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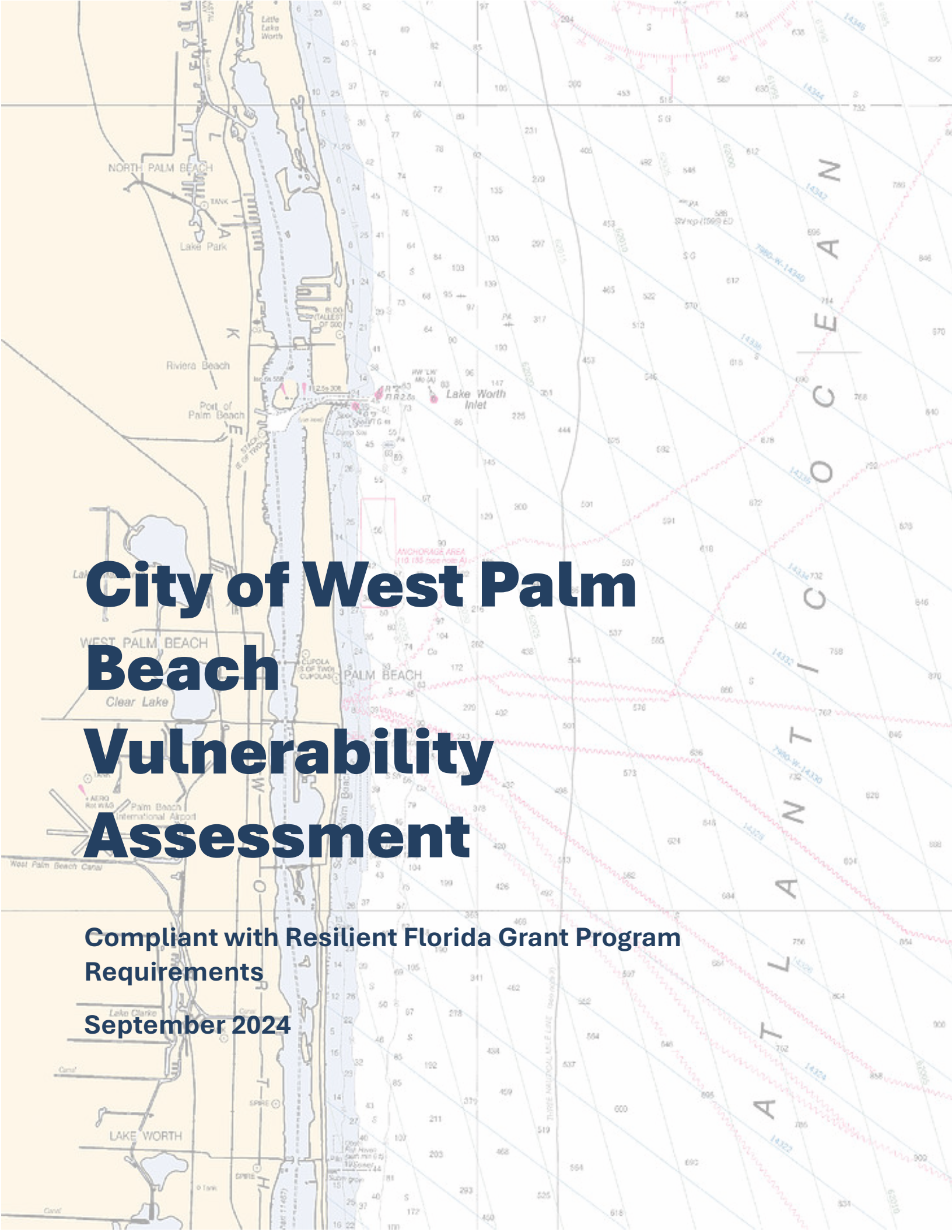
CITY OF WEST PALM BEACH VULNERABILITY ASSESSMENT UPDATE & COMPLIANCE

West Palm Beach, Florida

Final Project Report

September 2024

This report is funded in part through a grant agreement from the Florida Department of Environmental Protection. The views, statements, findings, conclusions, and recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of the State of Florida or any of its subagencies.



City of West Palm Beach Vulnerability Assessment

Compliant with Resilient Florida Grant Program Requirements

September 2024

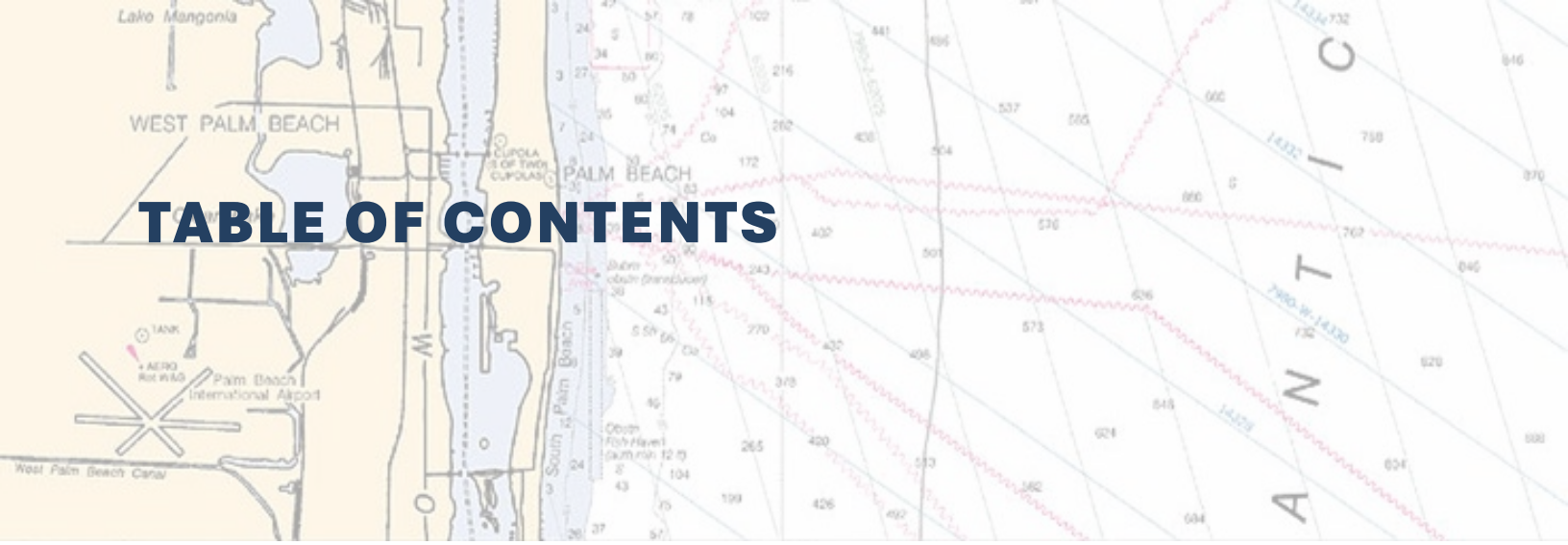


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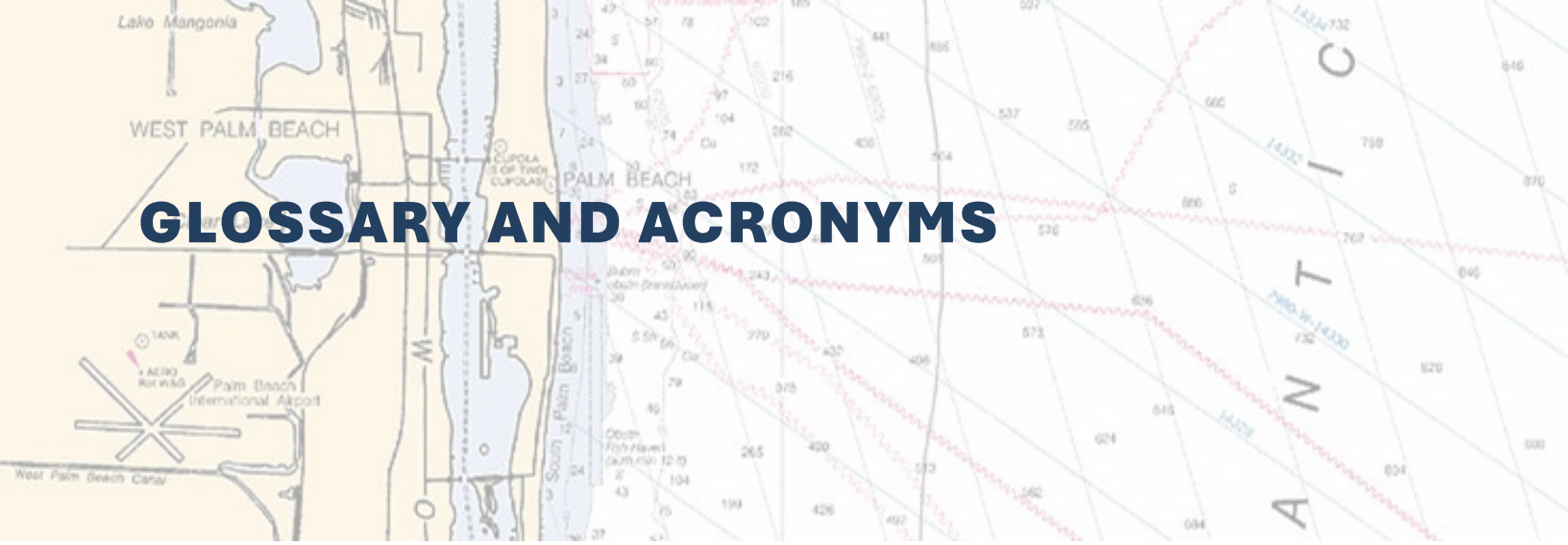


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GLOSSARY AND ACRONYMS

Adaptation (to climate change) - The process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. Adaptive capacity is the ability to make these adjustments.

Assets - People, resources, ecosystems, infrastructure, and the services they provide. Assets are the tangible and intangible things people or communities' value.

Bathtub method / model - The projected sea level rise at a point in time is added to the current water elevation and overlaid on the existing topography to identify inundated areas.

Climate change - The increasing changes in the measures of climate over a long period of time - including precipitation, temperature, and wind patterns.

CRS - Community Rating System, a FEMA program that encourages communities to prepare for flooding events by awarding FEMA flood insurance premium discounts for completing floodplain management and other flood mitigation activities.

Exposure - The presence of people, assets, and ecosystems in places where they could be adversely affected by hazards.

FEMA - Federal Emergency Management Agency.

Global warming - The rise in global temperatures due mainly to the increasing concentrations of greenhouse gases in the atmosphere.

Hazard - An event or condition that may cause injury, illness, or death to people or damage to assets.

Hazard mitigation - When used by the Federal Emergency Management Agency (FEMA), the effort to reduce loss of life and property by lessening the impact of near future disasters.

IPCC AR5 RCP 8.5 Scenario - This condition is known as a representative concentration pathway for the concentration and trajectory of greenhouse gases was developed and intended by members of the Intergovernmental Panel on Climate Change (IPCC) to be a "very high baseline emission scenario" representing the 90th percentile of the volume of emissions that could occur in various future years if society does not make efforts to reduce greenhouse gas emissions. It is a "business as usual" scenario.

Impacts - Effects on natural and human systems that result from hazards. Evaluating potential impacts is a critical step in assessing vulnerability.

King tide - A non-scientific term describing an especially high tide caused by alignment of the gravitational pull between the sun and moon. A King Tide usually occurs three to four times a year.

Mitigation (of climate change) - A human intervention to reduce emissions or enhance the sinks of greenhouse gases.

NIH - NOAA Intermediate-High Sea Level Projection.

NIL - NOAA Intermediate-Low Sea Level Projection.

NOAA - National Oceanographic and Atmospheric Administration.

Projections - The 2019 Unified Sea Level Rise Projections published by the Southeast Florida Regional Climate Change Compact. Potential future climate conditions calculated by computer-based models of the earth system. Projections are based on sets of assumptions about the future scenarios that may or may not be realized.

Relative sea level rise - The way the height of the ocean rises or falls relative to the land at a particular location.

Resilience - The capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption.

Risk - The potential total cost if something of value is damaged or lost, considered together with the likelihood of that loss occurring. Risk is often evaluated as the probability of a hazard occurring multiplied by the consequences that would result if it did happen.

Scenarios - A set of assumptions about the future regarding the level of mitigation efforts and other physical processes that have a level of uncertainty.

Sea level rise (absolute sea level rise) - The height of the ocean surface above the center of the earth, without regard whether nearby land is rising or falling.

Sensitivity - The degree to which a system, population, or resource is or might be affected by hazards.

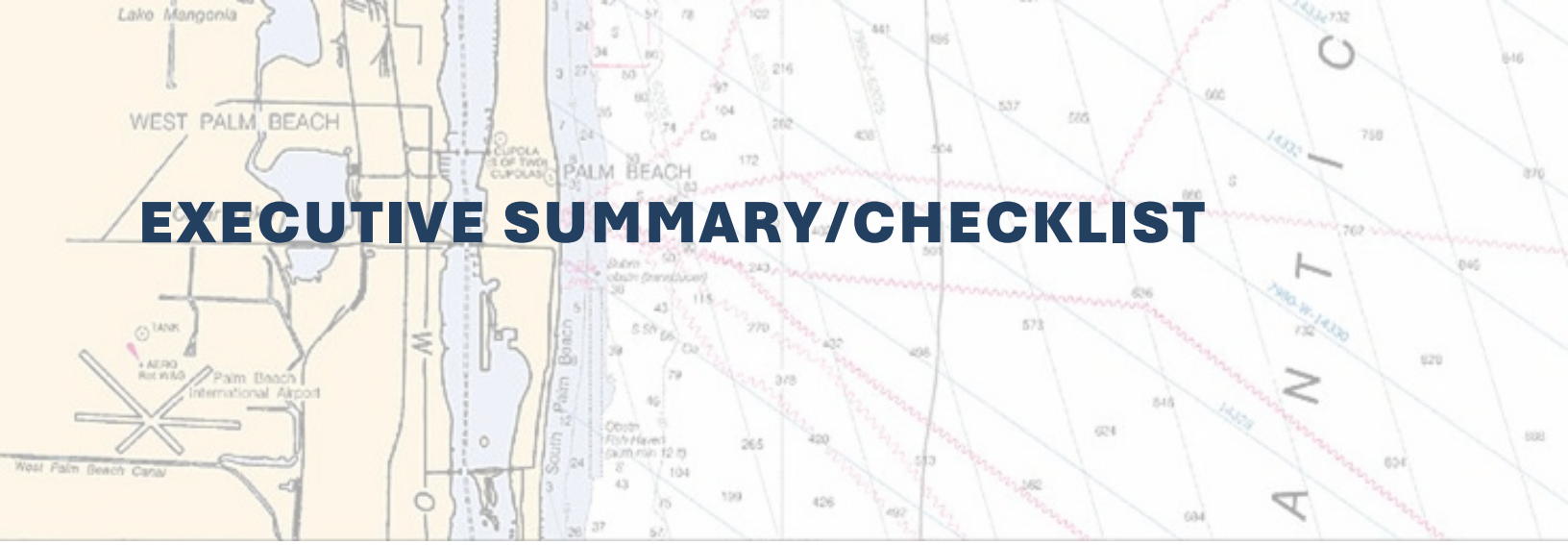
SLR - Sea level rise.

Uncertainty - A state of incomplete knowledge. Uncertainty about future climate arises from the complexity of the climate system and the ability of models to represent it, as well as the inability to predict the decisions that society will make.

Vulnerable populations - Vulnerable groups of people include those with low income, some communities of color, immigrant groups (including those with limited English proficiency), indigenous peoples, children and pregnant women, older adults, vulnerable occupational groups, persons with disabilities and persons with pre-existing or chronic medical conditions.

Vulnerability - The propensity or predisposition of assets to be adversely affected by hazards. Vulnerability encompasses the degree of exposure, sensitivity, potential impacts, and adaptive capacity.

Vulnerability assessment - A process for identifying who or what is impacted by climate change. It is the combination of exposure, sensitivity, and adaptive capacity.



EXECUTIVE SUMMARY/CHECKLIST

This section serves as both an Executive Summary of the full Vulnerability Assessment Report, as well as an outline corresponding to the items in the Resilient Florida Grant Program Vulnerability Assessment Compliance Checklist Certification document distributed by the Florida Department of Environmental Protection (FDEP). Headings and subheadings of sections in bold and / or italics with alphabetic letters in parentheses indicate the item identified in the FDEP Checklist.

Final Vulnerability Assessment Report (a)

The complete Vulnerability Assessment Report can be found after this Executive Summary.

Results

The main takeaways of the Vulnerability Assessment:

- Shoreline areas of the City of West Palm Beach are highly vulnerable to storm surge events, future sea level rise, and high tide flooding.
- Shoreline restoration efforts could greatly enhance the City of West Palm Beach's resiliency to current and future storm events.
- Inland areas of the City of West Palm Beach are impacted by a wide array of rainfall events, from 25-year storms to 500-year storms.
- Implementation of adaptation strategies is crucial for the City of West Palm Beach to become a more resilient community.

Conclusions

Rising sea levels and increasingly severe rainfall events are contributing to higher flood risks across all of Florida's coastal regions. Areas of West Palm Beach, particularly those near the Lake Worth Lagoon, already have substantial vulnerability

to flooding events. This vulnerability is expected to increase significantly over the next several decades, unless substantial actions are taken to mitigate and adapt to future climate risks.

Electronic Mapping Data

Geospatial data (b)

Per FDEP requirements, a list of assets is included in the report. See Appendix C for a complete list of the data types/layers/sources.

GIS metadata (c)

GIS information supplied to FDEP contains the required metadata.

Critical assets impacted by flooding and sea level rise (d)

The GIS analysis underpinning this Vulnerability Assessment incorporates layers including critical municipal and regionally-significant assets found throughout West Palm Beach. Critical assets generally are those owned and maintained by the City or are essential for the functioning of the City. It should be noted that some critical assets may not be owned or maintained by the City, for instance, health care or certain utility assets (such as electricity infrastructure). Regionally significant assets are those that may not be owned by the City but are no less critical to its functionality. These may be federal, state, or county assets.

Data summary for municipal assets

The following types of data were collected and evaluated for the project:

1. **Transportation Assets and Evacuation Routes**: airports, bridges, bus terminals, bus routes, boat ramps, major roadways, evacuation routes, port facilities, marinas, rail facilities, and railroad bridges.
2. **Critical Infrastructure:** wastewater conveyance structures and lift stations, potable water conveyance structures, stormwater drainage infrastructure and stormwater ponds, electric production and supply facilities, military installations, post offices, communications facilities, and disaster debris management sites.
3. **Critical Community and Emergency Facilities**: childcare facilities, schools, colleges, universities, assisted housing, community centers, emergency

medical service facilities, fire stations, emergency management services, health care facilities, hospitals, law enforcement facilities, risk shelters, local government facilities, and state government facilities.

4. **Natural, Cultural, and Historical Resources**: This category is dedicated to preserving and protecting natural areas and cultural/historical sites, including historic buildings and cemeteries, places of worship, and other historical and cultural assets, City and county parks, shorelines, surface waters, wetlands, and other terrestrial and aquatic natural areas.
5. **Supplementary Information**: This category includes additional data not explicitly required by Subsection 380.093, F.S., but valuable for a detailed vulnerability assessment. It encompasses FEMA's flood insurance study, flood zones, frequently flooded areas, soils, impervious surface areas, seawalls, land cover, land use, and property values.

Regionally-significant assets

Multiple asset types listed above would also be considered regionally significant assets; they are due special attention. Some are specifically mentioned in the statutory language which refers to critical assets that support the needs of communities spanning multiple geopolitical jurisdictions. They include:

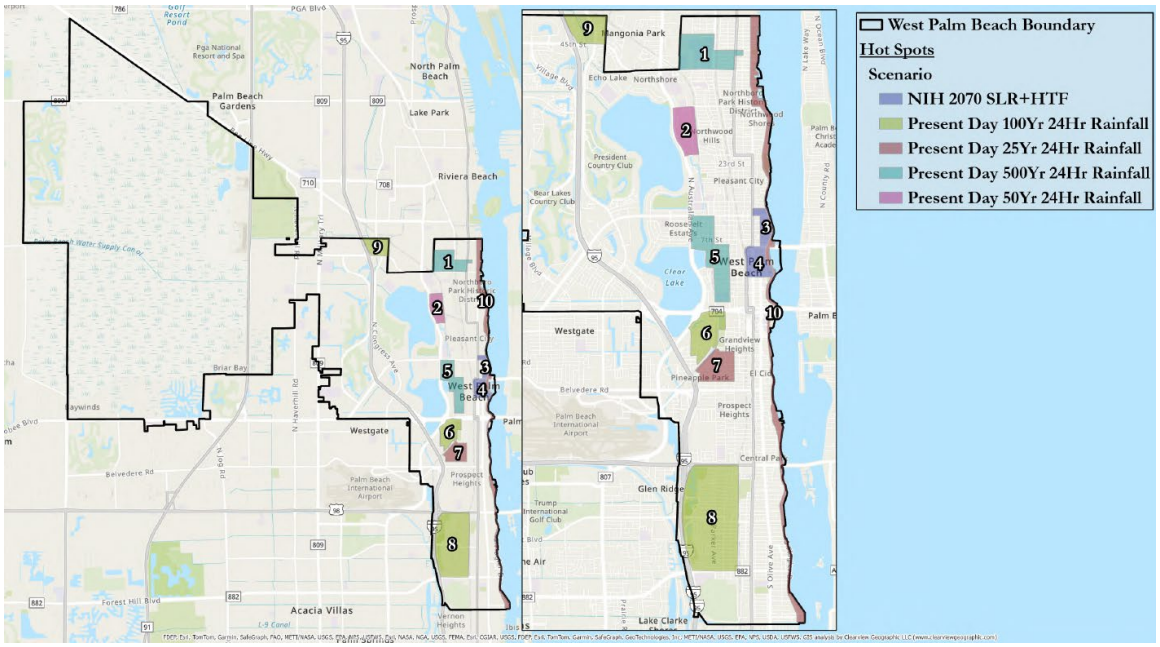
- Commercial and Strategic Intermodal System (SIS) ports
- Airports (SIS)
- Bus, rail, and multimodal terminals
- Evacuation routes
- Electric power infrastructure
- Drainage assets (including those maintained by water management district)
- Stormwater ponds
- Public water supply tanks
- Emergency medical services facilities
- Risk shelters

Asset layers were compiled initially in a comprehensive baseline asset inventory, which can be found in Appendix B. This baseline asset inventory was reviewed multiple times throughout the data compilation process. During this exchange, the importance and relevance to resilience was discussed and a critical asset inventory was established. (Appendix C contains a list of the types of assets included.) This serves as a foundational step for identifying assets to be further analyzed in the Vulnerability Assessment. Based on the rankings conducted in Appendix E.1 – Sensitivity Summary Tables, a map series focused on the highest priority assets

within flooding “hot spots” in the community. It can be found in Appendix E.3 - Sensitivity Analysis Maps.

Areas Prioritized in the Analysis

Figure 1 - Hot Spot Map



The project team identified 10 flooding “hot spots” based on the intensity of projected flooding caused by rainfall and storm events and future sea level rise and the concentration of assets identified by West Palm Beach. The analysis reviewed approximately 114,829 assets contained within these hot spots, which were then prioritized based on level of flood impacts. In addition, items of immediate need within the hot spots were also highlighted. Specifically:

- Approximately 53,518 point assets within 10 geographic hot spots, prioritized by:
    - Geographic area (Hot Spots 1-10)
- Immediate Need/Impact (Flood depth = inundation in modeled scenarios)
    - 2,698 assets were prioritized 1-3 (top 15% most vulnerable).
    - 4,866 assets were prioritized 4-5 (4 – top 15 to 25% and 5 – top 25-50% most vulnerable).
    - 107,265 assets were not prioritized (< 50%).

The “Hot Spot” maps can be found in Appendix E.3 - Sensitivity Analysis Maps.

Areas of Immediate Need

Based on the results of the exposure analysis and through collaboration with the City of West Palm Beach staff, the project team has prepared Table 1, summarizing hot spot locations, projecting impacts, and results of the asset prioritization.

Table 1 - Summary of Hot Spots

Hot Spot Description	Flood Impact Summary	Asset Prioritization Summary
Hot Spot 1: St. Mary's Medical Center Area	Projected to be impacted by extreme rainfall events and storm surge events	High frequency of assets with high to low prioritization including a hospital, waste facility, potable water facility, and stormwater infrastructure.
Hot Spot 2: 36th Street to 25th Street	Projected to be impacted by a moderate rainfall event and heavily impacted by storm surge	High frequency of infrastructure assets located in this hot spot with high to medium prioritization including an industrial facility, communication tower, disaster debris management, potable water infrastructure, and stormwater infrastructure.
Hot Spot 3: Good Samaritan Medical Center to Loftin Street	Projected to be impacted by future sea level rise, moderate rainfall events, and present-day storm surge	High frequency of assets with a high to low prioritization including a hospital, public park, private school, childcare facility, assisted living facility, stormwater infrastructure, and potable water infrastructure.
Hot Spot 4: Loftin Street to Datura Street	Projected to be impacted by future sea level rise, moderate rainfall events, and present-day storm surge	High frequency of assets with a high prioritization including a fire station, government facilities, communication towers, schools, parks, stormwater infrastructure, and potable water infrastructure.

