardening within ordinances. This policy highlights a potential conflict point where the long-term tax base will depend on securing future protection, yet taking property out of service reduces the tax base. Additional development in flood-prone areas should not be permitted without local solutions. State and local agencies have been averse to such regulations due to private property rights arguments. However, certain properties may have value to local governments for various purposes (storage of stormwater for example, or mangrove forests to counter waves). However, this is a policy decision that is likely years out.

Figure 205. Design considerations, benefits, barriers, and costs for changes in land use practices

5.3.14 Policy Changes (to land uses)

This option is wide ranging, from changes to zoning, requirements to elevate properties, and abandonment of property. These solutions are site specific, designed to reduce the potential for flooding in the community. This would apply only where property could not be protected from flooding without changes to the property. Elevation is common in low-lying coastal areas (Figure 206). Abandonment of property creates major issues with property rights. If properties were to be abandoned, adjacent properties could be affected. The domino effect of having large tracts being abandoned would suggest a lack of stability in the community, leading to lower property values, loss of taxable property, and a loss of tax base. This is a worst-case scenario for the community, and only a few communities would be prepared to look at it.

36. Policy Changes

Additional development in flood prone areas should not be permitted without local solutions that are vetted, tested, and accepted. With time, at-risk property values will diminish due to the lack of ability to secure insurance and financing. The property may have value to local governments for various purposes (storage of stormwater for example or mangrove forests to counter waves). However, this is a policy decision that is likely years out. Other policy changes that are developed to adapt to flood conditons should be prioirtized as a first step to enabling by right practices in mitigation by property owners, neighborhoods and governmental agencies in charge of land development policies.

Where it can applied
all low-lying and upland areas that are prone to flooding

Benefits
multiple

Barriers to implementation
conventional practices create obduracy and do not provide necessary outcomes

Cost
Varies

Figure 206. Policy changes including changing land use, abandonment of property

5.3.15 Flood Prone Property Acquisition

The loss of wetlands, mangroves, and other coastal ecosystems diminishes the ability to store water or to provide areas to direct excess precipitation to avoid flooding. Conservation of land to prevent development over areas where stormwater may collect, in floodplains and low areas should be a land use priority. While the NFIP and FEMA will not prohibit development in a flood zone, local officials have the capacity to enhance restrictions on land development and acquire properties that are repetitive losses. The goal is to remove land that is subject to flooding from development pressures. Landowners may willingly sell the property and may be compensated for losses incurred and zoning that prevents redevelopment and a host of other options. These are costly options, as the acquisition of developed property can be a major cost. However, the benefits of not having to protect such properties may prove to have a positive long-term outcome. A summary of considerations is shown in Figure 207.

Figure 207. Design considerations, benefits, barriers, and costs for flood-prone acquisition

Table 6. Summary of benefits, costs, and barriers for each of the engineering alternatives in the toolbox

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
Green	Rainwater harvesting	Local, small scale, easily implemented in developed areas	Protects property, treats runoff	Under $5,000	Limited volume disposed of, so many are needed, maintenance
Gray	Pervious paving	Parking lots, patios, driveways, anything except paved roads due to traffic loading	Reduces roadway and parking lot flooding	$10-20/sf, requires bumpers and sub-base to maintain paver integrity	Must be maintained via vacuuming or the perviousness fades after 2-3 years
Green	Detention	Common for new development, but difficult to retrofit; limited to open areas	Removes water from streets, reduces flooding	$200K/ac	Land availability, maintenance of pond, discharge location Uses up land that could otherwise be developed
Green	Bioswale	Parking lots, runoff from development - primarily treatment for discharge to another system	Protects property, treats runoff	$20K/ac	Maintenance, limited volume disposed of, used mostly for treatment
Green	Detention	Common for new development, but difficult to retrofit; limited to open areas	Removes water from streets, reduces flooding	$200K/ac	Land availability, maintenance of pond, discharge location Uses up land that could otherwise be developed
Green	Dry Swale	Parking lots, runoff from development - primarily treatment for discharge to another system	Protects Property, treats runoff	$200K/mi	Maintenance, limited volume disposed of, mostly for treatment