Hot Spot Description	Flood Impact Summary	Asset Prioritization Summary
Hot Spot 5: Palm Beach Lakes Blvd to Jessamine Street	Projected to be impacted by extreme rainfall events and storm surge events	High frequency of assets with a high to low priority including an electrical substation, water treatment facility and supporting infrastructure, government facilities, a waste facility, communication infrastructure, and stormwater infrastructure.
Hot Spot 6: S Australian Ave to the SCL Railroad	Projected to be impacted by moderate rainfall events and storm surge events	Medium frequency of infrastructure assets with a high to low priority including an electrical substation, disaster debris site, lift stations, and stormwater infrastructure.
Hot Spot 7: Park Place to Sunset Road	Projected to be impacted by minor rainfall events and storm surge events	Medium frequency of infrastructure assets including lift stations, stormwater infrastructure, and potable water infrastructure.
Hot Spot 8: Southern Blvd to Forest Hill Blvd	Projected to be impacted by moderate rainfall events and storm surge events	High frequency of infrastructure assets including potable water storage facilities and supporting infrastructure, an electric substation, and stormwater infrastructure.
Hot Spot 9: West Palm Hospital Area	Projected to be impacted by moderate rainfall events and storm surge events	High frequency of assets with a high to low priority including a hospital and supplemental medical facilities, communication infrastructure, stormwater infrastructure, and potable water infrastructure.
Hot Spot 10: Flagler Drive	Projected to be impacted by minor rainfall events, future sea level rise, and storm surge	High frequency of assets with a high to low priority including a critical roadway, parks, shorelines, and stormwater infrastructure.

Peril of Flood Compliance Plan Amendments (e)

The City of West Palm Beach Comprehensive Plan already complies with paragraph 163.3178(2)(f), Florida Statutes, pertaining to Peril of Flood; therefore, Peril of Flood amendments are not included within this Vulnerability Assessment.

Tidal Flooding

In the context of planning for future tidal flooding events, the Vulnerability Assessment Report for West Palm Beach incorporates detailed modeling techniques to predict how rising sea levels and high tide events will impact the area over several planning horizons (2040, 2070 and 2100). This modeling is particularly important given the City's vulnerability to climate change-induced phenomena. The assessment uses the North American Vertical Datum of 1988 (NAVD 88) as a benchmark for all elevations, ensuring accuracy and consistency in projection data.

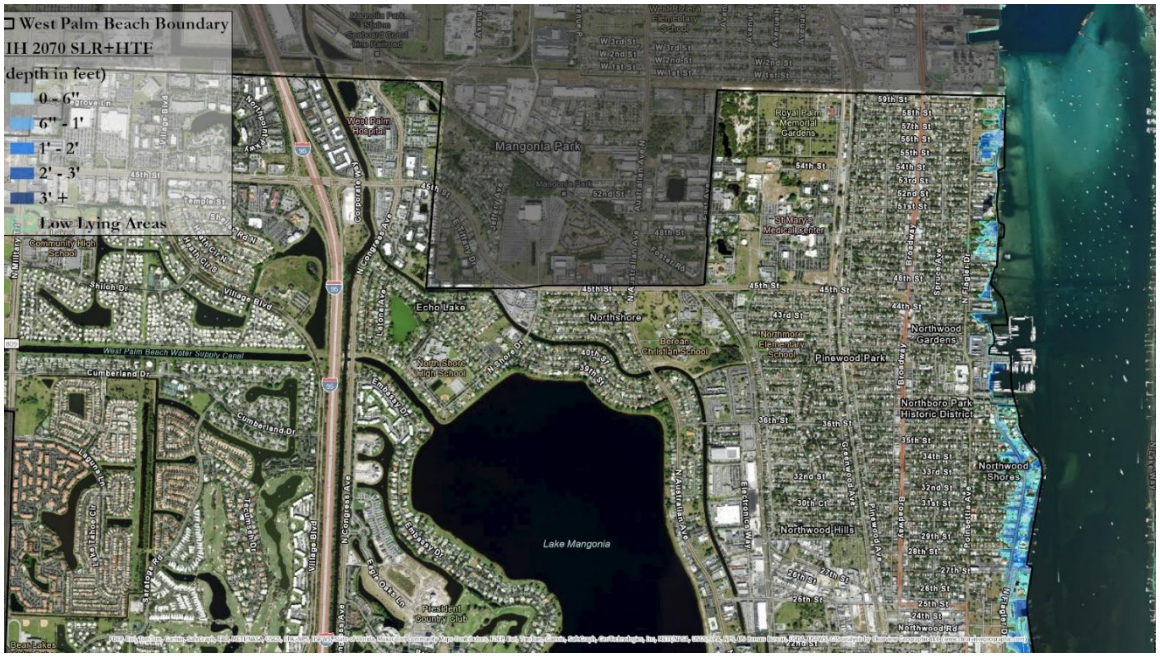
Key to the various flooding analyses (starting in this section with tidal flooding), is the complete map exposure series, included as Appendix D. A small sample of this map series is included in each of the sections detailing the various planning horizons, climate scenarios, and corresponding flood projections within this executive summary and complete Vulnerability Assessment. The first map included (Figure 2) shows the combination of sea level rise and high tide flooding (+2 feet MHHW[1]), alongside projections of the number of days tidal flooding is expected to occur. The climate scenarios represented within the model are based on NOAA's Intermediate-Low (NIL) and Intermediate-High (NIH) Sea Level Rise Projections from 2017, which were the required scenarios at the initiation of this Vulnerability Assessment. These projections provide a framework for understanding the range of possible future conditions, enabling the City to prepare for a variety of outcomes.

The analysis employs geospatial temporal modeling techniques, leveraging tools like ArcGIS Pro and the VDATUM tool for datum conversion, to assist with simulating tidal flooding scenarios. This methodology employs the National Oceanic and Atmospheric Administration's (NOAA) mapping sea level rise inundation methodology, ensuring the assessment accurately captures the complexities of tidal flooding under various future scenarios.

[1] Two feet over MHHW is the FDEP-set threshold for high tide flooding.

Figure 2 - Sample Tidal Flooding Scenario Map

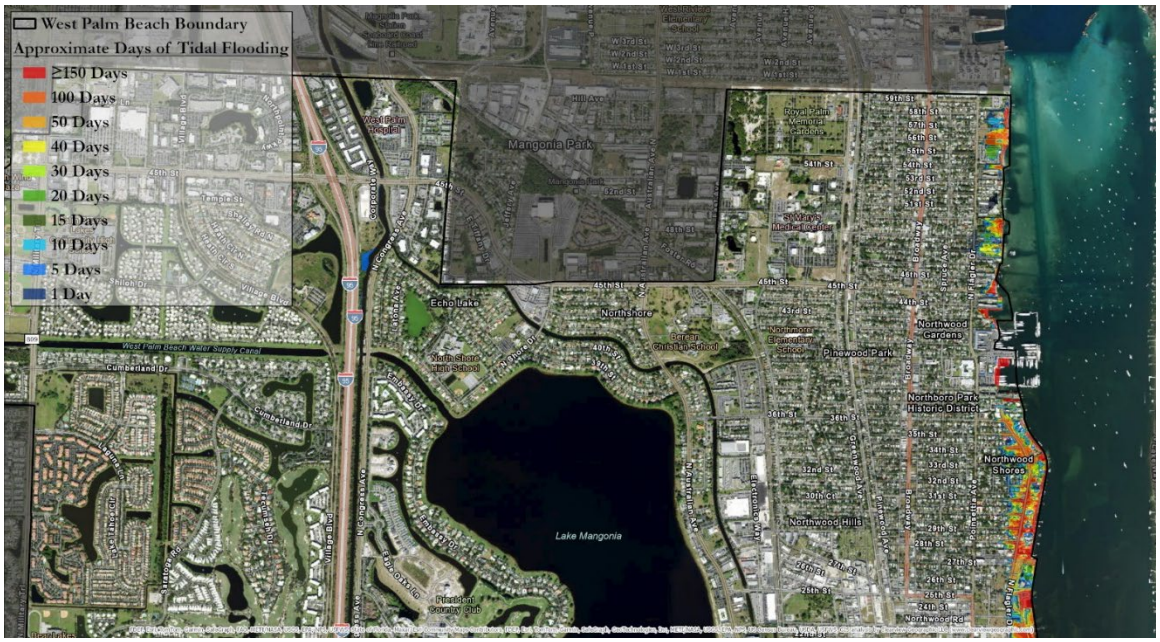
NIH 2070 SLR Projection and High Tide Flooding



Using this methodology, a representation of the analysis depicting a geographical display of the number of tidal flood days expected for each scenario and planning horizon is also included. This combination offers a nuanced view of the days each year that are expected to experience tidal flooding, contributing to a more comprehensive understanding of the temporal dynamics of flood risk.

Figure 3 - Approximate Number of Days of Tidal Flooding in 2070

Days of Tidal Flooding = SLR Projection and High Tide Flooding



This scenario utilizes FDEP's recommendation to add two feet to the MHHW mark, enhancing predictions for future tidal flooding by accounting for increased sea levels and high tide events. This conservative approach aids in planning for more frequent and severe flooding, underscoring the need for robust coastal defenses like seawalls and natural barriers.

Building on the previous analysis, this section projects the number of days expected to experience tidal flooding, emphasizing its impact on daily life and the economy. It highlights the importance of comprehensive flood risk management strategies to mitigate these effects, aiming to ensure West Palm Beach's resilience and sustainable development amidst rising sea levels and changing climate conditions.

The scenarios of Sea Level Rise + High Tide Flooding and Days of Tidal Flooding together provide priority information to guide West Palm Beach's climate resilience strategy. They highlight expected changes along coastlines and low-lying areas, steering the conversation towards adapting urban plans, emergency readiness, and strengthening community resilience. Integrating these insights into West Palm Beach's long-term planning enables proactive responses to sea level rise and tidal flooding challenges, aiming for sustainable development and a resilient future for the community.

Storm Surge Flooding

This analysis leverages FEMA's storm surge data and the HAZUS-MH software, adjusting historical data monumented within the most recent effective Flood Insurance Study (FIS) from 2017 based on future sea level rise projections. It offers a detailed planning grade understanding of future storm surge impacts by integrating these projections with existing FEMA FIS data.

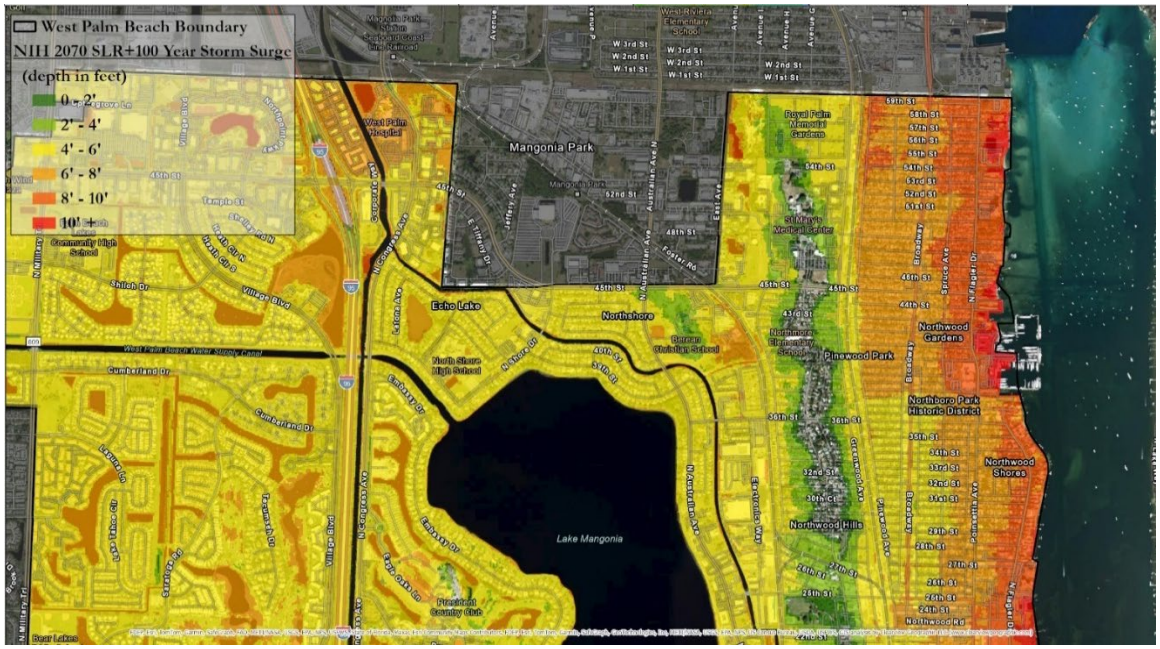
Depth of current and future storm surge flooding (h)

Using FEMA's comprehensive storm surge data in conjunction with HAZUS-MH software, historical storm surge events were adjusted to align with projected sea level increases for 2040, 2070, and 2100 planning horizons. This process enabled the prediction of storm surge depths across different timelines, providing a granular view of how storm surge flooding may evolve. The outcomes reveal significant increases in storm surge depths, underscoring the urgent need for adaptive infrastructure and planning measures to mitigate the impacts on vulnerable coastal communities.

Initial storm surge event equals or exceeds current 100-year flood event (i)

The initial storm surge event analyzed in this assessment equals or exceeds the magnitude of the current 100-year flood event as required by statute. This comparison highlights a stark increase in the severity and frequency of storm surge events, likely attributable to ongoing climatic changes and sea level rise. This implies that an event previously considered to be a once-in-a-century occurrence may now happen more frequently, requiring a reevaluation of flood risk assessments and flood zone designations. This finding is critical for updating building codes, insurance rates, and disaster preparedness plans to better reflect the heightened risk of significant storm surge flooding in the future. All storm surge maps can be found in the Exposure Map series (see Appendix D).

Figure 4 - NIH 2070 SLR + 100-Year Storm Surge



The 100-year and 500-year storm surge scenarios are critical to understanding West Palm Beach's flood risks, with the former having a 1% annual chance of occurrence and the latter a 0.2% chance. These scenarios, crucial for urban and infrastructure resilience planning, consider the compounded impacts of climate change on storm surge risks using FEMA data and HAZUS-MH software, adjusted for future sea level rise. They provide a foundation for developing flood defenses, revising building codes, and crafting evacuation strategies. This comprehensive risk assessment aids West Palm Beach in proactive planning against storm surge flooding, ensuring a holistic approach by integrating with tidal flooding and sea level rise projections. It is a strategic effort to bolster the City's resilience, protect its community, and maintain infrastructure integrity in the face of climate change.

Rainfall-Induced Flooding (k)

Following the requirements of Section 380.093(3), F.S., this Vulnerability Assessment employs a spatiotemporal analysis, leveraging existing modeling results and developing new simulations to assess flood risk accurately. Use of the Hydrologic Engineering Center's River Analysis System (HEC-RAS) tool allows for detailed rainfall simulation and runoff computation. The integration of NOAA's Atlas 14 precipitation data and the South Florida Water Management District's (SFWMD) future rainfall change factors facilitates a comprehensive evaluation of potential future scenarios of rainfall-induced flooding. This methodological approach ensures that the assessment adheres to legislative requirements while providing a robust

framework for predicting flood elevations under various conditions. All rainfall maps can be found in the Exposure Map series (see Appendix D).

In the progression of the Vulnerability Assessment Report for West Palm Beach, attention shifts towards an equally pivotal domain: rainfall-induced flooding. This section meticulously outlines scenarios ranging from the more frequent 25-year events to the rare but devastating 1,000-year events, alongside adjusted projections that consider anticipated changes in climate patterns. Each scenario represents a distinct level of flood risk based on the probability and intensity of rainfall over a 24-hour period, thereby providing a comprehensive spectrum of potential flood hazards.

Future boundary conditions (I)

To account for the evolving nature of flood risk due to climate change, the future boundary conditions for this analysis have been carefully adjusted via overlays and change coefficient multipliers. These modifications incorporate elements of sea level rise and high tide conditions to the extent practicable, ensuring that the assessment reflects the most accurate and relevant scenarios for evaluating future flood risks. By doing so, the study aligns its predictions with the latest climate science, providing a more realistic projection of flood elevations and areas at risk.

The assessment adjusts the 25-year and 100-year 24-hour scenarios to reflect the impact of climate change on rainfall patterns, offering a forward-looking analysis of flood risks. By incorporating projections of increased rainfall intensity and frequency, these scenarios provide a clearer picture of potential future flood hazards. This comprehensive approach enables West Palm Beach to adapt its infrastructure and policies to the realities of a changing climate, ensuring informed decision-making in flood mitigation and resilience planning. This effort is vital for maintaining community well-being and sustainable development amidst the challenges posed by more frequent and intense rainfall events.

Depth of rainfall-induced flooding (m)

The analysis delves into the projected depths of rainfall-induced flooding for significant storm events, specifically the 25-year, 50-year, 100-year, 500-year, and 1,000-year storms. By examining these scenarios, the study identifies critical areas that are likely to experience substantial flooding, thus presenting a clear picture of the potential impact on infrastructure and communities. The depth of flooding is quantified through detailed maps and tables, offering valuable insights into the spatial distribution of flood risks.

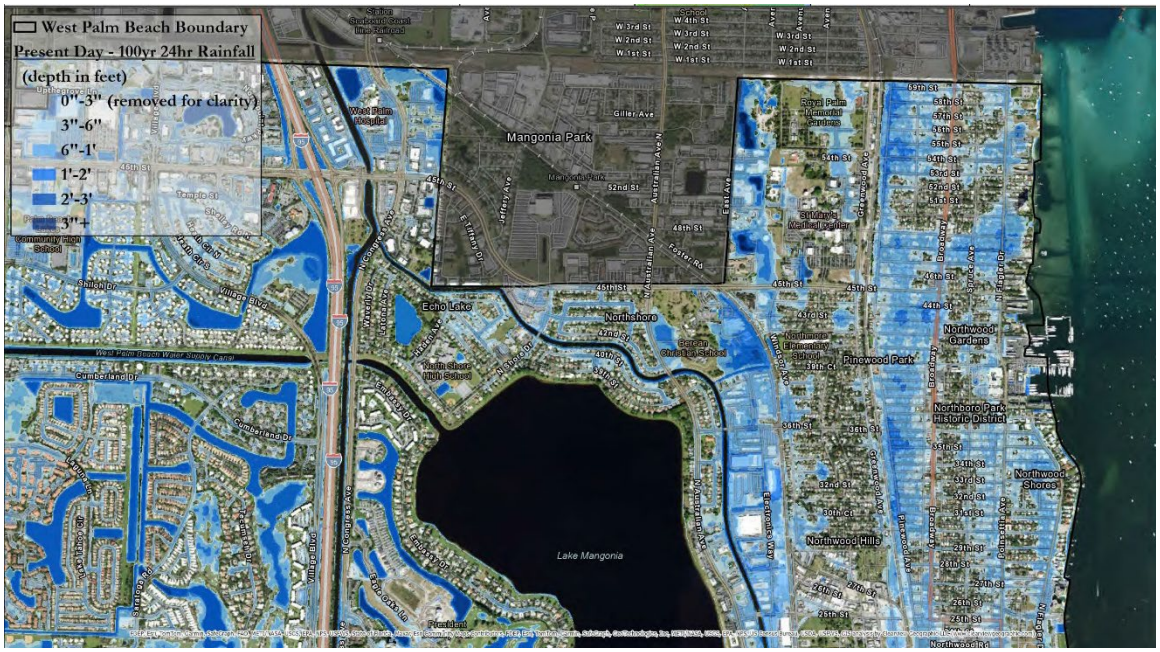
The study presents its findings through a series of maps and tables that visualize the depth and extent of rainfall-induced flooding for all storm scenarios within the exposure series. These mapped visual aids facilitate a better understanding of the

spatial distribution of flood risks, enabling stakeholders to identify high-risk areas and prioritize mitigation efforts accordingly.

100-year storm

This scenario predicts the extent and depth of flooding with a 1% chance of occurring during any given year, providing a baseline for flood risk management and urban planning. This concept is widely used in flood risk management and planning to design standards for infrastructure resilience, such as levees, dams, and floodplains.

Figure 5 - Present Day - 100-Year 24-Hour Rainfall



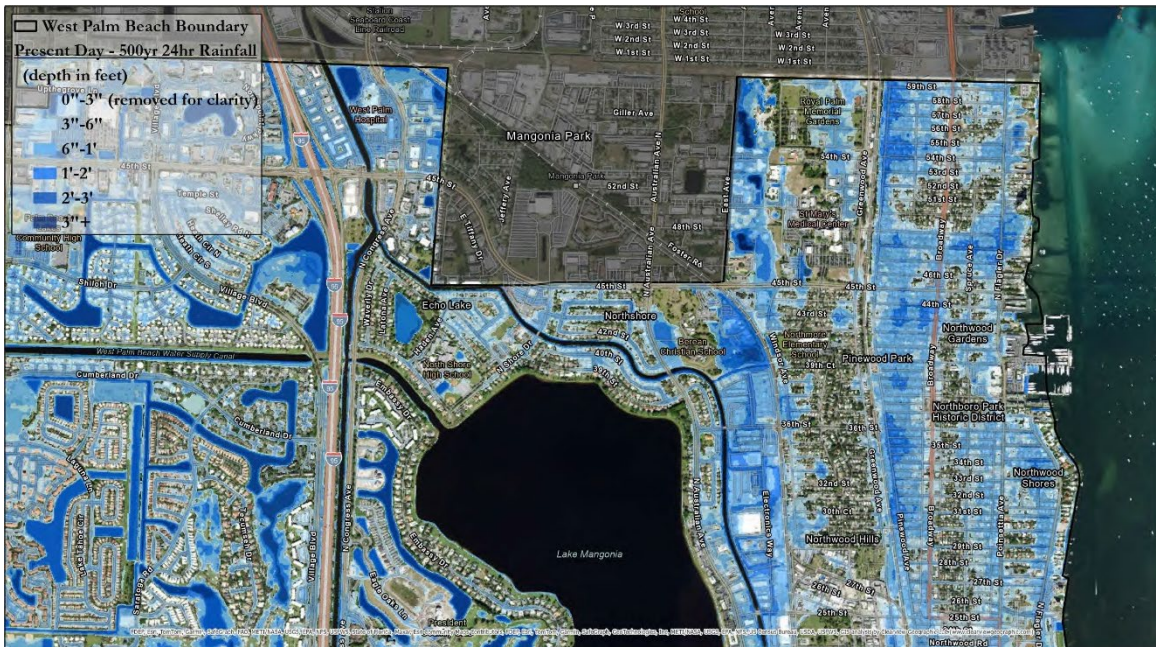
The 100-year 24-hour scenario, modeling a severe storm with a 1% annual occurrence chance, is essential for guiding flood risk management and urban development strategies. It informs the creation of flood mitigation infrastructure, zoning laws, and insurance policies, pinpointing areas for strategic investments to lower flood risks and bolster community resilience.

500-year storm

An assessment of the more extreme but less frequent 500-year storm event gives insights into the potential for catastrophic flooding, informing long-term resilience strategies. It signifies a storm that has a 0.2% chance of occurring in any given year. This statistical measure describes the severity and likelihood of extreme weather

events, helping in the planning and construction of infrastructure designed to withstand such rare but potentially devastating storms.

Figure 6 - Present Day - 500-Year 24-Hour Rainfall



The 500-year 24-hour scenario, modeling an extreme rainfall event with a 0.2% annual chance, is vital for assessing the maximum flood risk potential, identifying areas and infrastructure at risk of severe flooding. This scenario underscores the need for extensive planning and advanced mitigation efforts to prepare for and reduce the impacts of such catastrophic events.