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
Gray	Exfiltration Trench	Any low-lying area where stormwater collects and the water table is more than 3 ft below the surface; densely developed areas where retention is not available, roadways	Excess water drains to an aquifer, some treatment provided	$250/ft	Significant damage to roadways for installation, maintenance needed, clogging issues reduce benefits
Gray	Central sewer installation	All areas where there are septic tanks. Mostly a water quality issue	Public health benefit of reducing discharges to lawns, canals, and groundwater from septic tanks	$15,000 per household	Cost, assessments against property owners, property rights issues
Green	Flood-prone property acquisition	Regional agency - could be any low-lying areas	Removes flood-prone areas from risk	$2K-$100K/ac depending on whether it is already developed	Difficult to implement if occupied, issues with willing sellers, cost, lack of funds for acquisition
Gray	Pump stations	Any low-lying area where stormwater collects, and there is a place to pump the excess stormwater to such as a canal; common for developed areas	Removes water from streets, reduces flooding	Start at $1.5 to 5 million each, number unclear without more study	NPDES permits, maintenance cost, land acquisition, discharge quality

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
Gray	Armored sewer systems	Any area where gravity sanitary sewers are installed	Keeps stormwater out of sanitary sewer system and reduces the potential for disease spread from sewage overflows	$500/manhole	Limited expense beyond capital cost
Gray	Sea walls	Barrier islands and downtown coastal areas	Protects property	$1200/ft	Private property rights, neighbors
Policy	Changes in land use	Applicable universally	Achieves flood risk mitigation by adjusting permitted land use	Low but may incur private property rights conflicts and litigation	Private property rights conflicts and litigation
Gray	Roadway base protection	Low-lying areas, coastal communities	Protects roads and access routes	$1 million per lane-mile	Cost, adjacent properties become uninsurable
Policy	Enhanced elevation of buildings	Developers would implement this for new construction	Reduced flood risk	Varies	Potential issues with building structure or latticework, and existing homes that are not elevated

5.4 Capital Improvement and Financing Plan

Once the vulnerability assessment and mitigation measures are determined, the next step is to implement the plan to address these issues—in other words, it is often possible to add mitigation measures to existing capital improvement programs. Every infrastructure agency will spend money to operate and maintain the infrastructure system. Agencies involved in flood protection are no different, they all spend money on operations, debt, and capital. These factors are brought together in annual budget documents. Budgets are a necessary part of operations and are statutorily required for most jurisdictions. In most cases, all infrastructure agencies should set up as an enterprise fund to allow the organization to pay its own way, which will also make it easier to evaluate the operational aspects of an infrastructure system.

Coordination between the financial, budget, and operating policies of a utility system allows managers to properly allocate costs to those benefiting from the service, develop pricing strategies that can be clearly explained to the public, and prevent challenges to allocation methodologies. Operations, capital programs, and long-term variability of the utility system operation require financial and facility planning. Multi-year economic forecasts and financial plans are standard tools in business and are worthy of consideration by watershed and flood protection agencies and elected officials

An example process that USEPA (2013) suggests for capital plans is:

1. "Inventory existing management efforts in the watershed, considering local priorities and institutional drivers
2. Quantify the effectiveness of current management measures
3. Identify new management opportunities
4. Identify critical areas in the watershed where additional management efforts are needed
5. Identify possible management practices
6. Identify relative pollutant reduction efficiencies
7. Develop screening criteria to identify opportunities and constraints
8. Rank alternatives and develop candidate management opportunities"

A best practice is to develop a prioritized project list.

5.4.1 SWFWMD/USACE Regional Capital Improvement Projects

The SWFWMD has an extensive effort devoted to floodplain management. The program is funded with over $46 million. In addition, they have a BMP matching program involving $9.2 million and $2.2 million for canal maintenance, although exactly where any of this will be spent is unclear.

5.4.2 County-Wide Capital Improvement Projects

Manatee County has about $6.6 million in improvements for stormwater improvements, including stormwater pipe replacement, upgrades, and lining.

Sarasota County has about $23 million in improvements for stormwater improvements, including stormwater pipe replacement and upgrade of Phillippi Creek and other waterways.