Higher frequency storm analyzed for exposure of a critical asset (j)

In addition to the standard 100-year and 500-year storm scenarios, the analysis also includes a detailed examination of higher frequency storms to assess the exposure of critical infrastructure and assets. This focused analysis helps in identifying vulnerabilities and planning for protective measures to safeguard essential services and facilities against the impact of more frequent, higher-intensity flooding events. Further exploring a range of storm events, including the 25-year, 50-year, 100-year, 500-year, and 1,000-year storms, provides a more comprehensive overview of flood risks over a spectrum of probabilities meeting and exceeding the statutory requirements for vulnerability assessments. This detailed assessment, summarized

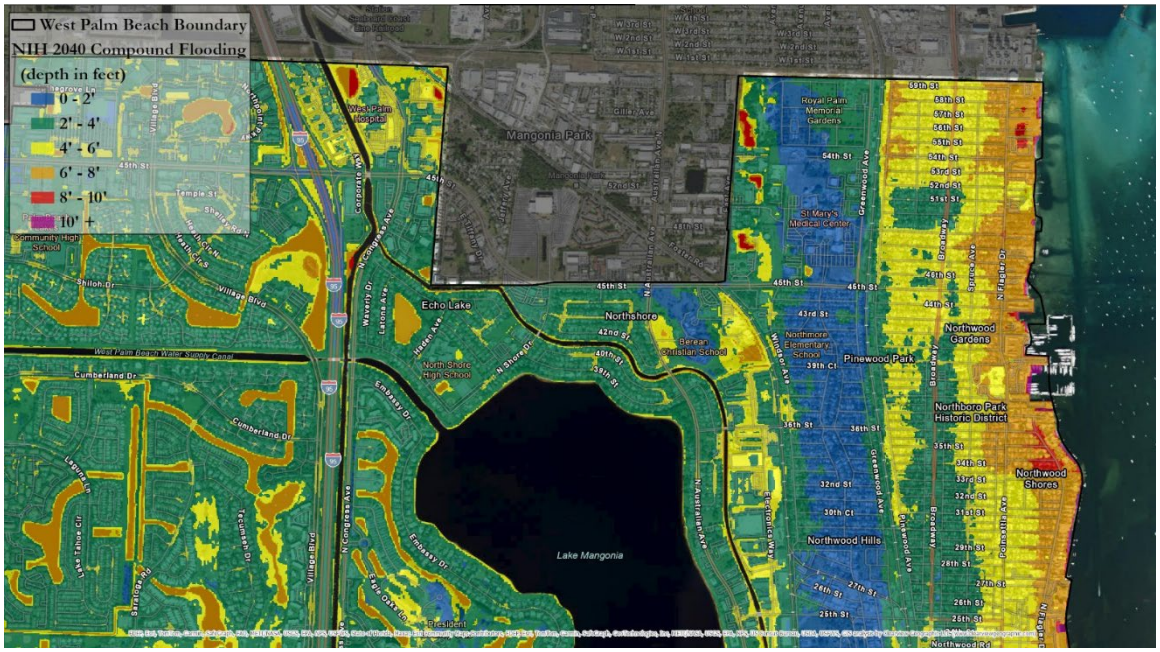
in accompanying tables, aids in the development of a nuanced flood risk management strategy that addresses both common and severe flooding scenarios.

The rainfall scenarios ranging from 25-year to 1,000-year events provide a comprehensive spectrum of flood risk assessments essential for West Palm Beach's flood management and urban planning. The 25-year scenario, with a 4% annual chance, highlights moderate flooding risks, emphasizing the need for improved drainage and community preparedness. Progressing in severity, the 50-year scenario (2% annual chance) evaluates the adequacy of flood defenses and critical infrastructure resilience. The 100-year scenario is a key benchmark in flood risk management, guiding urban development, flood mitigation, and zoning with a 1% occurrence chance. It calls for strategic investments to enhance community resilience. The 500-year scenario, reflecting a 0.2% annual chance of extreme rainfall, and the 1,000-year scenario, with a 0.1% annual chance, both underscore the importance of comprehensive planning and robust mitigation to address the highest levels of flood risk and potential catastrophic impacts. Collectively, these scenarios underscore the necessity of a forward-looking approach to urban planning, emergency management, and resilience building against increasing flood risks.

Compound/Combined Flooding (n)

This segment addresses the compound effects of tidal, storm surge, and rainfall-induced flooding under various scenarios primarily focused on the 100-year and 500-year storm surge events plus 25-year and 100-year rainfall events with the compounding effect of sea level rise. It involves overlaying depth grids from various scenarios, acknowledging the resource and time constraints of the project. Combined flooding maps can be found in the Exposure Map series (see Appendix D).

Figure 7 - NIH 2040 SLR + 100-Year Surge + 25-Year 24-Hour Rainfall



Through the comprehensive analysis of these compounded scenarios, the report underscores the importance of integrating multidimensional flood risk assessments into urban planning and infrastructure development. Such detailed projections facilitate the strategic implementation of adaptation and mitigation strategies, ensuring that communities are better prepared and more resilient to the increasingly complex and severe flooding challenges posed by climate change.

Scenario Development Specifications

North American Vertical Datum of 1988 (o)

All elevations referenced in and analyzed for this Vulnerability Assessment are expressed in North American Vertical Datum of 1988 (NAVD 88) values. Any exceptions are limited and are specifically noted in the Vulnerability Assessment and further appendices.

Local Sea Level Rise Scenarios (p)

The sea-level rise scenarios included in the Vulnerability Assessment include the 2017 NOAA Intermediate-Low (NIL) Sea Level Rise Projection and the 2017 NOAA Intermediate-High (NIH) Sea Level Rise Projection. These scenarios were the

required scenarios when work on this Vulnerability Assessment began. However, legislation adopted by the Florida Legislature and signed into law by the Governor in 2024[2] instead mandates the use of the 2022 NOAA Intermediate Low and Intermediate scenarios for vulnerability assessments initiated after July 1, 2024. The City should consider this in future updates to this Vulnerability Assessment. The selected NOAA 2017 and 2022 projections align for 2040; however, the NOAA 2017 projections are higher for the 2070 and 2100 scenarios and thus more conservative for planning purposes.

The benefit of evaluating a range of conditions is that the City can determine the tolerance for risk for any adaptation strategy decision and act upon data from this analysis that reflects a wider range of conditions. For assets, adaptation projects and policy decisions where there is a higher criticality for that decision, the higher end of the projections and output should be considered. Where there is a lower tolerance for flood impact, the lower end of the projections could be considered. The range provides options needed for more place-based and flood impact decision-making.

Planning horizons (q)

The planning horizons for this Assessment coincide with NOAA's forecasting years: 2040, 2070 and 2100. While Section 380.093(3), F.S., only requires the 2040 and 2070 planning scenarios, this Vulnerability Assessment also includes the 2100 condition.

Sea level data selection (r)(s)

According to statute, vulnerability assessments must include local sea level data that has been interpolated between the two closest National Oceanic and Atmospheric Administration (NOAA) tide gauges or use the sea level data from whichever of those two nearest gauges reports a higher mean sea level.

For West Palm Beach, this Vulnerability Assessment uses NOAA's Virginia Key tide gauge (8723214). The Virginia Key tide gauge was selected over Lake Worth Pier for the projection of future tides due to the period of record established by the gauges. Given that the mean sea level reported by Virginia Key is greater than that of Lake Worth Pier, interpolation between the two tide gauges is not necessary. Data from the Virginia Key tide gauge is integrated directly into the exposure analysis methodology by converting the original North American Vertical Datum of 1988 (NAVD88) elevations from the Digital Elevation Model (DEM) to the localized vertical tidal datums. By aligning the DEM elevations with data from local tide gauges, this

[2] Signed into law by the Governor on May 13, 2024.

conversion ensures accurate and consistent comparisons, correctly reflecting local sea level elevations and allowing precise data manipulations.



VULNERABILITY ASSESSMENT REPORT

Introduction

This City of West Palm Beach Vulnerability Assessment (2024) represents the latest in a series of steps taken by the City of West Palm Beach (City) to build its resilience to the impacts of climate change, most notably sea level rise, precipitation, and combined flooding impacts. This document also complies with the criteria established by the State of Florida in 2021 for eligibility for resiliency infrastructure grants annually evaluated and ranked for appropriations in the Statewide Flooding and Sea Level Rise Resilience Plan. Those requirements, detailed in subsection 380.093(3), F.S., name the "components, scenarios, data, and information" that must be included for a vulnerability assessment to be considered complete.

Even more importantly, however, this Vulnerability Assessment assists the City of West Palm Beach in protecting its residents, infrastructure, properties, natural landscapes, and way of life from the threats of sea level rise and extreme flooding.

West Palm Beach knows that the need for climate adaptation and mitigation planning does not exist in a vacuum, but rather stems from evidence of increasing sea levels and damaging rain and storm events, recognition of serious future risks, and the stark damage flooding is already causing in the region. Faced with these realities, the City of West Palm Beach is pursuing an aggressive and overarching planning strategy to address underlying climate change threats.

Background

As a coastal city in the tropics, West Palm Beach has grappled with issues of sustainability and resilience for as long as it has been settled by humans. Its modern history of engagement on these issues dates to back at least 2005, when the City signed onto the US Conference of Mayors' Climate Protection Agreement. Creation of the City's Office of Sustainability followed in 2008, with that office heading up development of the first West Palm Beach Sustainability Action Plan in 2012. Since those first few years, the City has been a leader among cities in Florida and across the nation in its sustainability vision and achievements, including active participation in a number of national and international coalitions dedicated to climate action and deep involvement with the Southeast Florida Regional Climate Change Compact ("Compact"), a highly effective and influential climate resilience collaborative led by the four counties of Southeast Florida.

More recently, West Palm Beach's resilience planning and implementation efforts have been supported by the State of Florida, through its Resilient Florida program. Among many other provisions, the Statewide Flooding and Sea Level Rise Resilience Act (SB 1954/HB 7019), approved by the Legislature in April 2021 and Governor DeSantis in May 2021, (now Section 380.093, F.S.) created the Resilient Florida Grant Program to provide funding to local governments for resilience planning grants and creation of the process to establish the annual Statewide Flooding and Sea Level Rise Resilience Plan appropriating annual funding for resilient infrastructure upgrades. State funding is predicated on local governments identifying assets at risk via vulnerability assessments conducted according to requirements detailed in the legislation and providing prioritized lists of proposed projects to the state. FDEP is also charged with creating a statewide vulnerability assessment based on the local assessments.

Notably, West Palm Beach was one of the first communities to apply for and win funding through the Resilient Florida program. In the first year of funding, Fiscal Year 2021-22, the City was awarded a Resilient Florida Planning Grant ($267,475) by the Florida Department of Environmental Protection (FDEP) to create this Vulnerability Assessment. It also won several Resilient Florida implementation grants in Fiscal Years 2022-23 and 2023-24:

Table 2 - Resilient Florida Grant Program Awards

	Total Project Cost	FDEP Award	City Cost-Share
Flagler Drive Lift Station Retrofits – Design & Construction	$810,000	$405,000	$405,000
Pilot Seawall Elevation Project	7,250,000	3,625,000	3,625,000
Currie Park Redevelopment Project	3,750,000	1,875,000	1,875,000
North Flagler Drive Drainage Improvements	2,000,000	1,000,000	1,000,000
Flagler Drive Utilities Hardening	1,500,000	750,000	750,000
Utilities Adaptation Project	2,000,000	1,000,000	1,000,000
Tidal Valve Adaptation Project	1,600,000	800,000	800,000
TOTAL	**$17,310,000**	**$8,655,000**	**$8,655,000**

In addition, FDEP awarded the City a second Resilient Florida planning grant of $150,000 in 2023 for a Resilient Waterfront Adaptation Plan.

West Palm Beach has also been an active participant in emergency management planning and programs which consider strategies for improving the long-term resilience of the community to natural hazards by reducing risk for people and property. These efforts include the Local Mitigation Strategy for Palm Beach County and its municipalities.

Public Participation and Engagement

Community resilience is the capacity of governments, individuals, organizations, institutions, and businesses to plan for, respond to, withstand, and bounce back from acute and chronic stressors related to climate change impacts, including sea level rise, flooding, and more intense storms. To successfully build long-term community resilience, stakeholders must be consulted and invited to shape planning processes and decisions about adaptation measures and infrastructure investments. Otherwise, these policies will lack the broad-based public support needed to sustain them over the long term and through political or economic challenges.

The City of West Palm Beach organized several consultative forums to gather input

on the Vulnerability Assessment. On July 9, 2024, the consultant team met with the City's Sustainability Advisory Committee, delivering a lengthy, technically-focused presentation on the project. There was significant discussion about the importance of the Vulnerability Assessment and other near-term City efforts like the Waterfront Adaptation Plan.

Later, on July 31, 2024, the City held its official Public Workshop on the Vulnerability Assessment at the Mandel Public Library of West Palm Beach. An evening open house took place, conducted with presentation boards and a multimedia presentation featuring live polling. The consultant team and City staff were on hand to have one-on-one conversations about the project with residents as they reviewed the various presentation boards. A mapping station was also set up so that attendees could request certain exposure maps be reviewed to answer any questions. A recording of this workshop and a copy of the presentation materials were made available to the public in early August.

On August 5, 2024, City staff and the consultant team presented to the City Commission, providing next action steps for the Vulnerability Assessment project. City staff made note that direction to prepare key priority projects for design and permitting and to develop implementation strategies to a greater stage of readiness will help in subsequent grant cycles.

Resilience Initiatives in West Palm Beach

West Palm Beach has been a leader in sustainability and resilience efforts for nearly two decades, dating back to 2005, when the City signed onto the US Conference of Mayors' Climate Protection Agreement. The Office of Sustainability was created three years later, in 2008, with the City's first Sustainability Action Plan, "Rethink Paradise," following in 2012.

West Palm Beach was also an early municipal participant of the Southeast Florida Regional Climate Change Compact (the "Compact"), continuing to the present day. In 2013, the City joined the Global Compact of Mayors (now the Global Covenant of Mayors (GCoM), pledging to cut greenhouse gas (GHG) emissions and undertake certain climate planning efforts.

As part of the GCoM, West Palm Beach uses the Carbon Disclosure Project (CDP) protocols to submit its GHG emissions inventory and other required information, including climate resilience plans and actions. The City has submitted to CDP annually since 2017, earning an "A" rating five times, most recently in 2023. The City is also a participant in the LEED for Cities and Communities (L4C) program (formerly STAR Certification), earning a Gold Certification in 2022. L4C includes significant components related to community resilience.

The original West Palm Beach Rethink Paradise Sustainability Action Plan ("Plan") was updated in 2017, with a subsequent update begun in 2020. However, due to the COVID-19 pandemic, the 2020 update was never finalized. Instead, those updates and additional actions taken between 2020 and 2023 were incorporated in a 2024 Plan update, a draft of which is pending City Commission approval as of the writing of this Vulnerability Assessment.

All versions of the Sustainability Action Plan have taken a wide view, incorporating assessments and recommendations related to energy, water, transportation and land use, natural resources, waste management, community outreach, and adaptation and resilience.

Climate resilience has been examined even more deeply by the City in several additional efforts. In 2019, the City partnered with NEMAC+FernLeaf, a public-private partnership that helps communities quantify climate risk and identify the best actions for adaptation, to conduct a West Palm Beach Resilience Assessment ("Resilience Assessment") based on the nationally-recognized "Steps to Resilience" framework from the U.S. Climate Resilience Toolkit. The framework's five steps – further defined by language quoted from the Resilience Assessment – are as follows:

- Step One: Explore Climate Threats - *Identify relevant climate and non-climate stressors and related hazards and threats and quantify the impact on regional assets*
- Step Two: Assess Vulnerability and Risks - *Perform a detailed vulnerability and risk assessment based on the national standard risk framework to understand the comparative magnitude of impacts*
- Step Three: Investigate Options - *Develop options and strategies to address the most critical issues and build resilience*
- Step Four: Prioritize and Plan - *Prioritize and list the options that should be implemented to effectively build resilience*
- Step Five: Take Action - *Identify key resources and stakeholders to implement the prioritized strategies*

The analysis assessed assets in various categories by their exposure to specific threats. This assessment was performed at the specific asset level (e.g., a property parcel or road segment) by location and then aggregated to the census block group scale, enabling comparison with socioeconomic data.

The Resilience Assessment summarized the findings of the exposure analysis:

- *Inland flooding is a major challenge. In addition to likely inundation of assets, limited access to industrial, commercial, and critical facilities (restricted by the presence of a hazard, such as flood waters) is likely a primary concern.*

- *Sea level rise and storm surge inundation is likely to be less severe in West Palm Beach than in Broward and Miami-Dade counties to the south.*
- *West Palm Beach enjoys several socioeconomic strengths, but does face challenges in this arena—including income inequality.*

That initial exposure analysis revealed which "asset-threat pairs" were most common in the City or featured a high proportion of exposed assets. The "asset-threat" pairs were then assessed according to two vulnerability criteria (potential impact and adaptive capacity) and two risk criteria (probability and consequence). A matrix was then created with vulnerability on one axis and risk on the other, for a combined vulnerability and risk rating.

According to the Resilience Assessment, this vulnerability and risk analysis found that:

- *Large areas of the city are vulnerable and at risk to rainfall-induced flooding. City staff should note key thresholds covered in the risk analysis (10-year storm or other severity) to determine the best options to build resilience.*
- *Some areas of the city have multiple assets with high vulnerability and risk to rainfall-induced flooding. These areas are key focal points for investment to build resilience.*
- *Despite low percentages for vulnerability and risk, some areas that are likely to be deemed critical to the city are vulnerable to storm surge and sea level rise. These areas deserve investment to build resilience.*
- *Some highly vulnerable areas of the city may not offer optimal solutions for either reducing exposure or building adaptive capacity. They will rely on investment in emergency response to build resilience.*
- *Social vulnerability is an important consideration for all threats. Including socioeconomic metrics in prioritization will support social equity in the city.*
- *Although not quantified on a parcel level, the impact of water shortage on the city is important to prioritize for investment.*

As a next step, potential actions were prioritized according to several criteria: significance of vulnerabilities and risks, co-benefits provided, feasibility of implementing the action, and equitability. Actions related to flooding and sea level rise included:

- Improvements to the stormwater system, especially through Capital Improvement Program funding
- Identification of adaptation action areas that could be vulnerable to climate threats, to be included in the City's Comprehensive Plan
- Development of policies to increase capacity beyond a three-year event (2–3

inches of rainfall in a single storm)

- Ordinance updates for threatened areas outside of special flood hazard zones
- Implementation of a stream monitoring system to alert emergency managers of rising water levels
- Establishment of green stormwater infrastructure programs and fee credit programs for stormwater retention
- Creation of green infrastructure incentives and/or policies for redevelopment and new development
- Requirements for more adaptive capacity in new construction
- Inventory and assessment of seawalls and stormwater outfalls to better understand vulnerability and opportunities to secure funding
- Installation of green/gray seawalls, including integration with stormwater system upgrades

FEMA Community Rating System

Since its creation in 1968, the National Flood Insurance Program (NFIP) has provided federally-backed flood insurance in communities that enact and enforce floodplain regulations. By requiring communities to plan for and protect against a 1%-average-annual-chance flood event (also known as a 100-year flood event), the NFIP encourages the regulation of development in flood areas.

The Federal Emergency Management Agency (FEMA) oversees the NFIP and administers its Community Rating System, a voluntary program that offers NFIP insurance rate reductions for property owners in communities that exceed the minimum NFIP participation requirements through certain additional floodplain management and conservation activities. Local governments are classified according to their total CRS scores.

West Palm Beach joined CRS in October 1992 and has continually advanced in the CRS program. In 2018, West Palm Beach was awarded a CRS Class 5, scoring 3,444 CRS credit points. The Class 5 designation affords most NFIP policy holders a 25% percent annual discount on flood insurance. Table 3 below shows CRS participation in Florida and the percentage reduction in flood insurance rates associated with each rating class.

Table 3 - CRS Participation in Florida

CRS Class	Number of Florida Communities	NFIP Discount
9	17	5%
8	40	10%
7	53	15%
6	72	20%
5	58	25%
4	1	30%
3	4	35%

Discounted flood insurance provides a powerful incentive for communities to take steps that will reduce flood damage to existing buildings and manage development in certain unmapped areas, encouraging the restoration and preservation of the natural functions of floodplains.

CRS provides both incentives and tools to further the goals of providing flood insurance to property owners, reducing flood loss, and saving taxpayers' money. With the City participating in the program, property owners can receive discounted flood insurance premium rates; with effective floodplain management, the community becomes more resilient.

These rate reductions are due, in part, to the City's initiatives that help to implement three basic CRS goals:

1. Reduce flood damage to insurable property. The CRS program encourages communities to reduce the exposure of existing buildings (and their contents) to flood damage, especially properties that have flooded multiple times. Standards exceeding the minimum criteria of the NFIP may be needed to protect buildings and contents from flood hazards. The CRS encourages communities to map and provide data on their flood hazards and employ such data in their regulatory programs.

2. Strengthen and support the insurance aspects of the NFIP. Communities are awarded CRS points for activities that support accurate risk rating of flood insurance premiums, through mapping and information programs that help assess individual property risk and reduce repetitive flood losses. Local governments can receive additional points for informing residents of their

flood risk and inducing them to purchase and maintain flood insurance policies.

3. Encourage a comprehensive approach to floodplain management. The CRS program encourages communities to use all available tools to implement comprehensive local floodplain management programs, which can address concerns beyond the protection of insurable property. The CRS program recognizes local efforts that protect lives; advance public health, safety, and welfare; minimize damage and disruption to infrastructure and critical facilities; preserve and restore the natural functions and resources of floodplains and coastal areas; and ensure that new development does not shift adverse impacts to other parts of the watershed or other properties. Understanding the physical and biological processes that form and alter floodplains and watersheds allows communities to appropriately address flooding, erosion, habitat loss, water quality, and special flood-related hazards. The "comprehensive approach" envisioned by the CRS program includes planning, public information, regulations, financial support, open space protection, public works activities, emergency management, and other appropriate techniques.

CRS Requirements and Creditable Activities

In recognition of the fact that "floodplains and watersheds change over time" due to "many natural and manmade changes," the CRS Manual introduced a series of credit options for "community efforts to anticipate" future flood risk in relation to climate change. Because sea level rise is expected to be an increasingly critical issue for floodplain management, many of the credit options and assessment criteria for coastal communities specifically refer to studies of sea level rise impacts on future hydrologic conditions and local drainage systems.

These options are summarized in section 116.c of the CRS Manual as:

1. Credit is provided in Section 322.c for communities that provide information about areas (not mapped on the Flood Insurance Rate Map (FIRM) that are predicted to be susceptible to flooding in the future because of climate change or sea level rise.

2. To achieve CRS Class 1, a community must receive credit for using regulatory flood elevations in the V and coastal A Zones that reflect future conditions, including sea level rise.

3. Credit is provided in Section 342.d when prospective buyers of a property are advised of the potential for flooding due to climate changes and/or sea level rise.

4. Credit is provided in Section 412.d when the community's regulatory map is based on future-conditions hydrology, including sea level rise.

5. Credit is provided in Section 432.k when a community accounts for sea level rise in managing its coastal A Zones.

6. Credit is provided in Section 452.b for a coastal community whose watershed master plan addresses the impact of sea level rise.

7. Credit is provided in Section 512.a, Steps 4 and 5, for flood hazard assessment and problem analyses that address areas likely to flood and flood problems that are likely to get worse in the future, including (1) changes in floodplain development and demographics, (2) development in the watershed, and (3) climate change or sea level rise.

There are 19 creditable CRS activities organized under four categories as reflected in Table 4. Each of the 19 activities has one or more elements. The CRS Manual assigns credit points based on the extent to which each activity advances the goals of the CRS, which are 1) to reduce and avoid flood damage to insurable property, 2) to strengthen and support the insurance aspects of the NFIP, and 3) to foster comprehensive floodplain management.

Table 4 below outlines the CRS Activities and the current scores in each of the CRS Activities.

Table 4 - West Palm Beach CRS Activities

CRS Activity Number	Activity	Current Points Scored
310	Elevation Certificates	38
320	Map Information	90
330	Outreach Projects	350
340	Hazard Disclosure	10
350	Flood Protection Information	113
360	Flood Protection Assistance	100
370	Flood Insurance Promotion	110
410	Flood Hazard Mapping	0
420	Open Space Preservation	1,337
430	Higher Regulatory Standards	192
440	Flood Data Maintenance	169

CRS Activity Number	Activity	Current Points Scored
450	Stormwater Management	30
510	Floodplain Management Planning	482
520	Acquisition and Relocation	0
530	Flood Protection	0
540	Drainage System Maintenance	0
610	Flood Warning and Response	285
620	Levee Safety	0
630	Dam Safety	0
	TOTAL	**3,306**

West Palm Beach's CRS program is currently under review, with a new score to be released within the next calendar year. The new score will be used to determine future Class 4 eligibility, which would require reaching 3,000 points and meeting other requirements. Historically, one of the major hurdles for Florida communities reaching Class 4 is adopting a Watershed Master Plan that meets the rigorous CRS standards, but the City has such a plan underway.

Good floodplain management acknowledges and thinks about how floodplains might look over time. This includes many factors such as rising sea levels. The CRS Manual incorporates acknowledgement of—and credit for—community efforts to anticipate future flood risk and climate resilience and to take actions to mitigate adverse impacts. The City of West Palm Beach will be well situated to earn CRS points related to sea level rise, not only by completing this Vulnerability Assessment, but also undertaking other efforts, such as the City's current work on its FDEM-funded Watershed Master Plan.