Charlotte County has about $14 million in improvements for stormwater improvements mostly via funds for dredging. There are no specific stormwater projects noted although the County funds these with MSTU/MSBU districts (assessments).

5.4.3 Local Capital Improvement Projects

Programs for monitoring operations and ensuring that ongoing inspections take place are needed. FDEP can coordinate the regulatory compliance with these Clean Water Act requirements. In addition, upon completion of the regional reservoir projects, re-modeling of the watershed should be conducted to incorporate these features. This practice will permit a change to the impact maps, allowing for some potential reductions to impacted areas. The impact of sea level rise must also be considered as it may mean an effort in the east to reduce flooding.

The City of Sarasota spends $50,000 per year on curbing, but contracts with Sarasota County for stormwater maintenance.

Bradenton has allotted over $5 million for stormwater piping upgrades, replacement, and repairs, as well as neighborhood improvements. The city has about $6.6 million in improvements for stormwater improvements, including stormwater pipe replacement, upgrades, and lining. Palmetto has budgeted $558,000 for similar purposes. Longboat Key spends roughly $1 million on capital including drainage projects. Cape Coral spends just over $ 1 million per year on general maintenance of the stormwater system including swale cutting and general projects. Priorities go to flooded areas. Table 7 outlines the capital efforts of all lower southwest Florida communities.

Table 7. Capital plan and prioritization estimate

Problem	Goal	Project	Agency	Cost (000)	Scale	Risk	Consq
Drainage	Flooding	curbing program	City of Sar	50	Local	2	2
Flood control	Storage/Flooding	Bahai Vista Levee	SarCounty	312	Local	2	2
Flood control	Storage/Flooding	Dona Bay Ph 4 Kings Gate	SarCounty	530	Local	2	2
Flood control	Storage/Flooding	Dona Bay Ph 5 Blackburn Canal	SarCounty	385	Local	2	2
Flood control	Storage/Flooding	Phillippi Creek Trib restoration/C4-86 canal	SarCounty	2450	Local	4	4
Flood control	Storage/Flooding	Sarah Ave Drainage	SarCounty	153	Local	2	2
Water quality	Water quality	Sediment Abatement	SarCounty	7703	Local	2	2
Flood control	Storage/Flooding	S Venic Garden Pipe inspection	SarCounty	600	Local	2	2
Water quality	Water quality/reduce flooding	N Phillippi Creek SW Quality	SarCounty	3198	Local	2	2
Water quality	Water quality/reduce flooding	Phillippi Creek Natural system restoration PH 2	SarCounty	2757	Local	2	2
Water quality	Water quality	S Alligator Creek WQ	SarCounty	2974	Local	2	2
Flood control	Storage/Flooding	Briarwood	SarCounty	990	Local	2	2
Water quality/flood protection	Water quality/reduce flooding	Alligator Creek Stream restoration	SarCounty	990	Local	2	2
Drainage	Flooding	Curbing program	City of Sar	50	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	57th Ave Dr Storm Drain replacement	Manatee Co	100	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	87th Ave Ct Storm Drain replacement	Manatee Co	565	Local	2	2

Potential risk, flood and failure	Drainage, infra condition	Cortez Villr Storm Drain replacement	Manatee Co	150	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Culvert upsizing	Manatee Co	1051	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Glenn Creek SW piping	Manatee Co	951	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Lambeth Ac SW Outflal Repl	Manatee Co	534	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	North Palm Aire SW Rehab	Manatee Co	50	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Sugarhouse Ct 301- Mock Hill SW	Manatee Co	264	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Sunniland and North Palm pipe rehab	Manatee Co	650	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Tallecast Rd SW Repl	Manatee Co	1800	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Tidevue Est SW Repl	Manatee Co	470	Local	2	2
Flood control	Storage/Flooding	14th St SW pipe and pond	Bradenton	200	Local	2	2
Flood control	Storage/Flooding	3rd ave ext	Bradenton	279	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Misc SW impr	Bradenton	2000	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	City Plaza Draiange	Bradenton	1000	Local	2	2
Flood control	Storage/Flooding	Oak St Drainage	Bradenton	604	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	18th Ste	Bradenton	152	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	26th St	Bradenton	150	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	9th and Avesta	Bradenton	125	Local	2	2