Current Context of Vulnerability

Climate Change and Sea Level Rise

Globally, climate change presents a monumental challenge, characterized by rising temperatures, shifting weather patterns, and increased frequency of extreme weather events. In the context of West Palm Beach, these global trends manifest in specific regional impacts that directly affect the City's environmental and socioeconomic fabric. West Palm Beach faces unique challenges due to its geographical character and location, with climate change exacerbating existing environmental vulnerabilities. The Assessment specifically focuses on

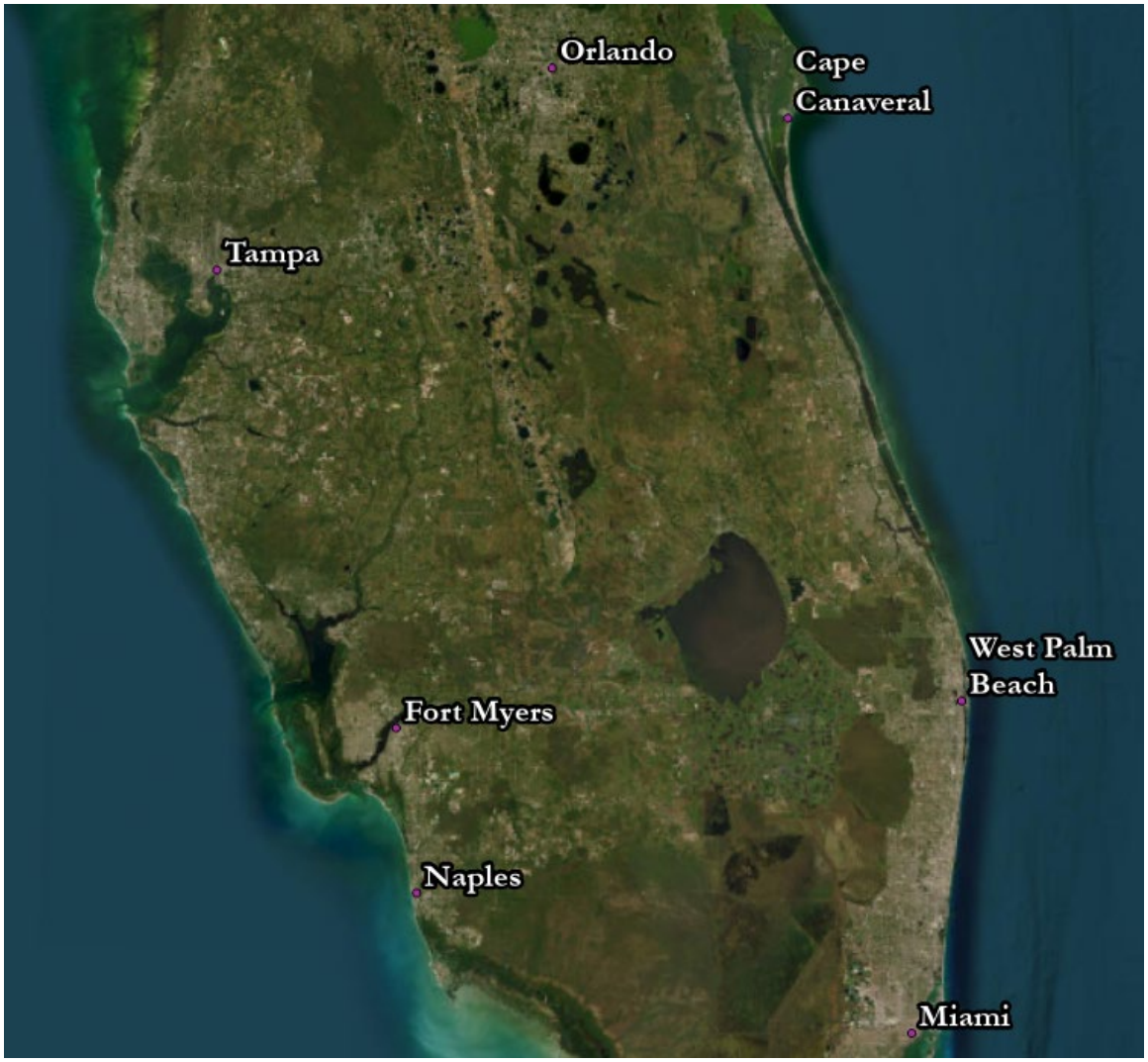
understanding these local implications, including how shifts in climate patterns are influencing the City's natural ecosystems, urban infrastructure, and socio-economic dynamics.

In the case of West Palm Beach, climate change presents a multifaceted set of challenges that demand careful examination and proactive response. Characterized by rising global temperatures, altered weather patterns, and a heightened frequency of extreme events, these changes have direct and indirect effects on the City and other parts of Palm Beach County, impacting various aspects of the region's environment, economy, and society.

One notable consequence is the increase in sea levels, which is primarily driven by the thermal expansion of seawater and the melting of polar ice caps and glaciers. Even though the City is located on the Intracoastal Waterway, rather than directly facing the Atlantic Ocean, as sea levels continue to rise, West Palm Beach's shorelines nevertheless face escalating risks. These include coastal erosion, more frequent and severe flooding, and compromised infrastructure. Much of West Palm Beach sits on the coastal ridge at a much higher elevation than many other areas in southeast Florida. However, these impacts still threaten low-lying areas in particular of the City and the City’s reliance on a a robust coastal economy in general.

Sea-level rise is a critical concern for coastal communities like West Palm Beach, posing significant risks to their infrastructure, ecosystems, and communities. The city's coastline, characterized by its shorelines and vital economic assets, is under threat as sea levels encroach further inland. Shoreline erosion and compromised drainage system operations are two consequences of these impacts likely to increase in the future.

Figure 8 - Regional Context of West Palm Beach



Furthermore, the increased frequency and intensity of storms, including hurricanes and tropical cyclones, pose a substantial risk to West Palm Beach. Rising sea levels exacerbate the storm surge effect, magnifying the potential for devastating inundation during these events.

Additionally, the economic vitality of West Palm Beach, with its reliance on tourism, fisheries, and maritime industries, is intricately linked to its coastal assets. As sea levels rise and coastal vulnerabilities grow, these sectors face increasing uncertainty and disruption.

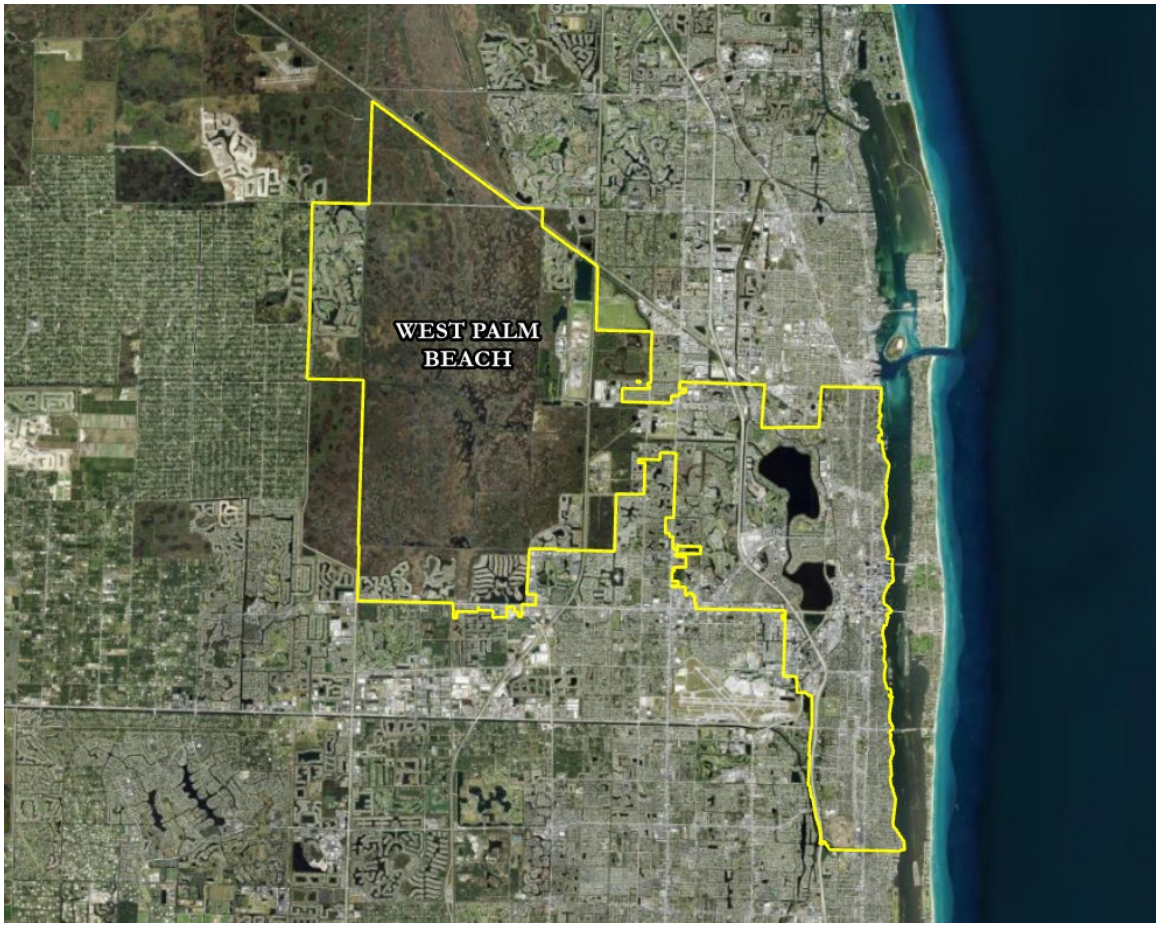
Physical Descriptors of Area

Geographical Setting and Characteristics

West Palm Beach's geographical characteristics render it particularly susceptible to climate change impacts. These characteristics include:

Coastal Location: Located on the Lake Worth Lagoon near the Atlantic Ocean, West Palm Beach is highly susceptible to a range of coastal hazards. This includes the threat of sea-level rise, which can lead to temporary or permanent inundation of shorelines and land. It also includes storm surges from tropical storms and hurricanes, which may be capable of reaching inland landscapes. Additionally, by increasing the base water level, sea level rise elevates the risk of flooding during daily and seasonal high tides.

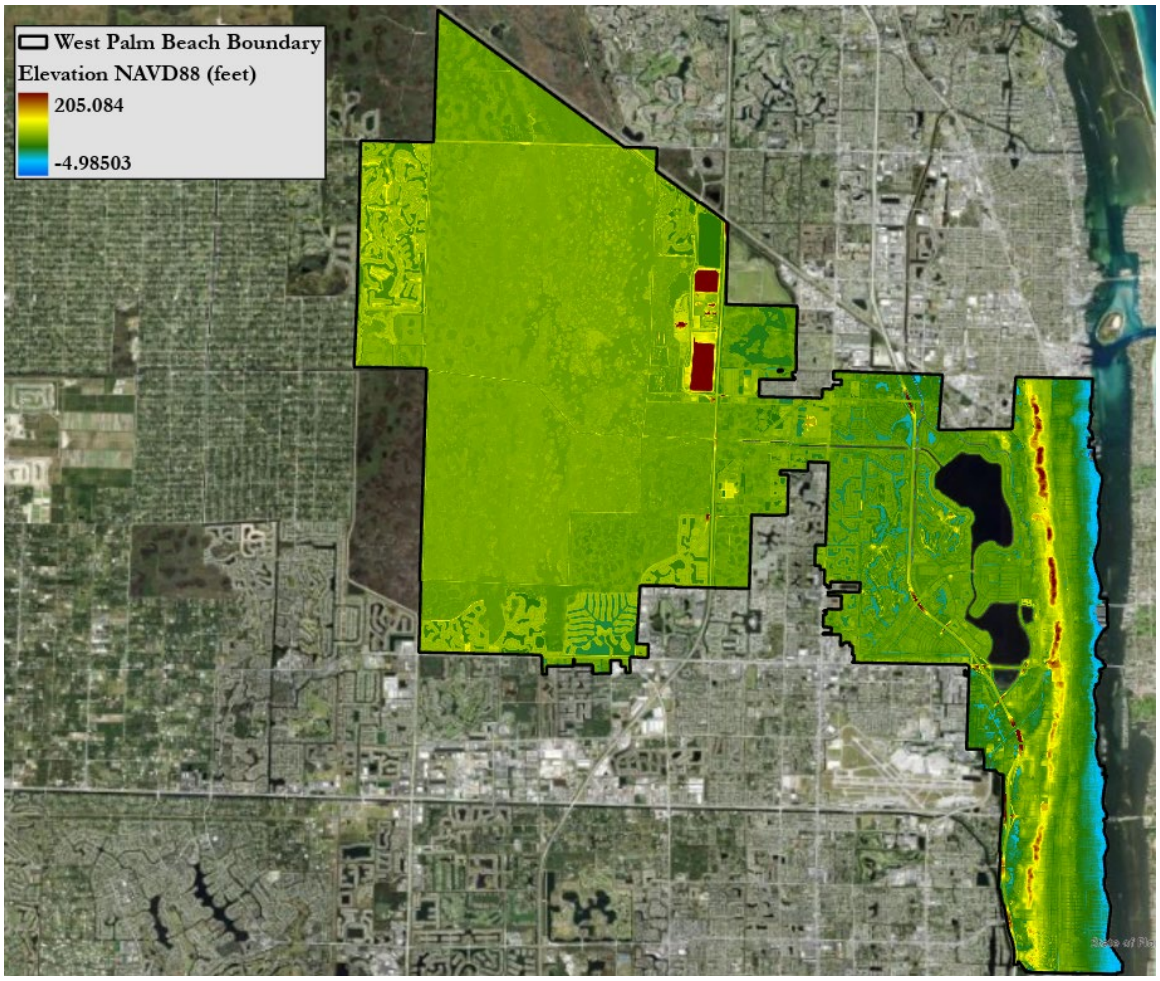
Figure 9 - Map of West Palm Beach



Elevation and Topography: While some parts of the city feature relatively flat terrain, others exhibit slightly elevated landscapes. These topographical differences greatly influence flood risk and drainage patterns. Low-lying areas with minimal elevation are at greater risk of flooding, while elevated regions may experience comparatively lower flood risk.

Figure 10 - Elevation

Lower elevations in blue and green, higher in yellow and red



Demographic Overview

Understanding the demographic characteristics of West Palm Beach is crucial for evaluating residents' vulnerability in the face of climate change. A comprehensive analysis provides insights into the population dynamics, growth trends, socioeconomic factors, and the application of tools like the Social Vulnerability Index and the Location Affordability Index. Evaluating these indicators offers a

multifaceted understanding of the challenges and potential solutions for climate resilience.

Population Dynamics and Distribution

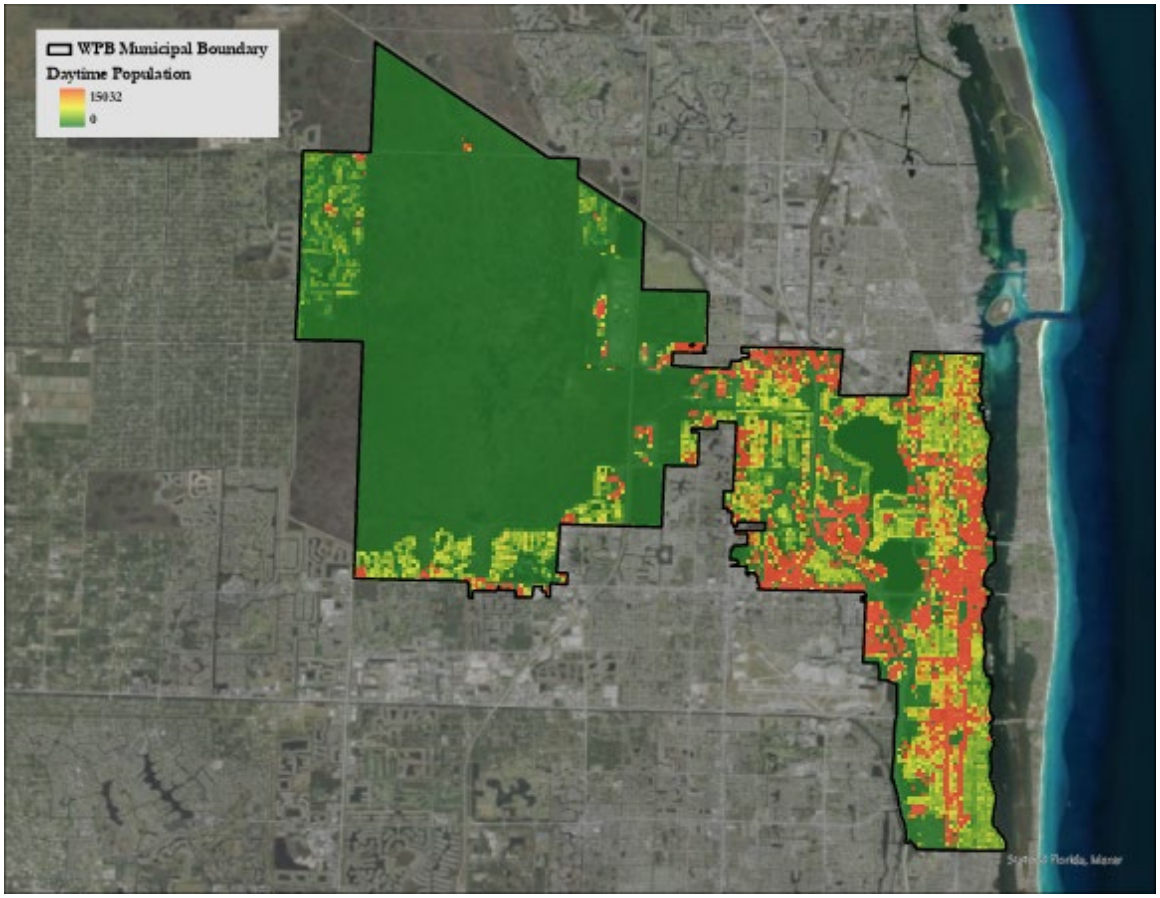
Population concentrations across West Palm Beach fluctuate significantly between day and night, directly affecting flood risk exposure during potential flood events. During the day, the city's commercial centers, schools, and government facilities become densely populated as people converge for work and activities. At night, the population disperses into residential neighborhoods, resulting in lower density in these areas. Figures 11 and 12 illustrate these shifts, using color-coded maps: red for high concentration, yellow for medium, and green for low, highlighting how population density changes between daytime and nighttime.

- **Daytime Activities:** During the day, commercial areas are bustling with activity, including workplaces, shopping districts, and dining establishments. This influx significantly increases the flood exposure of these zones. A flood event during business hours would disrupt essential services, impact transportation, and displace a large number of workers and visitors, especially in high-density commercial districts.

- **Nighttime Quietude:** As businesses close and traffic decreases, the population retreats to residential areas and tourist accommodations. The flood risk shifts accordingly, with residential neighborhoods becoming more vulnerable to flood-related impacts. In case of a nighttime flood, displacement of residents and potential damage to homes would be a primary concern, particularly in densely populated or economically vulnerable neighborhoods.

Figure 11 - Daytime Population Concentration

Red indicates high concentration, yellow medium, and green low



This graphic illustrates the daytime population distribution across the City of West Palm Beach, highlighting areas of varying population densities within the municipal boundaries. The color-coded map shows areas in green as having lower population densities, while areas in red indicate higher population concentrations during the day. The highest densities are concentrated in the eastern and central parts of the city, likely corresponding to commercial, business, and government districts. In contrast, the western and peripheral areas, marked predominantly in green, experience much lower population densities, potentially representing suburban, agricultural, or parkland regions.

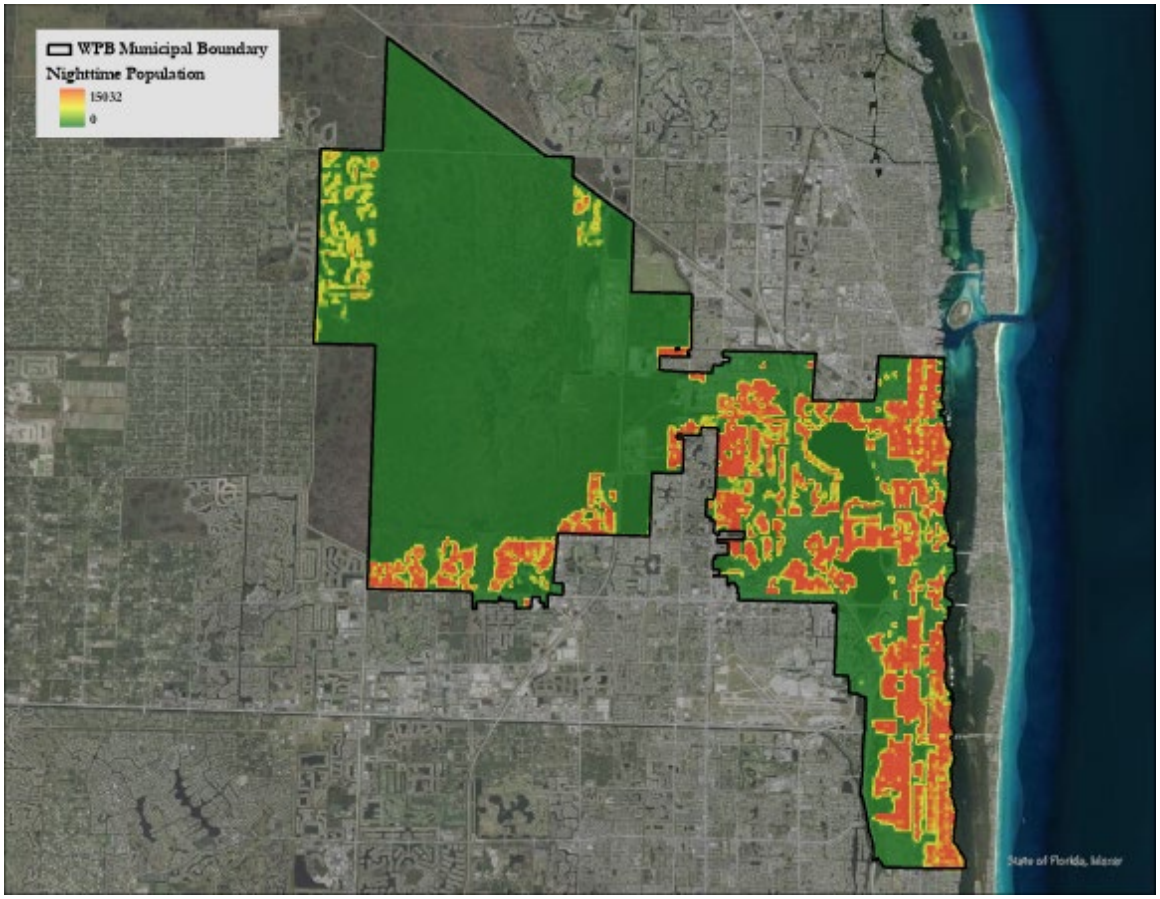
While the model generally aligns with expected patterns, certain areas, such as a red dot in the northern part of the city, may reflect small facilities like a Fish & Wildlife office and City Watershed Management site, which do not typically attract large crowds. These localized details help refine the interpretation of the data.

This daytime pattern has important implications for flood risk management, as the

most densely populated areas are at higher risk of disruption during a flood event, especially during business hours.

Figure 12 - Nighttime Population Concentration

Red indicates high concentration, yellow medium, and green low



This graphic displays the nighttime population distribution across West Palm Beach, highlighting areas of varying population densities within the municipal boundaries. Similar to the daytime map, the color-coded system uses green to represent low-density areas and red to indicate high-density population clusters. The nighttime map shows a significant shift in population, with high-density residential areas located mostly in the eastern and southern parts of the city, which are represented by red. These regions likely correspond to residential neighborhoods where people return after work. The western and less developed areas, marked in green, experience lower population densities at night, possibly indicating suburban or less populated regions. This pattern emphasizes that during nighttime flood events, densely populated residential areas face higher risks of displacement and damage, while infrastructure in low-density zones may be impacted with less direct exposure

to residents.

The dynamic nature of West Palm Beach's population distribution reveals key insights into climate vulnerability. During the day, commercial and civic areas are at heightened risk, relying on robust infrastructure to prevent significant disruption from flooding. At night, residential areas, particularly those with less economic resilience, are more exposed to the dangers of flooding.

Key considerations include:

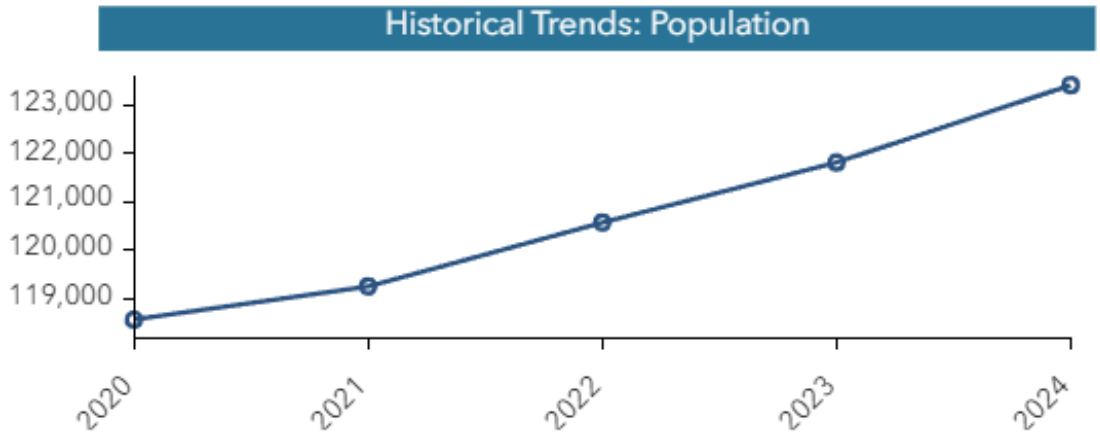
- **High-risk Red Zones**: During both day and night, red zones remain highly vulnerable to floods. These areas house either large workforces or densely populated residential communities, meaning that flood defenses need to prioritize protecting both economic hubs during the day and homes at night.
- **Medium-risk Yellow Zones**: These areas see moderate activity during the day, with a mixture of residential and commercial use. Preparedness measures in these zones should address the varying flood risk throughout the day, ensuring that both workers and residents are protected.
- **Low-risk Green Zones**: Sparsely populated areas, though less impacted by flooding in terms of human displacement, still require protection to maintain critical infrastructure, including transportation routes and utilities.