Potential risk, flood and failure	Drainage, infra condition	CMP Repairs	Bradenton	250	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	CMP repl	Bradenton	346	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Vilage Green linine	Bradenton	100	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Vilalage Green Repl	Bradenton	50	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Vota South SW Pipe	Bradenton	500	Local	2	2
Potential risk, flood and failure	Fllod risk reduction	SW Master plan	Palmetto	25	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Dredging	Palmetto	150	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	27th Ave Box Vlvert	Palmetto	250	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	4th&10th Storm drain	Palmetto	133	Local	2	2
Potential risk, flood and failure	Drainage, infra condition	Dredging	Longboat Key	1000/yr est	Local	2	2
Flood risk	reduce flood risk	Alligator Creek Entracne canal	Charlotte County	399	Local	2	2
Flood risk	reduce flood risk	Buena Vissta Dredging	Charlotte County	466	Local	2	2
Flood risk	reduce flood risk	Gulf Cove dreging	Charlotte County	1785	Local	2	2
Flood risk	reduce flood risk	Harbour Heights dredging	Charlotte County	65	Local	2	2
Flood risk	reduce flood risk	Hayward Cnaal dredging	Charlotte County	356	Local	2	2
Flood risk	reduce flood risk	Manchestr canal dredging	Charlotte County	732	Local	2	2

Flood risk	reduce flood risk	NWPC Interior cnaal dredgeing	Charlotte County	741	Local	2	2
Flood risk	reduce flood risk	NWPC Exterior dredginb	Charlotte County	357	Local	2	2
Flood risk	reduce flood risk	Pirae Harbor dredging	Charlotte County	468	Local	2	2
Flood risk	reduce flood risk	S Gulf Cove dredging	Charlotte County	1611	Local	2	2
Flood risk	reduce flood risk	Stump Pass Dredging	Charlotte County	6736	Local	2	2
Flood risk	reduce flood risk	Suncoast Dredging	Charlotte County	tbd	Local	2	2
Flood Control	reduce flood risk	BMP matching program	SWFWMD	9200	Regional	2	2
Flood Control	reduce flood risk	Canal Maint	SWFWMD	2200	Regional	2	2
Flood protection/mgmt	reduce flood risk	Flood plain mgmt program	SWFWMD	46319	Regional	2	2
Potential risk, flood and failure	Drainage, infra condition	Bridge rehab	Cape Coral	1000/yr	Local	3	1
Flooding	Flood resiliency	28 Weir Rehab	Cape Coral	1000/yr	Local	3	3
Flooding, repairs	Reduce Flooding	Operation Rwpairs	Cape Coral	3600/yr	Local	3	4
Water quality	Reduce Flooding	Street sweeping	Cape Coral	400/yr	Local	2	3
Flooding	Reduce Flooding	Swale Cutting	Cape Coral	4,000/yr	Local	2	2
Flood control	Storage/Flooding	SW Capital	Cape Coral	144	Local	2	2

6.0 ACTION PLAN

The key components of the implementation phase are: 1) the implementation team, 2) information/education, 3) capital improvement projects, 4) maintenance, 5) monitoring, and 6) evaluation and adjustments. A watershed implementation team made up of key stakeholder partners from the planning team, particularly those whose responsibilities include making sure tasks are being implemented, reviewing monitoring data, ensuring technical assistance in the design and installation of management measures, finding new funding sources, and communicating results to the public.

6.1 Information/Education Plan

Every WMP should include an outreach component that involves the community. Because individual actions and voluntary practices are involved in the solutions outlined in the plan, effective public involvement and participation will promote the adoption of management practices, ensure sustainability, and encourage changes in behavior that will help to successfully achieve the goals and objectives. This comprehensive guide has six critical steps of outreach:

1. Defining goals and objectives
2. Identifying target audiences
3. Developing appropriate messaging
4. Selecting materials and activities
5. Distributing the messages
6. Conducting evaluation and continuous improvement

Although awareness of the issues is a good first start, the public should be educated on the challenges facing the watershed and become invested in the solution by knowing what specific actions they can take to participate in successful implementation (Appendix A).