Flood preparedness efforts must account for these shifting patterns to effectively safeguard both economic and residential centers.

Population Growth Trends

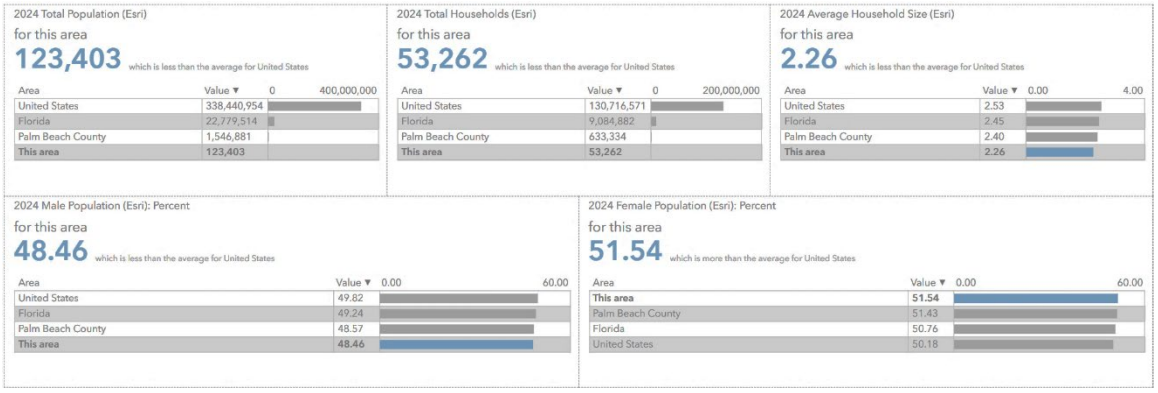
With a burgeoning population of approximately 124,000, a growth rate of 5.8% from 2020 to 2023, and future forecasts of strong growth, the city's population will likely continue to expand. Consequently, West Palm Beach may see significant revenue windfalls from increased development. These insights, backed by data gathered by the American Community Survey (ACS) and the U.S. Census Bureau, underscore the necessity for targeted infrastructure development and resilience planning. Appendix H contains demographic information extracted from the American Community Survey and US Census Bureau.

Figure 13 - West Palm Beach Population Trends, 2020-2024



The population of West Palm Beach has increased steadily, from just under 120,000 in 2020 to over 123,000 by 2024, reflecting a growth rate of 5.8% over the last four years. This growth is important to note because increased population often leads to greater infrastructure development, including homes, roads, and businesses, many of which may be located in flood-prone areas. With more people and properties at risk, the potential for uninsured property losses increases, highlighting the need for enhanced floodplain mapping and zoning regulations to ensure new developments consider flood risks.

Figure 14 - Population and Household Size Infographic



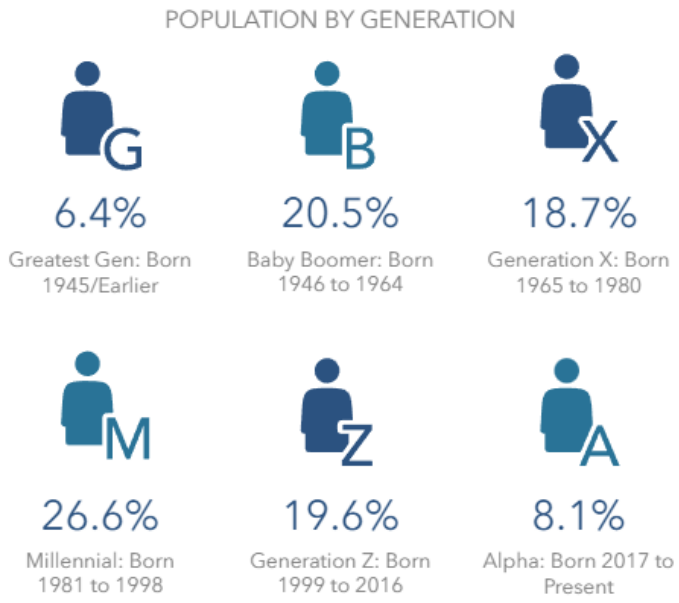
This detailed breakdown of the 2024 population shows that there are 53,262 total households in West Palm Beach, with an average household size of 2.26. This is slightly lower than the state and national averages (2.45 and 2.53, respectively), which could have implications for the city's social vulnerability to flooding. Smaller household sizes often mean fewer individuals available to assist with flood preparedness and recovery, especially for vulnerable populations like the elderly or

low-income families. Moreover, lower household sizes suggest more single-family homes or individual living arrangements, potentially increasing the number of structures exposed to floodwaters.

Smaller Household Sizes: The city's relatively small household size could indicate more households overall, meaning more buildings and properties exposed to flooding. It also suggests that many homes may be occupied by single individuals, who might lack the resources and physical ability to prepare for or recover from a flood.

Additionally, the city's male population is 59,779 (48.46%), and the female population is 63,604 (51.54%), close to a balanced gender split. While this may seem neutral in terms of flood vulnerability, women, particularly single mothers and elderly women, often face unique challenges during disaster recovery, including lower financial resources and caregiving responsibilities. Ensuring that these populations have access to resources like flood insurance and post-disaster assistance is critical.

Figure 15 - Percent of Population By Generation



West Palm Beach's demographic breakdown shows a diverse generational mix, with Millennials (born 1981 to 1998) making up the largest segment at 26.6%, followed by Baby Boomers (born 1946 to 1964) at 20.5%, and Generation X (born 1965 to 1980) at 18.7%. Younger generations, such as Millennials and Generation Z (19.6%), tend to be more mobile and adaptable but may lack the financial resources to invest in adequate flood insurance or property fortifications. This could leave many homes

uninsured and exposed to significant financial losses during a flood event.

On the other hand, Baby Boomers and the elderly (6.4% from the Greatest Generation, born 1945 or earlier) are less mobile and may face greater physical and logistical difficulties during evacuation. The city's flood resilience planning must take into account these age-based vulnerabilities, ensuring that older residents receive adequate support, both in terms of evacuation plans and recovery assistance.

Generational Considerations: The large proportion of Millennials and Generation Z might present challenges in terms of flood preparedness, as younger residents may not yet have the financial stability or experience with home ownership that often accompanies taking precautionary flood measures. Additionally, the significant share of Baby Boomers and elderly residents highlights the need for targeted emergency response planning, particularly for those with limited mobility or health concerns.

Income and Vulnerability: While the infographics above do not provide direct income data about the City of West Palm Beach, the generational and household data suggest varying levels of economic vulnerability. Younger residents might be more likely to rent, and rental properties are less likely to be insured for flood damage. On the other hand, retirees, while potentially more affluent, might not have the same income stability or flexibility to recover from a significant flood event, particularly if their properties are uninsured.

West Palm Beach's demographic profile in 2024 presents both opportunities and challenges for flood resilience planning. The city's growing population and expanding infrastructure will increase exposure to flood risks, particularly if development continues in flood-prone areas. Ensuring that all segments of the population, from younger renters to older homeowners, have access to flood mitigation resources will be key in minimizing the impacts of future flood events. Comprehensive flood risk strategies should include upgrading stormwater systems, improving floodplain zoning, and tailoring public outreach to address the specific needs of diverse generational and household groups.

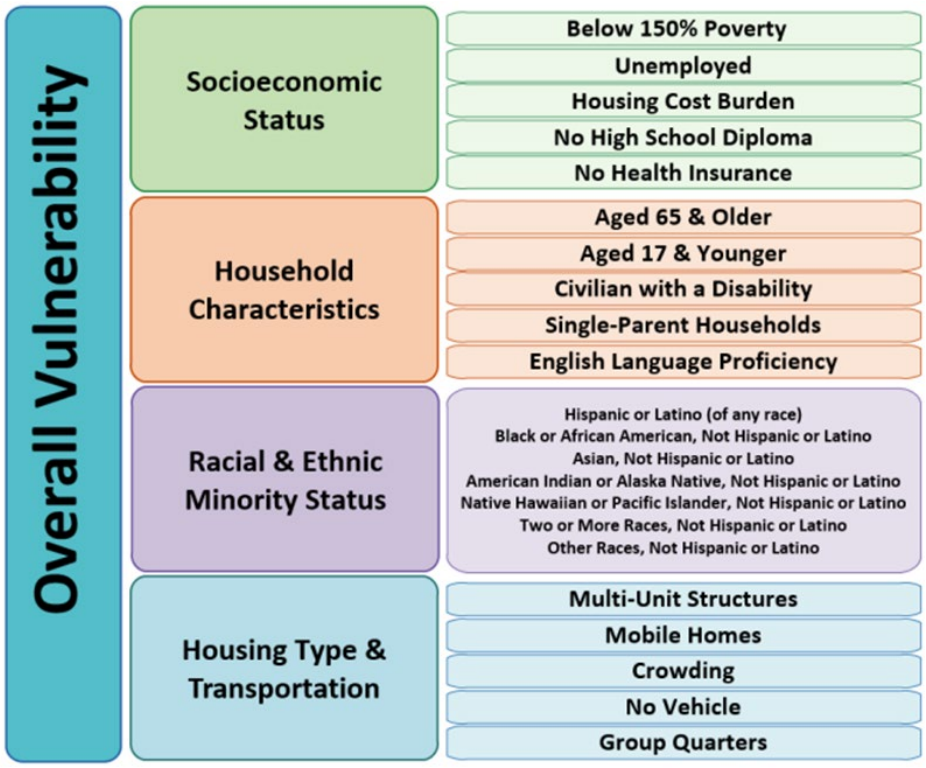
Socioeconomic Vulnerability

Socioeconomic disparities significantly influence community resilience to flood risk. Vulnerable populations may face disproportionate impacts from flooding and climate change due to limited resources and resilience. It is essential to identify and address socioeconomic disparities to ensure an equitable response to climate-related and increased flood-risk related challenges.

Socioeconomic disparities play a crucial role in determining a community's resilience to climate change. Vulnerable populations, identified through the most recent Centers for Disease Control and Prevention (CDC) Social Vulnerability Index

(SVI), are at increased risk due to factors such as poverty, lack of vehicle access, and crowded housing conditions. The SVI provides a comprehensive assessment across four key themes—socioeconomic status, minority status and language, housing composition and disability, and housing and transportation—offering valuable insights for emergency preparedness, supply estimation, shelter identification, and evacuation planning in the face of sea-level rise and potential flooding scenarios. See Figure 16. The latest SVI data highlights West Palm Beach's at-risk communities, emphasizing the need for targeted support and intervention.

Figure 16 - Components of Social Vulnerability Index



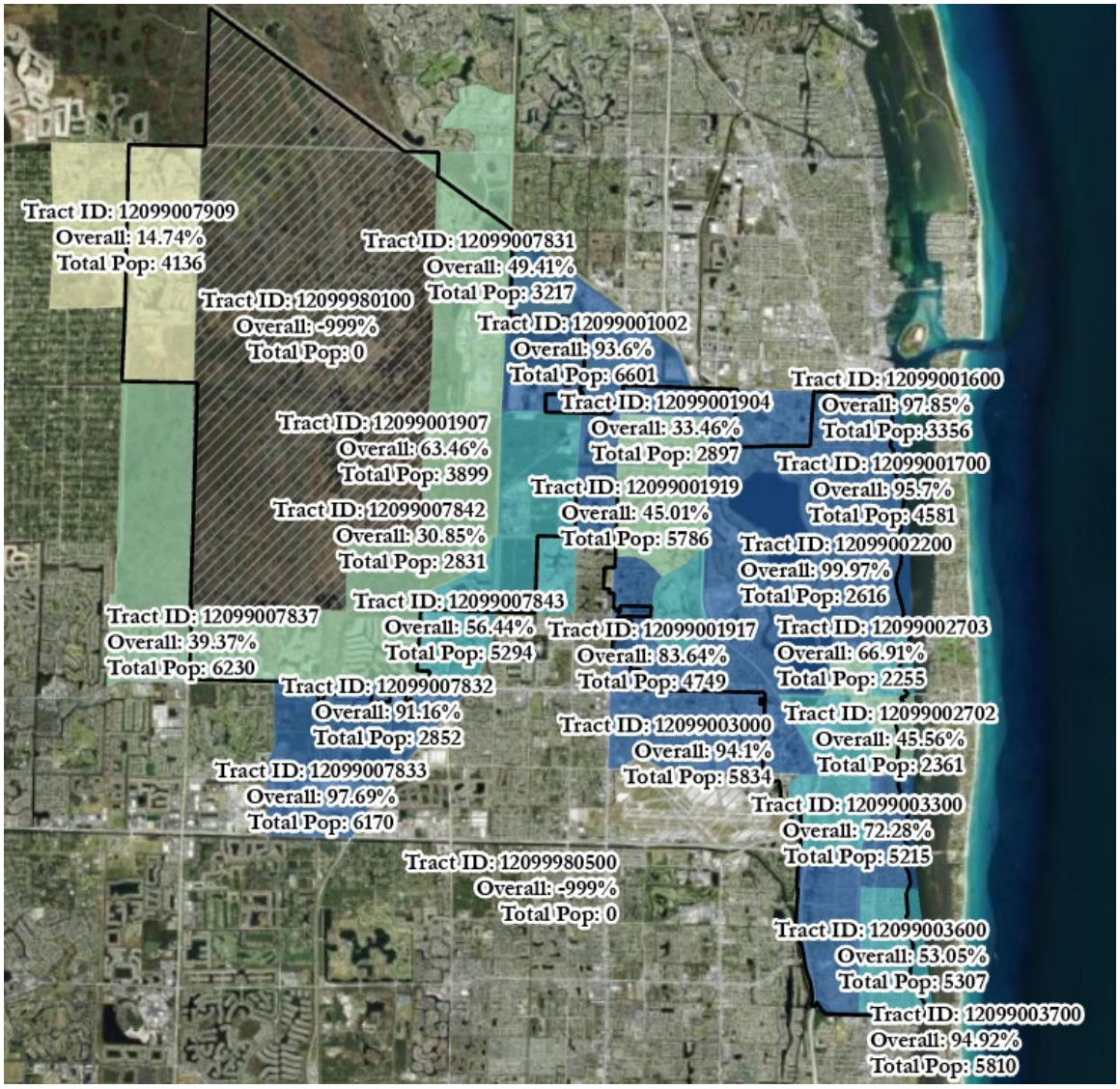
The SVI was utilized to identify vulnerable populations and serve as a framework to discuss population characteristics that are exacerbated by flooding under future flooding conditions.

The CDC's SVI database and mapping tools can assist with emergency preparedness in several ways. It can be used to estimate the amount of necessary supplies, such as food, water, medicine, and bedding, as well as how many emergency personnel are needed to assist at specific sites. The tool can also identify areas in need of emergency shelters and generically, in the preparation of evacuation plans, accounting for those with special needs, and highlighting those communities that may need continued support to recover from a natural disaster.

As reflected in Figure 17, the analysis of the City's social vulnerability using the latest CDC's SVI utilizes U.S. Census data to analyze the social vulnerability of every census tract. Each census tract is ranked on 15 social factors, including poverty, lack of vehicle access, and crowded housing, and groups them info four related themes to create an average score between 0% - 100%.

Figure 17 - CDC Social Vulnerability Index Map

Most vulnerable populations highlighted w/hatching and labeling (<50% overall percentile ranking)



The U.S. Department and of Housing and Urban Development (HUD),with the help of the Department of Transportation, launched the Location Affordability Index (LAI),

which identifies areas based on cost estimates of housing and transportation for eight different household profiles (see Table 5). Furthermore, the LAI presents advanced insights into housing and transportation costs, which are critical for flood risk planning and enhancing climate resilience. By leveraging simultaneous equation modeling and an extensive dataset, the LAI accurately estimates costs for a variety of household profiles. This includes considerations of auto ownership, housing expenses, and transit usage, providing a nuanced understanding of affordability challenges faced by residents.

Table 5 - Location Affordability Index Household Income Profiles

Household Profile	Median Household Income for a Given Area (MHHI)
1. Median-Income Family	MHHI
2. Very Low-Income Individual	National Poverty Line
3. Working Individual	50% of MHHI
4. Single Professional	135% of MHHI
5. Retired Couple	80% of MHHI
6. Single-Parent Family	50% of MHHI
7. Moderate-Income Family	80% of MHHI
8. Dual-Professional Family	150% of MHHI

The term "Working Individual - 50% of MHHI" and others like it refer to metrics used to describe the income level of a working individual in relation to the Median Household Income (MHHI) of a given area. Here is a breakdown of what this means and its significance:

- MHHI (Median Household Income): This is the median income of all households in a specific area. The median is the middle value when you line up all the households by income, meaning half the households earn more than the MHHI and half earn less. It is a commonly used measure to understand the average income level of an area.
- 50% of MHHI: When an individual's income is described as "50% of MHHI," it means their income is half the median household income for their area. This is a relative measure indicating the individual's earnings compared to the average household in the community.

These metrics have significance in the context of flooding and vulnerability assessments:

- Economic Vulnerability: Individuals earning a low percentage of the MHHI may have less financial flexibility to recover from flood damage or to invest in preventative measures such as insurance or home improvements that reduce flood risk.
- Resource Allocation: Understanding the income levels of affected individuals or households in relation to the MHHI helps in tailoring flood resilience and recovery programs. It highlights populations that may need more support in terms of subsidies, grants, or other assistance.
- Planning and Preparedness: Identifying areas where a significant portion of the population earns a lower percentage of MHHI can inform emergency management agencies and local governments about potential needs for evacuation assistance, shelters, and other support services during and after a flooding event.

The incorporation of income levels as a percentage of MHHI in vulnerability assessments helps to paint a more detailed picture of risk and resilience within a community. It underscores the interconnectedness of socioeconomic status and disaster vulnerability, emphasizing the need for targeted approaches in resilience planning and support. The LAI scores across West Palm Beach identify areas of varying affordability and detail the distribution of owner-occupied versus renter-occupied housing (see Figure 18 below), illustrating the intersections of affordability, vulnerability, and climate risk. Higher renter areas are generally associated with more social vulnerability or where certain populations may be exponentially impacted by flooding. This comprehensive approach informs strategic planning and interventions, aiming to mitigate the impacts of climate change on the most vulnerable segments of the population. These enhancements, along with a broader dataset, make the LAI a robust tool for understanding and planning around housing and transportation affordability, potentially aiding in flood risk planning by highlighting areas where affordability and risk intersect.

In the context of flood risk, the correlation between higher rates of renters in a community and increased social vulnerability takes on an even more critical dimension. Renters often reside in areas more susceptible to flooding, either due to the lower cost of housing in such locations or due to limited availability of affordable options in safer areas. This situation places them at a disproportionate risk during flood events, not only in terms of immediate physical danger but also regarding the longer-term repercussions on their stability and well-being.

The transient nature of rental housing means that renters may have less knowledge about local flood risks and less incentive to invest in long-term flood preparedness measures. Furthermore, the financial instability associated with renting can

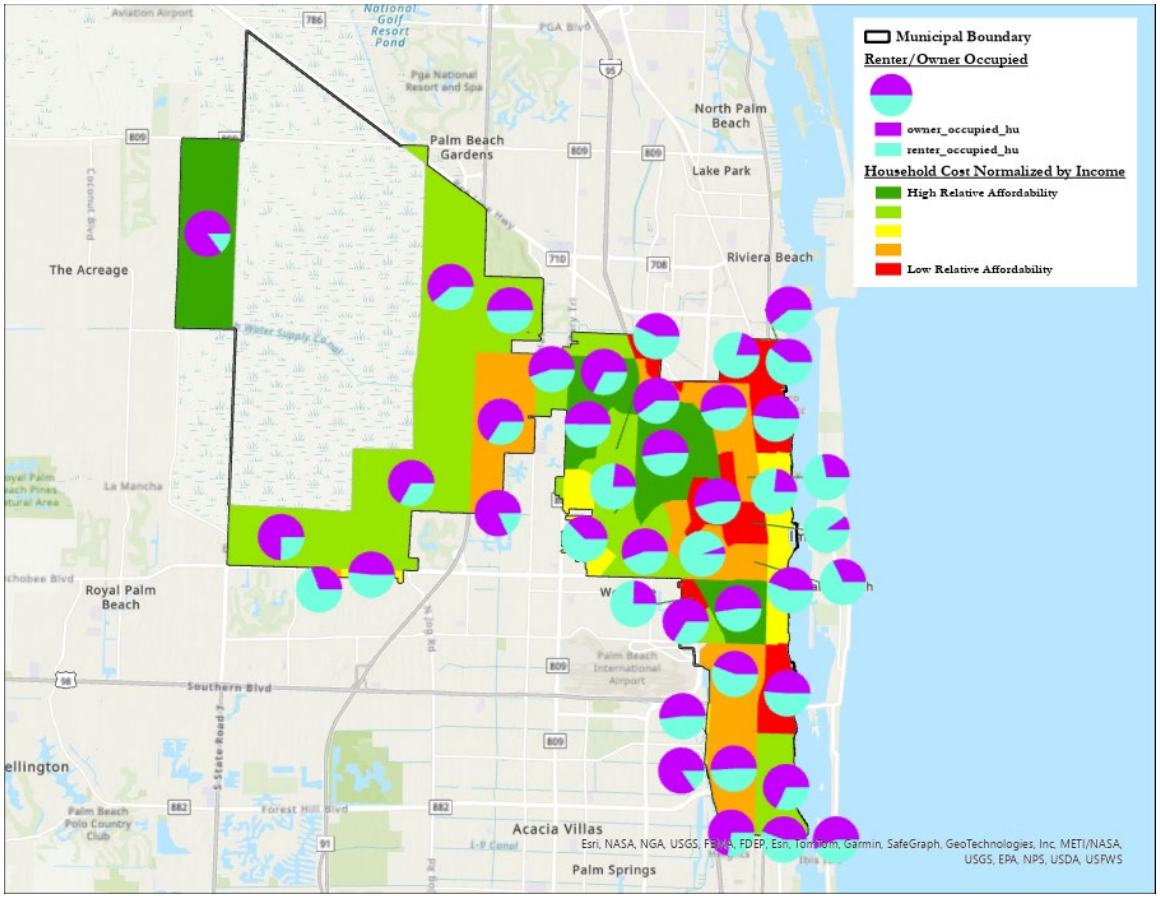
exacerbate the challenges of recovering from flood damage. Renters may lack the insurance coverage, savings, or resources to quickly rebound from the loss of property or displacement caused by flooding. This can lead to significant disruptions in their lives, including the loss of employment, educational discontinuity, and mental health stresses.

Moreover, the areas with high concentrations of rental properties may receive less attention in terms of flood mitigation infrastructure and services. Investment in flood defenses, such as levees, floodwalls, and green infrastructure, is often prioritized in areas with higher property values and stronger political influence, which can leave renter-dominated neighborhoods more exposed and vulnerable.

Given these dynamics, addressing the flood risk in communities with a high proportion of renters requires targeted policies and interventions. This includes not only enhancing the physical infrastructure to withstand flooding but also improving the resilience of the rental population through education on flood risks, access to affordable flood insurance, and the establishment of support systems for post-disaster recovery. Policies aimed at ensuring the availability of affordable, flood-resilient housing in safer areas are also crucial. Such comprehensive approaches can help mitigate the impact of floods on socially vulnerable populations, thereby reducing the overall risk and enhancing community resilience against climate change and natural disasters.

Figure 18 - HUD LAI Scores across West Palm Beach

Green denotes areas where housing and transportation costs are more affordable, relative to income; red and orange signify areas where incomes are less sufficient to cover housing and transportation costs; yellow is in between. Pie chart overlays represent the ratio of total owner-occupied housing in blue and renter-occupied housing in purple.



Key Infrastructure and Assets

West Palm Beach's critical infrastructure and assets are the backbone of the City's functionality and are integral to the Vulnerability Assessment. They are also required components of the analysis pursuant to statute divided out into four major "asset classes." These major asset classes are:

- Transportation assets and evacuation routes



- Critical infrastructure



- Critical community and emergency facilities



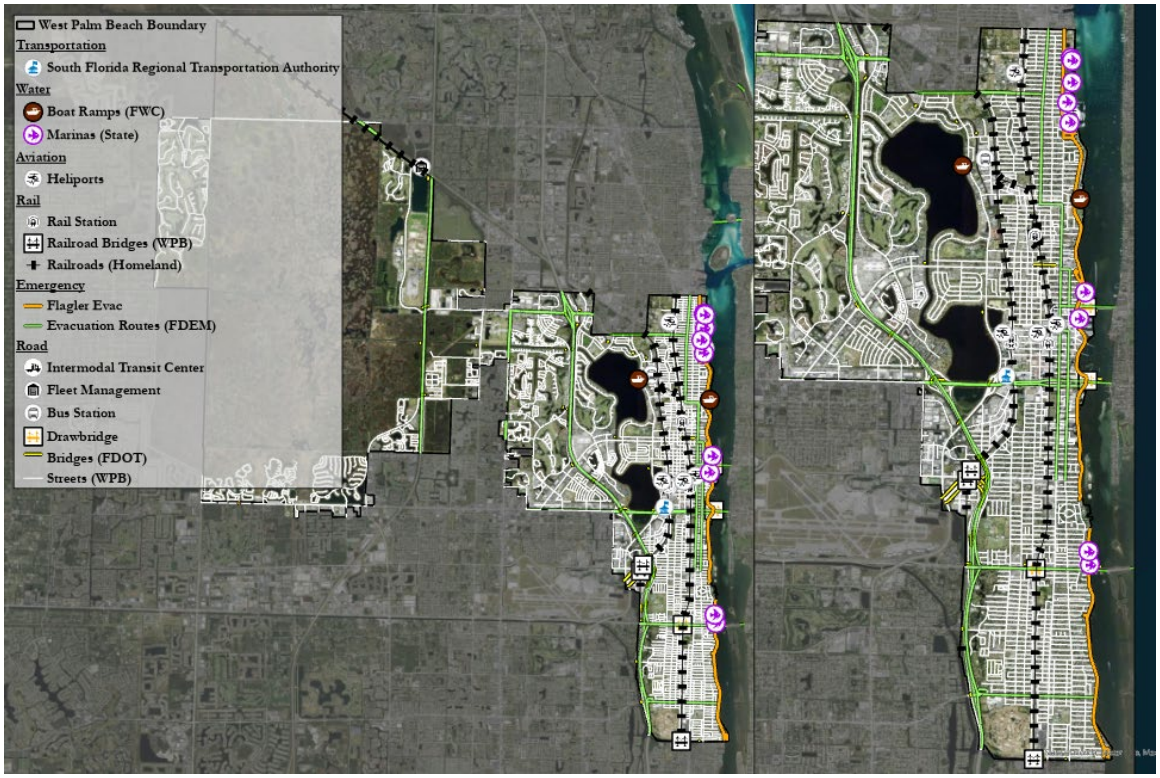
- Natural, cultural, and historical resources



These assets encompass a wide range of essential components:

Transportation Infrastructure: West Palm Beach includes a network of vital transportation assets, including bridges, heliports, and a series of roadways linked to one major evacuation route. Five private heliports, three of which are for law enforcement officials, and one private medical heliport makes up the City's air transport infrastructure, with marinas and boat ramps comprising the primary water transportation facilities.

Figure 19 - Map of Transportation Infrastructure



Critical Infrastructure: The City relies on a robust network of utilities that includes stormwater components, wastewater treatment facilities, water supply systems, and electrical infrastructure. These utilities are indispensable for maintaining essential services, and their vulnerability to climate-related disruptions can have cascading effects on the community. Some are owned by the City, and some are owned by other entities. These assets are included in Figures 20-23.

Figure 20 - Map of Stormwater Infrastructure

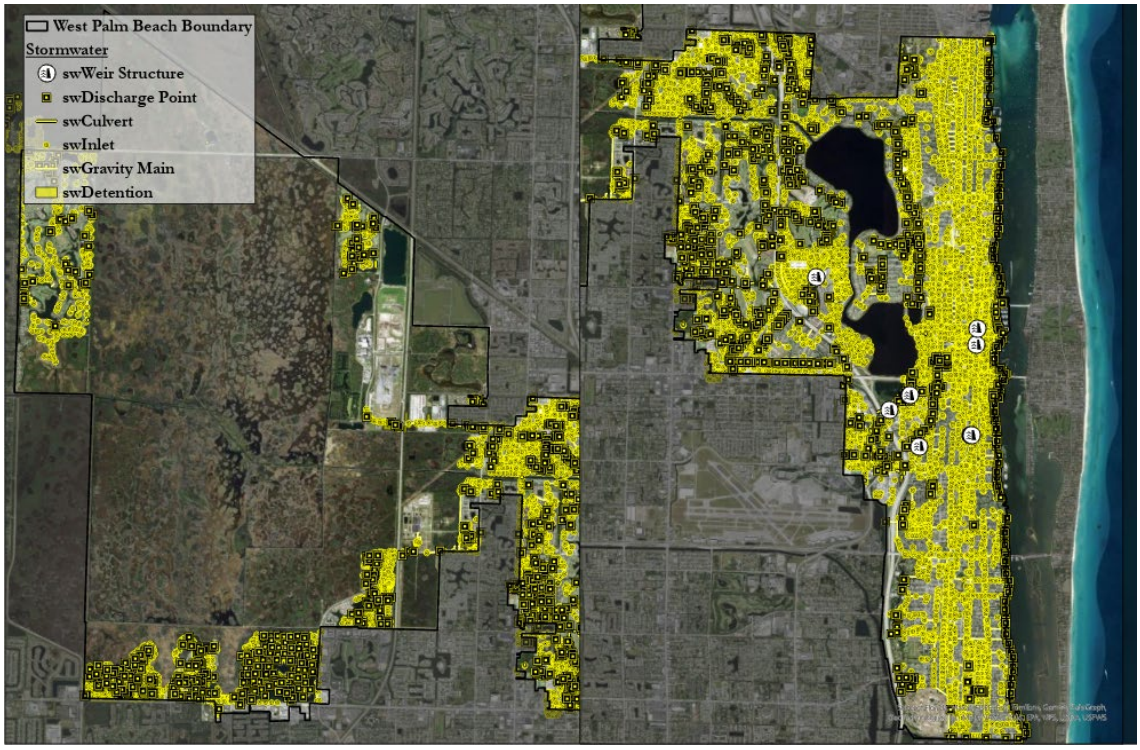


Figure 21 - Map of Sanitary Sewer Infrastructure

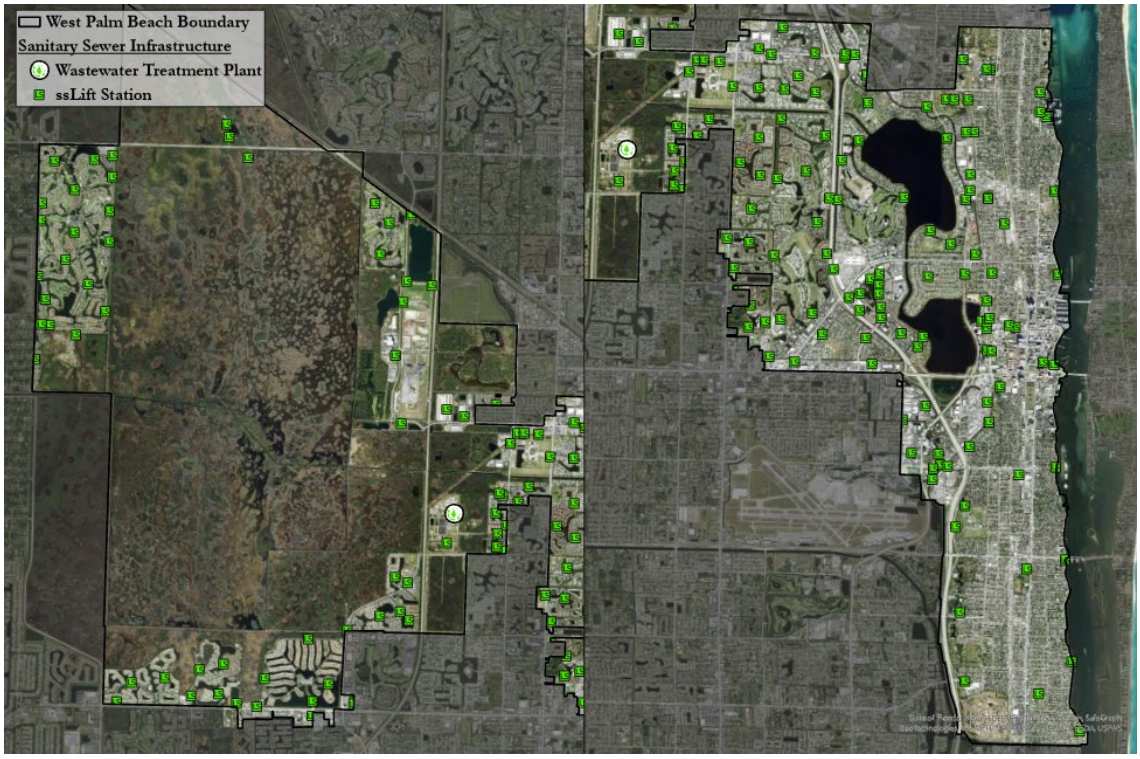


Figure 22 - Map of Potable Water Infrastructure

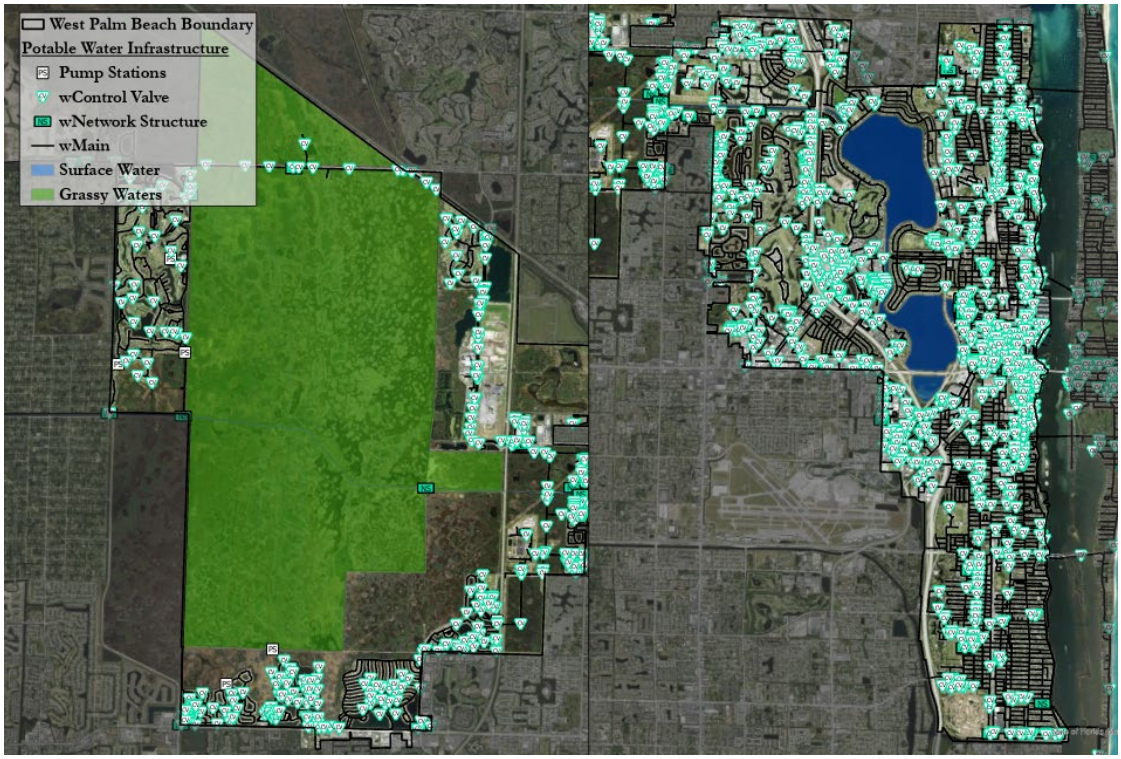
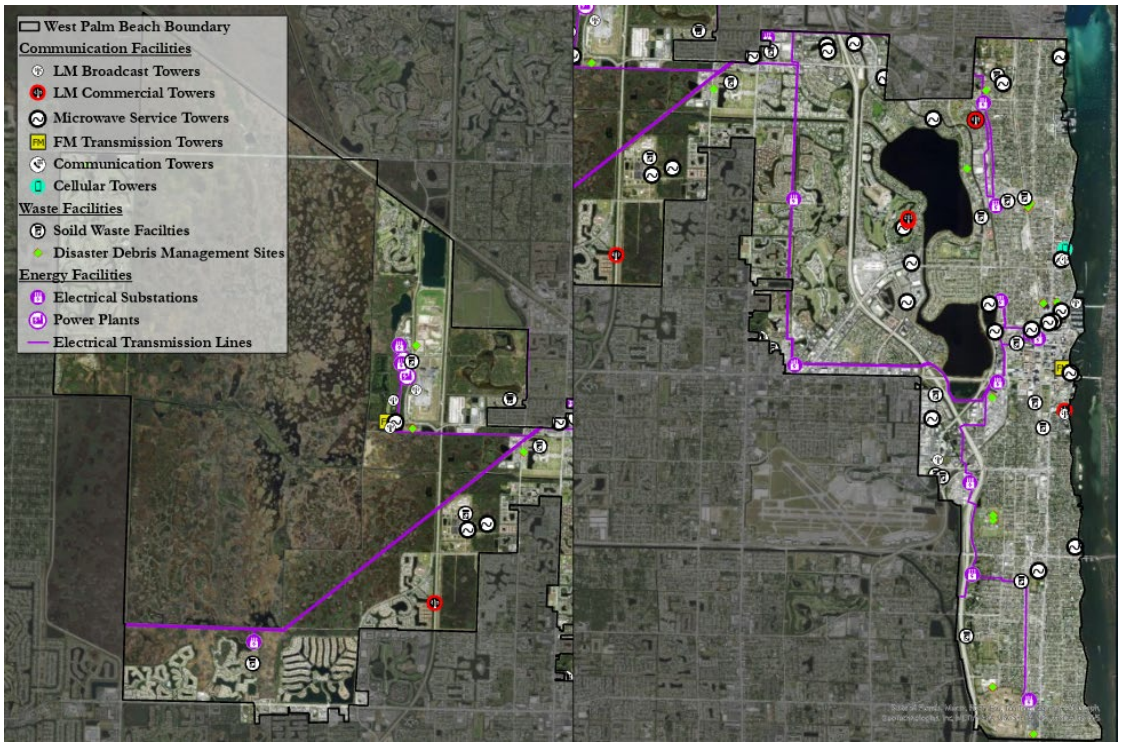
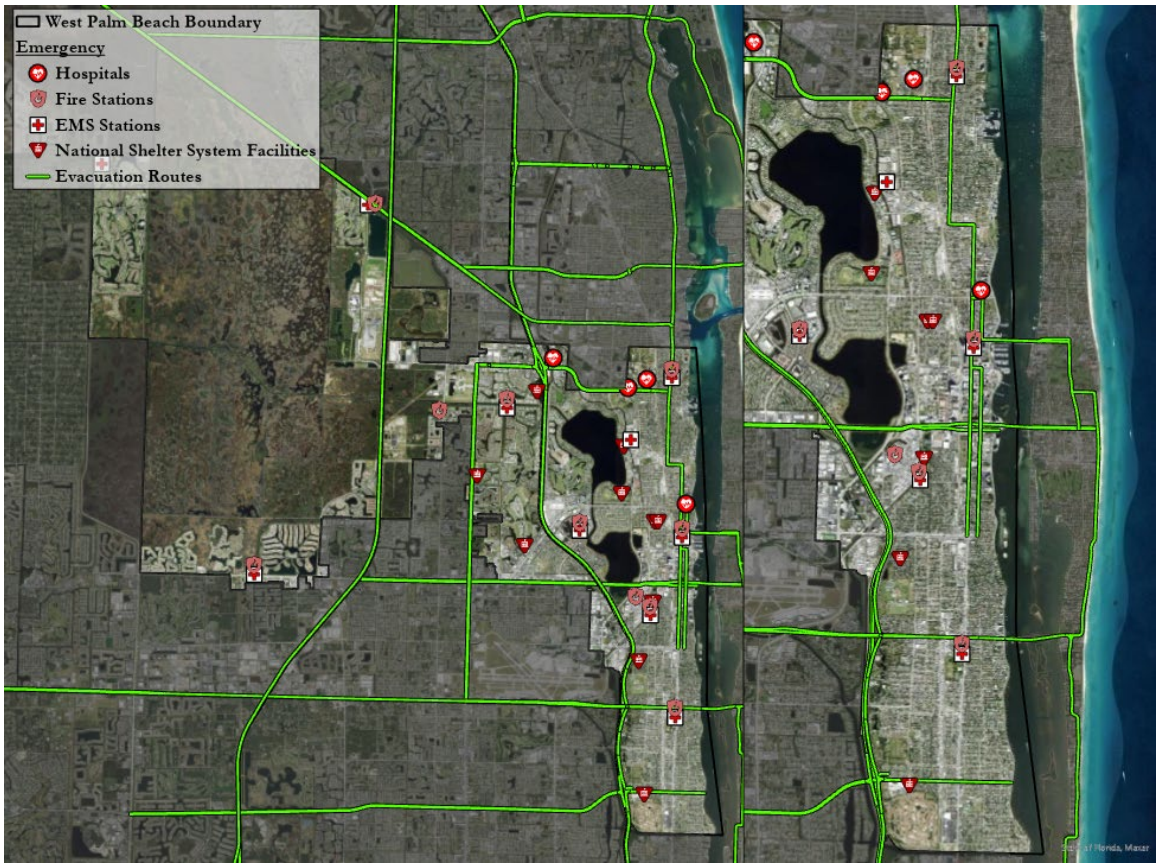


Figure 23 - Map of Other Critical Infrastructure Assets



Critical Emergency and Community Facilities: Hospitals and healthcare facilities, while generally not owned and maintained by the City, are lifelines during disaster response and recovery, especially in the face of extreme weather events. Regional healthcare facilities and their ability to function without interruption is vital for the well-being of the community. Emergency response centers serve as command hubs for coordinating emergency response efforts. They are pivotal in disaster management and require robust infrastructure and connectivity to ensure effective response during climate-related emergencies.

Figure 24 - Map of Emergency Management Infrastructure



Natural and Cultural Resources: West Palm Beach's natural areas, cultural assets, and historical sites contribute significantly to its identity and quality of life. Tourism is an integral part of the City and its economy. These resources are not only important for the well-being of the community but also need protection against climate change impacts to preserve the City's heritage.

Figure 25 - Map of Park Systems and Natural Areas

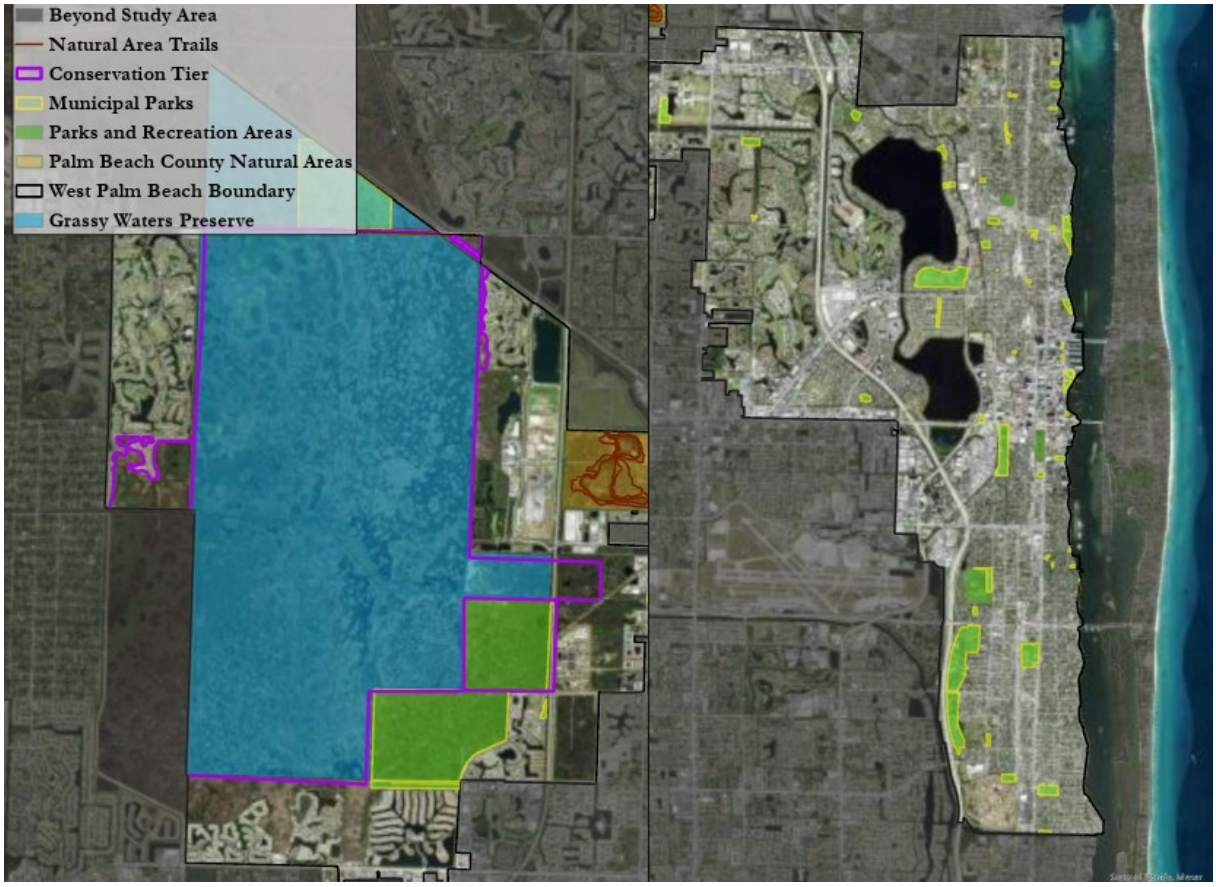
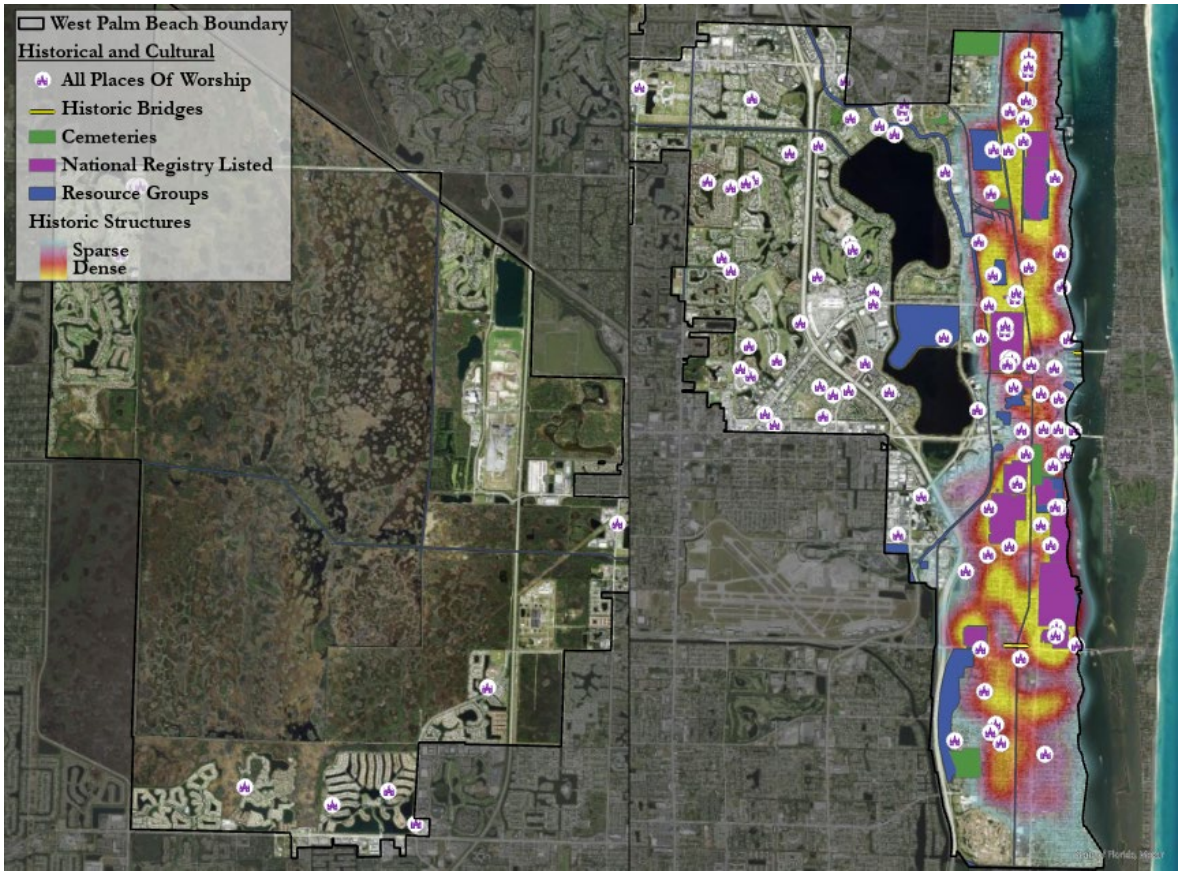


Figure 26 - Map of Cultural and Historic Assets



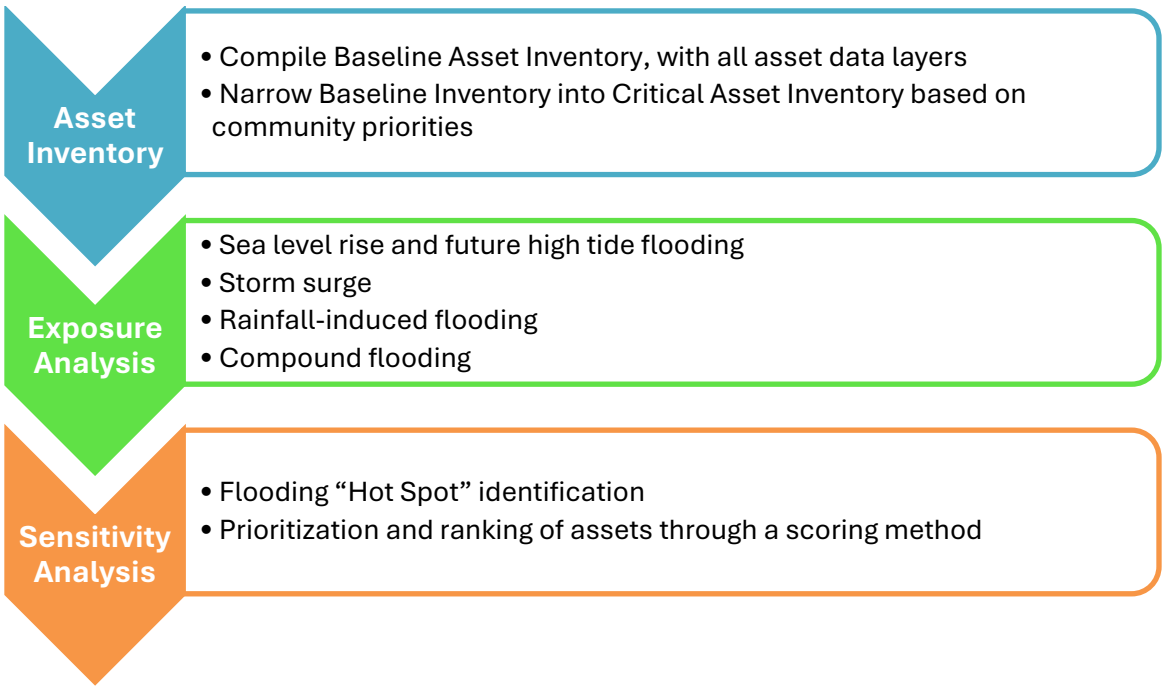
Regionally Significant Assets: As defined in Subsection 380.093, F.S., regionally significant assets are critical facilities that serve a broader geographic area, including neighboring communities, and are not necessarily owned and maintained by the City. These assets may encompass water resource facilities, regional medical centers, emergency operation centers, regional utilities, major transportation hubs, airports, and seaports. Identifying and safeguarding these assets is crucial for regional resilience and response coordination.