6.2 Maintenance Plan

The goal of managing stormwater is to protect public health, welfare, and safety by reducing flood impacts on a community, the potential for waterborne disease from flooding, and the potential for property damage if flooding occurs. Public and private property may include homes, businesses, roadways, railroads, bridges, utilities, etc., so the first objective is to remove excess water in a timely manner, to a place where it will not adversely impact the public and the economy. To prevent flooding and the potential for health risks associated with stagnant water, stormwater runoff must be managed in an organized and systematic manner if property owners are to enjoy the full use of their property and roadways are to be clear. As a result, stormwater facilities must be constructed and maintained to reduce the negative impacts of runoff.

The burden of managing this stormwater typically falls to a local community stormwater organization – typically a special district, stormwater utility, or a division of a local government. For this basin, these governments are:

- City of Sarasota
- Sarasota County
- Manatee County
- Southwest Florida Water Management District

Federal programs created under the Clean Water Act specify that those communities with local stormwater infrastructure – pipes, pumps, catch basins, exfiltration trenches, retention basins, etc. – are required to adequately fund and perform the following:

- Annual Maintenance
  - Disk dry retention area bottoms
  - Disk swale bottoms
  - Correct stormwater wet retention area

- Semi-Annual Maintenance
  - Correct areas of erosion, undercutting, or dead grass in wet and dry retention areas and swales
  - Take appropriate action on petroleum or other pollution spills noted
  - Swale cleaning
  - Remove invasive plants
  - Remove sediment from exfiltration trenches
  - Clean exfiltration trench

- As Needed Maintenance
  - Mow wet and dry retention areas and swales
  - Stabilize banks of wet and dry retention areas
  - Rehabilitate exfiltration trenches every 10 years
  - Correct wet and dry retention area equipment
  - Correct dry retention area bottoms
  - Nutrient/pesticide management
  - Clean bottom debris
  - Re-sod banks of wet and dry retention areas as needed

    - Inspect all retention ponds

Such maintenance activities also require good record-keeping to develop and maintain accurate mapping of the drainage system and track improvements in areas with ongoing stormwater issues.

6.3 Monitoring and Compliance Requirements

Because stormwater protection is often more regional than local in many cases, most communities participate in programs under permits secured by a regional agency (county level is common) to address the interconnectedness of water bodies through neighboring jurisdictions. Monitoring programs are primarily administrative features of watershed management. A good environmental monitoring program (EMP) will assess the effectiveness of the overall hygienic practices in a facility and provide necessary information to prevent failures or property damage, or at least reduce the risk of same. The following are typical monitoring program elements:

Inspections:

- Annual
    - Wet retention area
    - Swale bottoms
    - Disk bottom

- Semi-Annual
    - Dry Retention areas
    - Exfiltration trenches
    - Swales
    - Sediment in wet retention, dry retention, and swale areas

- Quarterly
    - Catch basins

Stormwater Management Program:

- Submit annual inspection and maintenance report
- Conduct required inspections and maintenance
- Develop and maintain record-keeping system

New Development:

- Implement state, local, and regional policies with regard to stormwater and drainage management controls
- Review Land Development Regulations to determine where changes must be made, especially to swales, low-impact development, stormwater reuse, and landscaping

Roads:

- Litter control
- Implement Best Management Practices (“BMPs”), also called Best Stormwater Practices
- Perform maintenance of catch basins, grates, storm drains, structures, swale gutters, and other features

Flood Control:

- Ensure new development flood control meets performance standards in 62-40 F.A.C.
- Strengthen local comprehensive plans and submit them to the County
- Maintain a GIS layer with water quality information
- Ensure flood control meets with water management district rules

Pesticides and Herbicides:

- Provide certification and licensing of applicators

Illicit Discharges:

- Conduct assessment of non-storm discharges
- Provide copies of newly adopted ordinances prohibiting illicit discharges and dumping
- Continue the random inspection program
- Define allotment of state and resources to stormwater program
- Report and prosecute all violators
- Conduct periodic training for staff on the identification and reporting of illicit discharges
- Terminate illicit discharges and document same.
- Develop municipal procedures for handling and disposing of chemicals and spills, including training of staff on emergency response
- Distribute brochures to the public on appropriate disposal of hazardous materials
- Develop public outreach efforts for oil, toxic, and hazardous waste for the public

- Promote Amnesty Day for hazardous materials
- Develop a voluntary storm drain marking program
- Continue infiltration and inflow program on sanitary sewer system
- Investigate septic tank discharges to stormwater system

Industrial Runoff:

- Maintain inventory of high-risk discharges, including outfall and surface waters where discharge occurs.
- Provide ongoing inspections of high-risk facilities
- Provide an annual report to the appropriate agency for enforcement
- Monitor high-risk facility discharge water quality

Construction Sites:

- Ensure stormwater system meets treatment performance standards in 62-40 FAC
- Continue construction site inspection program to ensure reduction of off-site pollutants
- Implement a standard, formalized checklist of stormwater management and water quality inspection items
- Maintain a log of stormwater management activities at construction sites
- Provide a detailed description of the inspection program and forms
- Provide a summary of activities
- Continue inspection certification program for stormwater management, erosion, and sediment control for operators, developers, and engineers
- Develop outreach programs for local professional organizations

Environmental/watershed monitoring programs should verify ongoing demonstration of maintenance using logs, work orders, photographic documentation, and geographic information systems (GIS) support to ensure all of these facilities not only operate properly but also reduce pollutants. These requirements mean that the community needs funds to ensure that monies are available to properly execute the program to ensure compliance. Effort is required to maintain the functioning of stormwater systems, many of which have been neglected with time. Extra effort may be recommended prior to rainy seasons to limit flooding potential from unmaintained facilities.

6.4 Conclusions

In the near term, the major concerns for the City of Sarasota are both rainstorms and inundation from storm surges as was noted during Hurricane Ian. Section 5.4 noted capital projects underway or proposed for the community.

Longer term is noted that residents are not in favor of sea walls or other structural improvements as noted earlier. While the rejection of pumps and sea walls may be feasible in the near term, beachfront property and back bay communities will not the able to stave off the slow and steady creep of sea level rise forever. Modeling indicates that a tipping point exists between 2-3 ft of sea level rise, as this is the point where most current sea walls will be overwhelmed since the average height is only 3-3.5 ft above mean tide (NGVD is before 1990) in most coastal communities (many were built using NGVD1929 vs more recent NAVD88 datum - there is about 1.5 ft difference, and sea level has risen about 14 inches since 1929). Therefore, despite the local sentiment to avoid creating structural solutions that might disrupt waterfront views, the following should be long-term policy changes for the community:

1. Increase the finished floor elevation minimum height for all new construction to 2 ft freeboard above the FEMA floor elevation.
2. Upon reaching 1 ft of sea level rise above current levels, increase the finished floor elevation again by one foot and continue that pattern. An increase of 1 ft in sea level is likely at least 30 feet away. Since housing averages less than 50 years before demolition and rebuilding in Florida, this would permit a gradual increase in finished floor elevations without negatively impacting an excessive number of residents at any one time.
3. Require sea walls that need to undergo major repairs to be replaced with new sea walls that are at the finished floor elevation. Note that placing a 2 ft cap on most existing sea walls is not structurally sound, so new seawalls will need to be constructed. The approach is to increase sea wall requirements incrementally at the same time the finished floor elevation increases, as described in 2. Note since king tides are 2.6 ft above mean high tide, and mean high tide can be over 2 ft NAVD88, the minimum future seal wall height will need to start at 6 ft NAVD88 tp create some freeboard
4. Develop a program to prevent the inflow of seawater into the streets. The flooded streets will cause the road base and pavement to fail faster, increasing maintenance costs. How the City accomplishes this can be determined with time, but increasing maintenance costs to the roads will reach a tipping point. To that end, roadway bases may need to be rebuilt using technology that is currently being developed but as yet, has not been implemented.

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