Assessment Methodology

Approach to Vulnerability Assessment

The methodology employed in this Vulnerability Assessment adheres to Subsection 380.093, F.S., and uses a comprehensive set of data sources and modeling techniques. This approach is designed to provide a detailed analysis of the City's vulnerability to climate change and sea-level rise. The primary components of this methodology are described in Figure 27.

Figure 27 - Vulnerability Assessment Process Steps



It is important to acknowledge the limitations of this methodology. While it provides a valuable foundational assessment, it is not a substitute for detailed, site-specific studies. Future studies involving engineering-grade hydrologic and hydraulic modeling are recommended for more localized flood risk understanding.

Data Collection & Asset Inventory Evaluation Process

To ensure accuracy and comprehensiveness, this Vulnerability Assessment employed an exhaustive data collection strategy. Data was gathered from various

authoritative sources, including federal agencies such as the Department of Homeland Security (DHS), National Oceanic and Atmospheric Administration (NOAA), and the Federal Emergency Management Agency (FEMA); state authorities such as the Florida Department of Environmental Protection (FDEP), Florida Department of Transportation (FDOT) and the Fish and Wildlife Conservation Commission (FWC); and local authorities, including City of West Palm Beach staff. The collected data was categorized as follows:

1. **Transportation Assets and Evacuation Routes**: airports, bridges, bus routes, railways, major roadways, evacuation routes, port facilities, marinas, boat ramps and waterways.
2. **Critical Infrastructure:** wastewater treatment facilities and lift stations, pump stations, drinking water facilities, water utility conveyance systems, drainage infrastructure and stormwater ponds, electric supply facilities, solid waste facilities, military installations, post offices, communications facilities, and disaster debris management sites.
3. **Critical Community and Emergency Facilities**: schools, assisted housing, community centers, correctional facilities, disaster recovery centers, emergency medical service facilities, fire stations, law enforcement facilities, local government facilities, logistical staging areas, affordable public housing, risk shelters, and state government facilities.
4. **Natural, Cultural, Historical Resources**: This category is dedicated to preserving and protecting natural areas and cultural/historical sites, including conservation lands, historic buildings and cemeteries, national and state parks, shorelines, surface waters, wetlands, and historical and cultural assets.
5. **Supplementary Information**: This category includes additional data not explicitly required by Subsection 380.093, F.S., but valuable for a detailed vulnerability assessment. It encompasses FEMA's flood insurance study, flood zones, photos of flooding, impervious surface areas, seawalls, and more. Geomorphological features and socioeconomic environment data are also included.

Additionally, multiple asset types listed above would be considered regionally significant assets; they are due special attention, given their specific mention in the statutory language which refers to critical assets that support the needs of communities spanning multiple geopolitical jurisdictions. These assets include Commercial and Strategic Intermodal System (SIS) ports, spaceports, waterways, railroad crossings, railroads, rail terminals, rail bridges, bus terminals, evacuation routes, electric power plants, electric power transmission lines, dams, and drainage assets maintained by water management districts. The mention of spaceports in this list is part of a generalized inventory of potential regional assets and does not necessarily indicate the presence of a spaceport in West Palm Beach. Additionally,

stormwater ponds, wastewater facilities, public water supply tanks, public water supply plants (non-federal), emergency medical services facilities, emergency operations centers, risk shelters for the general population, and risk shelters for those with special needs are considered crucial in supporting the infrastructure and safety requirements of multiple regions.

Supplemental information is included to augment resilience planning, capturing assets not explicitly identified in the statutory framework. This structured approach facilitates a comprehensive understanding and effective addressal of climate change adaptation and resilience challenges.

Data Request

The data collection and evaluation process for West Palm Beach's Vulnerability Assessment was methodical and robust, involving a variety of authoritative sources. The effort gathered topographical, hydrological, climatic, and tidal data via a standardized data request document directed to agencies including DHS, NOAA, FEMA, local authorities, and research institutions. The collected data was categorized into four primary categories, tracking the State's defined asset classes, with a fifth supplementary category to enhance resilience planning efforts. Details of the Data Request can be found in Appendix A.1.

Data Gap Analysis

The Gap Analysis conducted for the West Palm Beach Vulnerability Assessment identified key areas of data insufficiency and proposed strategic solutions and pathways to obtain more information (see Appendix A.2). These included enhancing geospatial data through mapping and system integration, improving infrastructure data with departmental reviews and responsible data management, and updating information on natural, cultural, and historic resources through community involvement. The analysis also recommended standardizing terminologies and developing comprehensive metadata to address inconsistencies and unclear data coverage. Employing a range of methods such as satellite imagery, government record analysis, and statistical modeling, the approach aims to achieve a thorough and dependable assessment to close gaps described in the Gap Analysis now and into the future.

Exposure Analyses: Tools and Models Used

The methodology of the Vulnerability Assessment Report encompasses a detailed analysis of the 2040, 2070 and 2100 planning horizons using advanced tools and models, meticulously aligned with compliance requirements. This section delves into four key aspects:

Future High Tide Modeling: This involves sophisticated modeling techniques using ArcGIS Pro and NOAA's methodology. The process includes creating VDATUM conversion surfaces and utilizing algorithms for tidal variability interpolation, ensuring accurate future high tide flood mapping accounting for the tidal flooding threshold of 2' above mean higher high water. This Analysis also includes a representation of the number of tidal flood days that is expected for each scenario as well as planning horizon in the map series titled "Days of Tidal Flooding" in the Exposure Map series (see Appendix D), which is supplemental to the 2' mean higher high-water threshold established by FDEP.

Storm Surge Analysis: Utilizing FEMA's storm surge data and HAZUS-MH software, this analysis adjusts the historical storm surge data by the future sea level rise projections discussed in the report. The approach integrates these projections with the community's existing FEMA Flood Insurance Study data, offering a nuanced understanding of future storm surge impacts.

Rainfall-Induced Flooding Evaluation: Adhering to specific legislative requirements, this part employs the Hydrologic Engineering Center's River Analysis System (HEC-RAS) for rainfall simulation and runoff computation. It incorporates NOAA's Atlas 14 data, enriched with SFWMD change factors[3], to create baseline rainfall depth grids essential for a comprehensive evaluation of potential future rainfall-induced flooding.

Compound Flooding Assessment: This segment addresses the compound effects of tidal, storm surge, and rainfall-induced flooding. It involves overlaying depth grids from various scenarios, acknowledging the resource and time constraints of the project.

Each of these components is detailed over multiple pages in the report, providing an exhaustive, data-driven approach to assess West Palm Beach's vulnerability to climate-induced changes. The methodology is crafted to not only meet compliance standards but also to provide a deep, actionable insight into the City's potential future flooding scenarios.

[3] https://sfwmd-district-resiliency-fsfwmd.hub.arcgis.com/apps/0616cf4890424ec8bd8a0f901dee7cf0

Scenario Development and Assumptions for Evaluations/Modeling

North American Vertical Datum of 1988

All elevations referenced in and analyzed for this Vulnerability Assessment are expressed in North American Vertical Datum of 1988 (NAVD 88) values.

Local Sea Level Rise Scenarios

The sea-level rise scenarios included in the Vulnerability Assessment include the 2017 NOAA Intermediate-Low Sea Level Rise Projection and the 2017 NOAA Intermediate-High Sea Level Rise Projection. These were the required scenarios when this Vulnerability Assessment was initiated. Legislation adopted by the Florida Legislature and signed into law by the Governor in 2024[4] will instead mandate use of the 2022 NOAA Intermediate Low and Intermediate scenarios for Vulnerability Assessments initiated after July 1, 2024.

The benefit of evaluating a range of conditions is that the City can determine the tolerance for risk for any adaptation strategy decision and act upon data from this analysis that reflects a wider range of conditions. For assets, adaptation projects, and policy decisions which are considered more critical, the higher end of the projections and output should be considered. Where flood impacts would be less critical, the lower end of the projections could be considered. The range provides options needed to make decisions based on the characteristics of specific places and flood impacts at those locations.

In the context of flood risk planning, the significance of assessing and preparing for risks varies widely across different types of assets, reflecting the underlying concept of risk tolerance. This differentiation becomes particularly evident when contrasting the planning requirements for infrastructure with divergent risk profiles and societal impacts, such as recreational facilities versus water and wastewater treatment plants.

Recreational facilities, for example, though valuable for community well-being and local economies, generally represent assets with a relatively lower criticality in the broader scope of City-wide emergency preparedness and long-term resilience planning. The risk tolerance for such facilities is comparatively higher, meaning that while flood impacts are undesirable, they are less likely to cause widespread or long-lasting harm. Therefore, in the adaptation strategy for these assets, a balanced

[4] Signed into law by the Governor on May 13, 2024.

approach may be adopted, potentially aligning with the lower end of sea-level rise projections. This approach prioritizes cost-effectiveness and practicality, acknowledging the lower relative impact of flooding on these facilities.

Conversely, the planning and risk assessment for water and wastewater facilities demand an exceptionally low tolerance for risk due to the potential for catastrophic consequences in the event of flooding. The critical nature of such infrastructure—not only in terms of water supply and treatment for daily needs, but also considering the immense implications for public health, safety, and environmental protection—necessitates that adaptation strategies are aligned with the most conservative projections and models available. In this case, the higher end of sea-level rise scenarios would be a prudent basis for planning, reflecting a commitment to safeguarding against even the most unlikely events. The imperative to ensure the utmost level of resilience against flooding underscores the non-negotiable demand for stringent precautionary measures in the context of water and wastewater planning.

Planning Horizons

The planning horizons for this Assessment coincide with NOAA's forecasting years: 2040, 2070 and 2100. While Section 380.093(3), F.S only requires the 2040 and 2070 planning scenarios, currently, this Vulnerability Assessment also includes the 2100 condition.

Sea Level Data Selection

According to statute, vulnerability assessments must include local sea level data that has been interpolated between the two closest National Oceanic and Atmospheric Administration (NOAA) tide gauges or use the sea level data from whichever of those two nearest gauges reports a higher mean sea level.

For West Palm Beach, this Vulnerability Analysis uses NOAA's Virginia Key tide gauge (8723214). The Virginia Key tide gauge was selected over Lake Worth Pier for the projection of future tides due to the longer period of record established by the gauges at Virginia Key. Further, since the mean sea level reported by Virginia Key is greater than that of Lake Worth Pier, interpolation between the two tide gauges is not necessary. Data from the Virginia Key tide gauge is integrated directly into the exposure analysis methodology by converting the original North American Vertical Datum of 1988 (NAVD88) elevations from the Digital Elevation Model (DEM) to the localized vertical tidal datums. By aligning the DEM elevations with data from local tide gauges, this conversion ensures accurate and consistent comparisons, correctly reflecting local sea level elevations and allowing precise data manipulations.

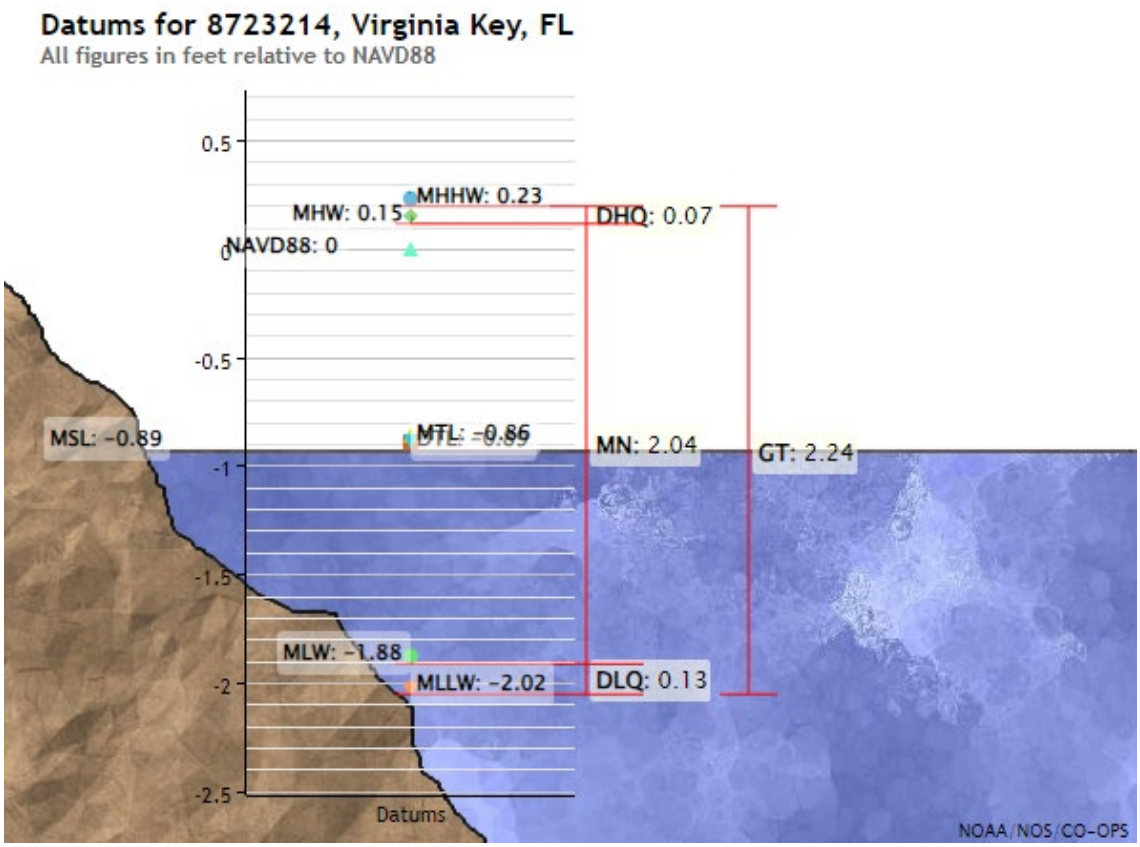
The datum chart below (Figure 28) is a visual representation of various reference levels (datums) related to the Virginia Key tide gauge. These datums are standardized elevations used to serve as reference points for measuring water levels. Each datum is related to specific tidal conditions and is used to predict tidal flooding, navigate ships, and for coastal and marine engineering. Here is a brief explanation of common datums on Figure 28:

- **Mean Higher High Water (MHHW):** This is the average elevation of the higher high tides over a specific period. It is important for construction and development in coastal zones as it indicates the highest average water level that can be expected.
- **Mean High Water (MHW):** This is the average of all the high-water heights observed over the National Tidal Datum Epoch (usually a period of 19 years).
- **Mean Sea Level (MSL):** This is the average sea level. The mean level of the ocean's surface, calculated from hourly tidal heights measured over extended periods.
- **Mean Low Water (MLW) and Mean Lower Low Water (MLLW):** These represent the average of the lowest tides and the lowest average tide recorded, respectively, and are often used for navigational purposes to ensure boats and ships do not run aground.

The specific values and their vertical relationship to each other provide critical information for a range of activities, including coastal planning, construction, and navigation. The chart is typically set against the North American Vertical Datum of 1988 (NAVD88), which is a standard geodetic datum for elevations used in the United States for mapping and construction.

The exact purpose and usage of these datums can vary depending on the context, such as flood risk assessment, where knowing the heights of various tide conditions is essential for preparing for potential flooding events.

Figure 28 - Datums for Virginia Key Tide Gauge



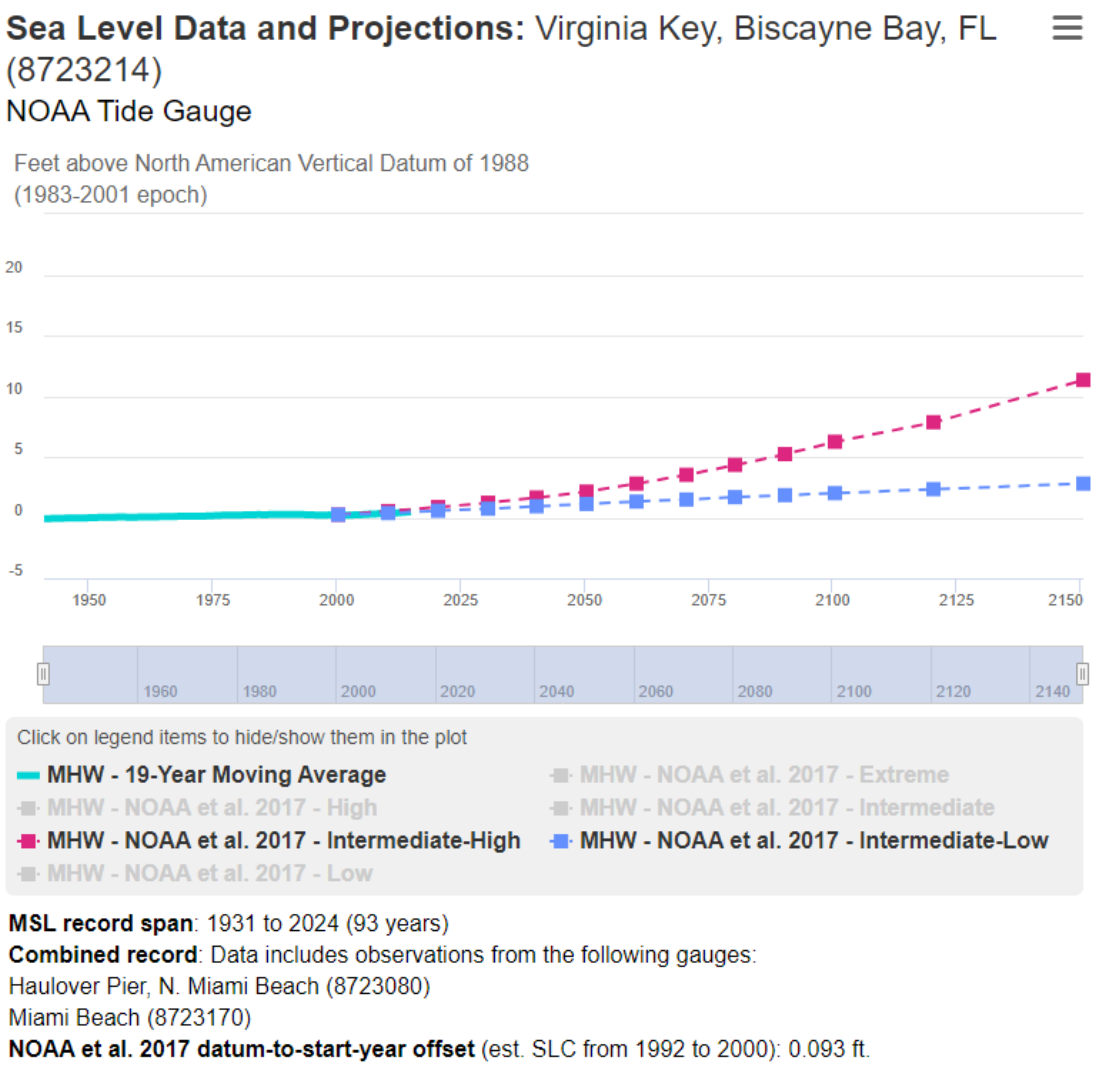
Datum charts in the context of water levels and elevations serve as a reference for understanding both current and future conditions. The following explains their usage and significance:

- **Current Water Levels (Datum Charts and Tide Gauge Record):** Datum charts represent the baseline or reference points from which water levels and land elevations are measured. These charts are crucial for a wide range of activities, including navigation, construction, and environmental management. They provide a snapshot of existing conditions, serving as a benchmark for comparing changes over time.
- **Projections in the Charts (Future Water Levels for NIL and NIH):** The projections found within these charts are predictive models that estimate future changes in water levels due to various factors, most notably climate change and sea-level rise. These projections are based on data analysis and simulation models that account for different scenarios, including greenhouse gas emission trajectories, polar ice melt rates, and ocean temperature changes.

In essence, datum charts provide a "ground truth" of current conditions against which future changes can be measured and predicted. These future projections are essential for planning and preparing for impacts related to rising sea levels, such as coastal flooding, habitat loss, and infrastructure vulnerability. They help policymakers, urban planners, and communities make informed decisions to mitigate risks and adapt to changing environmental conditions.

Understanding the difference between current conditions and future projections is crucial for effective environmental management and resilience planning. It allows for proactive measures to be put in place, reducing the potential damage and disruption caused by natural phenomena and climate change.

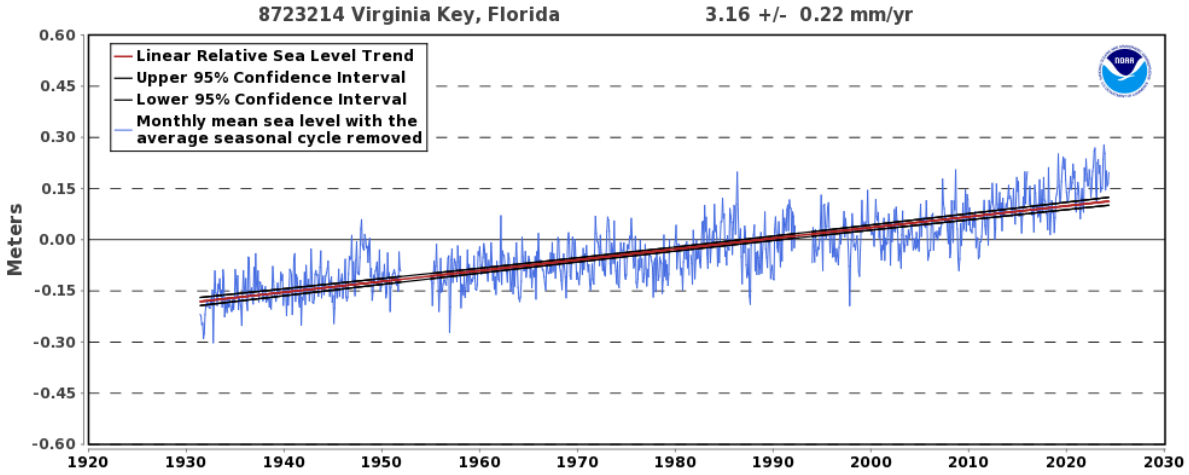
Figure 29 – Virginia Key Tide Gauge Sea Level Data and Projections



The USACE Sea Level Analysis Tool[5] was utilized to calculate the sea level rise values required for NOAAs method for mapping sea level rise[6] with the most recent digital elevation model and VDATUM[7] derived tidal surfaces. After reviewing the closest tide gauges available within the USACE Sea Level Change Curve Calculator, the NOAA tide gauge, referenced as "Virginia Key, Biscayne Bay, FL" (NOAA Gauge Station ID: 8723214, 2024) was selected for its proximity to the study area, mean sea level value, and the length of time that it has been established. The Virginia Key tide gauge indicates a relative sea-level trend of 3.16 millimeters/year with a 95% confidence interval of +/- 0.22 mm/year based on data from 1931 to 2023 (Figure 30).

Figure 30 - Sea Level Increase from 1931 to 2023

(3.16 +/- 0. 22 millimeters/year), equivalent to 1.04 feet in 100 years



The plots (Figure 30 and Figure 31) above and below describe the observed and future projected increase in sea levels within the region. The table values listed below correspond with each of the sea level rise curves *(Low, Intermediate-Low, Intermediate, Intermediate-High, and High)* for the year 2100 in Figure 31.

[5] https://climate.sec.usace.army.mil/slat/

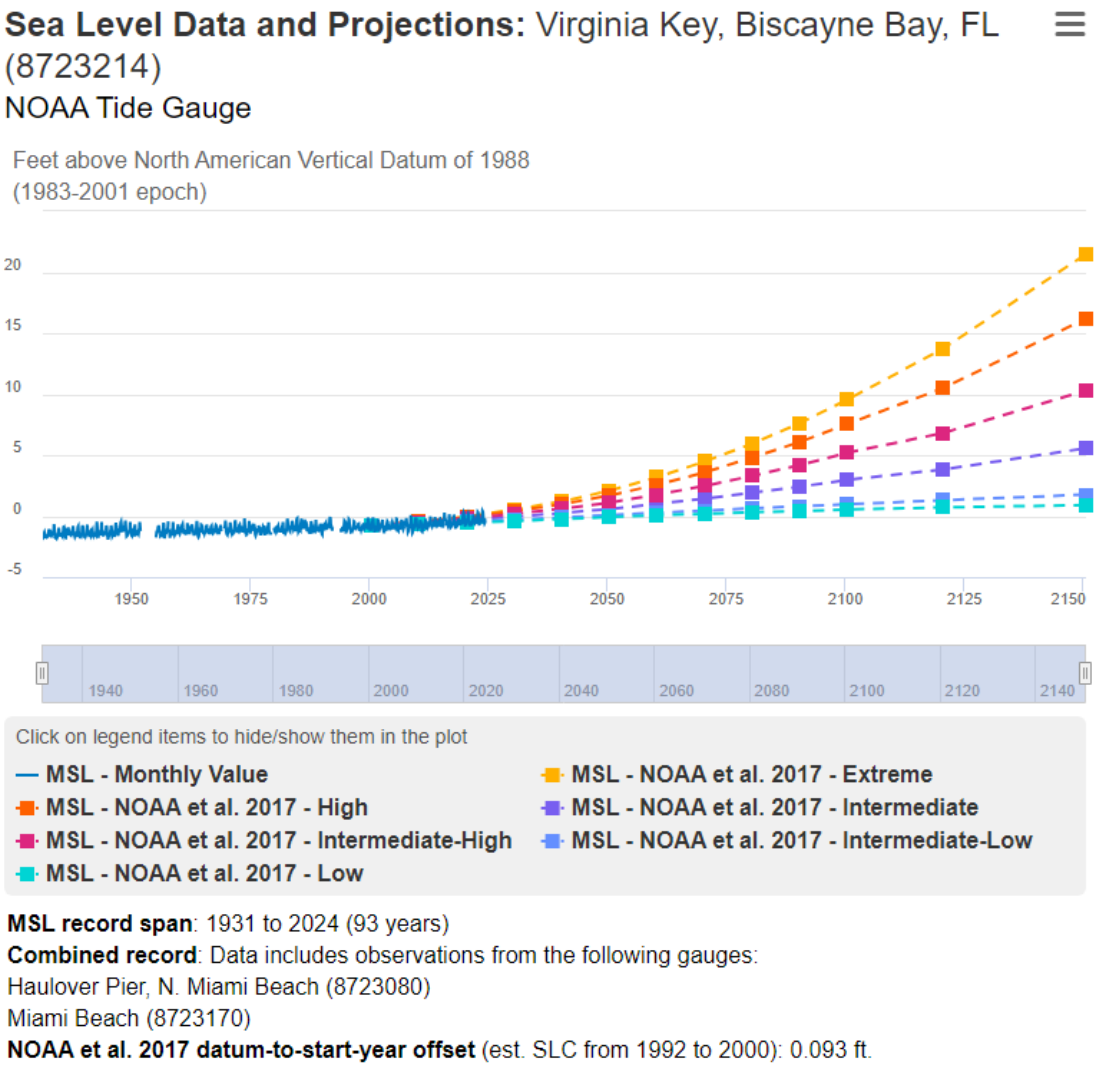
[6] Detailed Method for Mapping Sea Level Rise Inundation (NOAA, 2017): https://coast.noaa.gov/data/digitalcoast/pdf/slr-inundation-methods.pdf

[7] NOAA Vertical Datum Transformation: https://vdatum.noaa.gov/welcome.html

Table 6 - Mean Sea Level Values for West Palm Beach

Measurement Unit	Low	Interme-diate Low	Interme-diate	Intermedi-ate High	High	Extreme
Feet	0.55	0.98	2.98	5.21	7.57	9.57
Inches	6.60	11.76	35.76	62.52	90.84	114.84

Figure 31 - Mean Sea Level Projections for Virginia Key Tide Gauge



MSL record span: 1931 to 2024 (93 years)
Combined record: Data includes observations from the following gauges:
Haulover Pier, N. Miami Beach (8723080)
Miami Beach (8723170)
NOAA et al. 2017 datum-to-start-year offset (est. SLC from 1992 to 2000): 0.093 ft.

Exposure: Future High Tide

Using a planning-grade static coastal hydrology sea level rise modeling approach (NOAA, 2017), the project team assessed the area for its vulnerability to sea level rise (SLR) inundation, leveraging the latest version of ArcGIS Pro for data analysis and cartographic representation (Environmental Systems Research Institute, 2022). By following this comprehensive modeling process, detailed future high tide flooding maps are generated that account for both regional and local variations in tidal flooding, and specifically identify areas with similar elevation that are not tidally connected according to the elevation surface. These areas may still be vulnerable to flooding, especially if they connect to tidally influenced coastal systems via stormwater conveyance or some other type of groundwater/surface water connection not captured within elevation data.

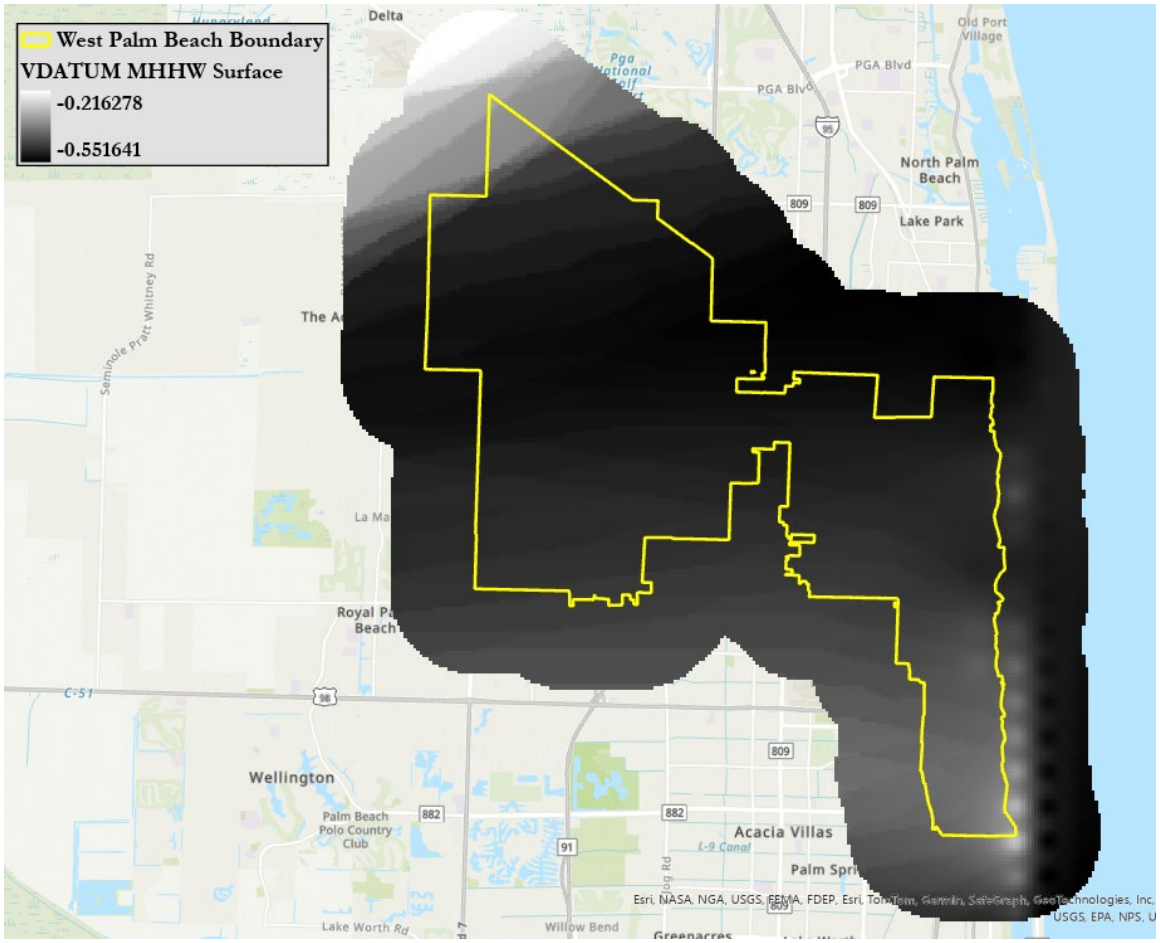
Table 7 below outlines West Palm Beach's sea-level rise projections over the coming decades, using the latest available data and climate models. These projections underpin the risk assessment, enabling evaluation of the potential consequences of rising sea levels in the context of this specific locale.

Table 7 - SLR with High Tide Flooding Modeling Scenarios

Timeframe	NOAA Intermediate Low 2017 (feet NAVD88)	NOAA Intermediate High 2017 (feet NAVD88)
Present Day	2.33	2.62
2040	2.69	3.41
2070	3.25	5.28
2100	3.77	8.00

The Future High Tide section makes use of ArcGIS Pro and NOAA's methods to predict flooding. It involves adjusting measurements for differences in sea level at various points and using algorithms to fill in gaps between these points. This process helps to accurately predict how high tides can rise, considering both current and future sea levels. Combining information on sea level rise with existing tide patterns yields detailed maps that show where and how high tide flooding could happen in the future. This method provides a clear picture of the risks of future high tide flooding.

Figure 32 - Vertical Datum Interpolation Surface



The above graphic shares the results of the tide gauge interpolation using NOAA's VDATUM tool. This surface, and others like it, is used within the modeling to convert between datums, specific to this Assessment, conversions between NAVD88, and mean higher high water (MHHW) and mean sea level (MSL) all common place benchmarks in floodplain management. Utilizing derivatives of this tool, local tide records, future change factors and a digital elevation model the exposure analysis was conducted considering not only the elevation of current storms, but also an adjustment of current heights to projected future conditions.

West Palm Beach's vulnerability to climate change, and sea-level rise in particular, necessitates a meticulous examination of projections tailored specifically to this coastal community. The incorporation of West Palm Beach-specific data and scenarios – especially those focused on the City's location along the shoreline – enhances the analysis of sea-level rise projections and potential impacts. In West Palm Beach, like many other locales with long, uninterrupted shorelines, the imminent threat of sea-level rise has the potential to significantly impact communities, infrastructure, and environment.

Exposure: Depth of Tidal Flooding, including Future High Tide Flooding

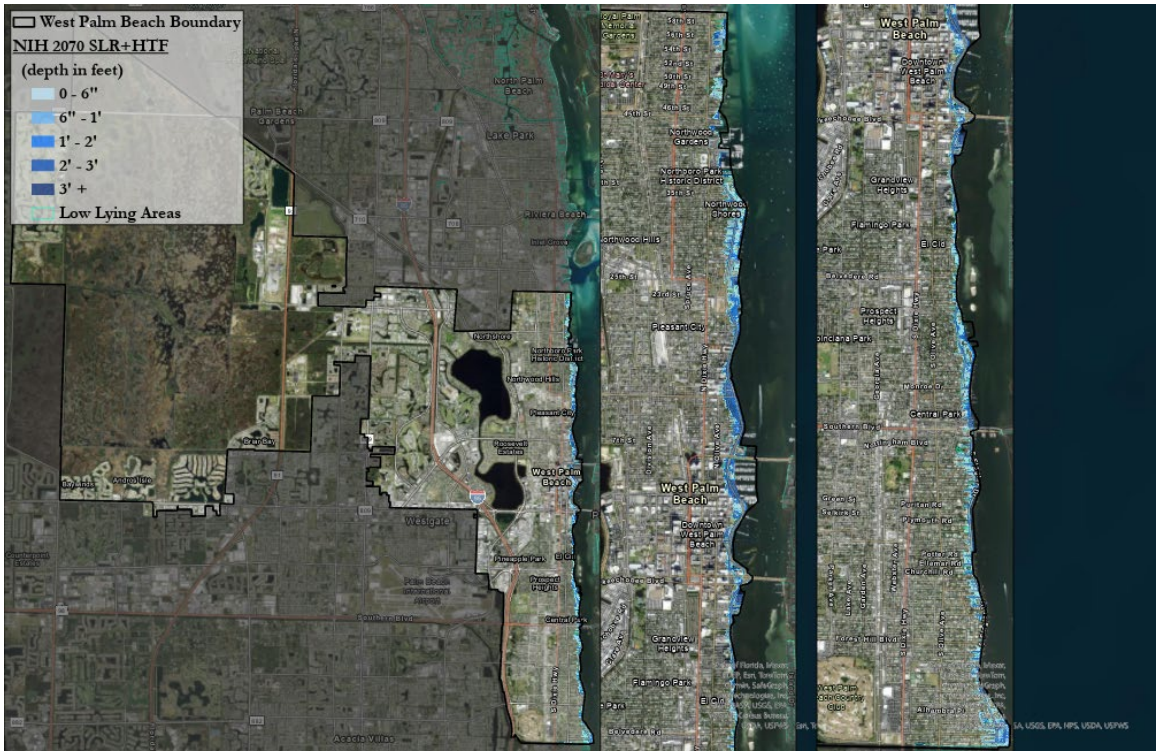
Incorporating the Florida Department of Environmental Protection's (FDEP) guideline of adding 2 feet to the Mean Higher High Water (MHHW) mark for determining the tidal flooding threshold, the "Sea Level Rise + High Tide Flooding Scenario" offers an enhanced perspective on anticipating future tidal flooding events. This adjustment to the MHHW benchmark is pivotal, as it provides a more conservative and therefore safer standard for assessing and preparing for tidal flooding risks. It acknowledges the potential for sea level rise to substantially elevate baseline water levels, which, when combined with high tide events, significantly intensifies the frequency and severity of tidal flooding.

This scenario, therefore, extends beyond merely understanding the dynamics of sea level rise and high tides; it actively incorporates FDEP's forward-looking standard to ensure that the projected impacts reflect a scenario where the threshold for tidal flooding is higher. This approach is critical for urban and infrastructure planning, highlighting the necessity for resilient coastal defense mechanisms designed to withstand not just current sea levels and tidal variations but also future increases. By integrating the +2 feet adjustment, the analysis underlines the imperative for seawalls, tide gates, and natural barriers that are not only effective under present conditions but are also robust enough to offer protection as sea levels continue to rise.

The following maps represent the results of projected scenarios incorporating high tide flooding in the present day and under future conditions based on the NIL and NIH[8] sea level rise curves.

[8] [1] Section 380.093(3)(d)2.b. requires: At least two local sea level rise scenarios, which must include the 2017 National Oceanic and Atmospheric Administration intermediate-low and intermediate-high sea level rise projections.

Figure 33 - NIH 2070 SLR with High Tide Flooding



Days of Tidal Flooding Analyses

Expanding upon the sea level rise and high tide flooding scenario, this part of the analysis focuses on quantifying the expected number of days experiencing tidal flooding under various future conditions. This projection is instrumental in understanding the temporal dimension of tidal flood risks, shifting the perspective from theoretical to tangible impacts on the community's day-to-day life. By estimating the frequency of tidal flooding days, the assessment highlights potential disruptions to transportation, economic activities, and the overall quality of life, especially in low-lying and waterfront areas. This scenario emphasizes the urgency of implementing comprehensive flood risk management strategies, including early warning systems, community education programs, and infrastructure resilience enhancements, to reduce the societal and economic impacts of increased tidal flooding.

The assessment of tidal flooding is an essential element of comprehensive vulnerability evaluations aimed at understanding the impacts of sea level rise on coastal communities. This analysis is meticulously conducted through the collection and examination of high and low tide data spanning at least 19 years, a period that encompasses the full metonic cycle, from specific NOAA tide gauges, such as the Virginia Key Tide Gauge. The objective is to extrapolate high tide values from

historical data, project them forward using the observed sea level trend, and then assess the potential frequency of tidal flooding events in the future.

Table 8 - Statistical Analysis of Historical Tide Record

Calculating the number of days where water elevations surpassed a "critical elevation"

Approximate Days of Tidal Flooding Observed	1995-2013 (feet NAVD88)	2004-2022 (feet NAVD88)
1	1.64	2.02
5	1.40	1.80
10	1.29	1.60
15	1.18	1.45
20	1.09	1.35
30	0.97	1.23
40	0.89	1.14
50	0.76	0.98
100	0.57	0.79
≥150	0.26	0.47

The above analysis employs statistical methods to correlate historic tide records with observed and projected days of tidal flooding, as illustrated in the provided table. Table 8 above reveals the changes in tide elevations over two distinct periods, 1992-2011 and 2004-2022, and associates these elevations with the observed frequency of tidal flooding events. The elevations are presented in feet NAVD88. A key observation from this data is the trend of increasing tide elevations over time, indicating rising sea levels and, consequently, an increased risk of tidal flooding.

Table 9 - Future Tidal Flooding Frequency

(feet NAVD88)

Approx. Days	NIL 2040	NIL 2070	NIL 2100	NIH 2040	NIH 2040	NIH 2040
1	2.33	2.99	3.51	3.15	5.29	8.05
5	2.13	2.77	3.29	2.87	5.02	7.75
10	1.97	2.55	3.16	2.73	4.81	7.54

Approx. Days	NIL 2040	NIL 2070	NIL 2100	NIH 2040	NIH 2040	NIH 2040
15	1.83	2.38	3.03	2.60	4.61	7.40
20	1.72	2.28	2.93	2.49	4.49	7.30
30	1.60	2.17	2.80	2.35	4.36	7.17
40	1.50	2.08	2.71	2.25	4.25	7.07
50	1.35	1.93	2.57	2.09	4.11	6.88
100	1.16	1.74	2.37	1.88	3.89	6.61
≥150	0.84	1.40	2.04	1.53	3.47	6.08

Understanding the implications of these findings is crucial. The elevations for the two periods underscore not just the absolute *rise* in sea levels but also the increasing likelihood of flooding events as these levels continue to rise. The observed days of tidal flooding serve as a direct indicator of how frequently communities might experience such events, given current and projected sea level rises.

The Vulnerability Assessment further contextualizes these findings by projecting future sea level rises under different NOAA scenarios, including both intermediate-low (NIL) and intermediate-high (NIH) projections for the years 2040, 2070, and 2100. These projections enable the estimation of future tidal flooding events' frequency, providing invaluable insights for planning and adaptation strategies. For instance, the NOAA intermediate-high scenario estimates that by 2040, high tide flooding for 150 or more days of the year will reach 0.84 feet, escalating to 2.04 feet by 2100. The intermediate-high scenario paints a more severe picture, with projections of up to 6.08 feet by 2100.

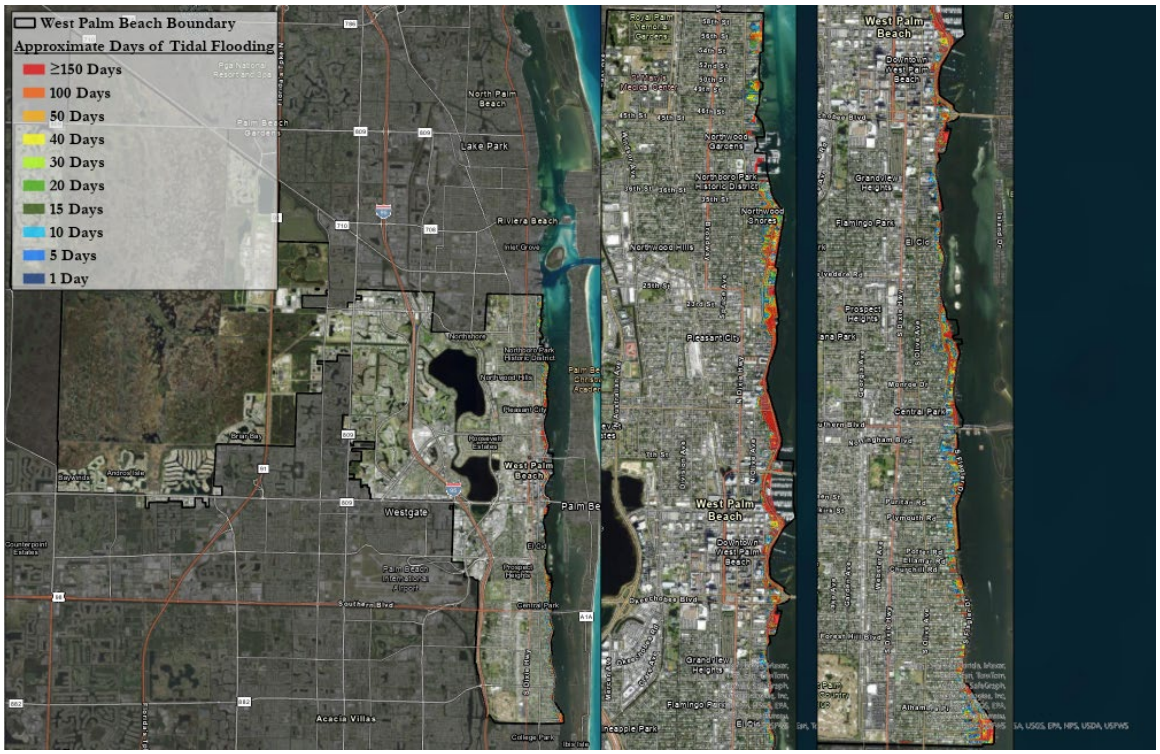
This forward-looking analysis is vital for urban planners, policymakers, and the community at large, offering a data-driven basis for understanding the risks associated with sea level rise and tidal flooding. By identifying the elevations at which tidal flooding becomes a significant risk and estimating the frequency of such events under various sea level rise scenarios, the assessment highlights the critical need for adaptive measures. These measures may include infrastructure improvements, policy adjustments, and community preparedness initiatives designed to mitigate the impacts of tidal flooding and enhance resilience against the growing threat of sea level rise.

Tidal Flood Days Expected for Each Scenario and Planning Horizon

These maps, found in the Exposure Map series in Appendix D, identify which communities, infrastructure, and natural areas are at increased risk due to multiple

days of tidal flooding, capturing the various vulnerabilities from the range of tides based on the NIL and NIH sea level rise projections.

Figure 34 - NIH 2070 Days of Tidal Flooding



Exposure: Storm Surge

Storm Surge modeling in this context uses FEMA's data and HAZUS-MH[9] software, adapted for future sea level rise. The approach integrates historical storm surge data from FEMA's Flood Insurance Study[10] with projections of sea level rise, creating models of adjusted storm surge inundation. This methodology is crucial to understand and anticipate the augmented impacts of storm surges in the future, enabling effective planning and resilience strategies against these events. The models suggest how rising sea levels could intensify storm surges, which is essential for informed decision-making and mitigation efforts. Unlike sea level rise and tidal flooding, storm surge is a less permanent condition, but due to the force and depth of flooding can be extremely debilitating to a community.

[9] https://www.fema.gov/flood-maps/products-tools/hazus

[10] Specifically adjusting the 100-year stillwater elevations by the rate of sea level change.

Figure 35 - FEMA Flood Insurance Study Non-Coastal Stillwater Elevations

Table 7: Summary of C-51 Stillwater Elevations

Subbasin	Water Surface Elevations (Feet NAVD88[1])			
	10-percent annual-chance	2-percent-annual-chance	1-percent-annual-chance	0.2-percent-annual-chance
1	17.34	*	19.24	*
2A	*	*	13.44	*
2B	13.04	*	13.84	*
3	13.64	*	14.54	*
4	14.94	*	15.54	*
5	15.84	*	17.24	*
6	17.04	*	17.24	*
7	17.54	*	17.64	*
8	18.14	*	18.54	*
9	15.84	*	17.24	*
10	17.54	*	17.64	*
11	17.54	*	17.64	*
12	17.54	*	17.64	*
13	14.04	*	15.44	*
14	14.04	*	15.44	*
15A	14.44	*	16.84	*
15B	17.94	*	18.64	*
16A	14.44	*	16.84	*
16B-1	17.64	*	18.64	*
16B-2	17.84	*	18.84	*
16B-3	17.54	*	18.34	*
17	12.94	*	14.54	*
18	12.94	*	14.54	*
20A	13.94	*	16.04	*
20B	14.44	*	15.54	*

[1]North American Vertical Datum of 1988; The datum conversion factor from NGVD to NAVD 88 in Palm Beach County is -1.56 feet

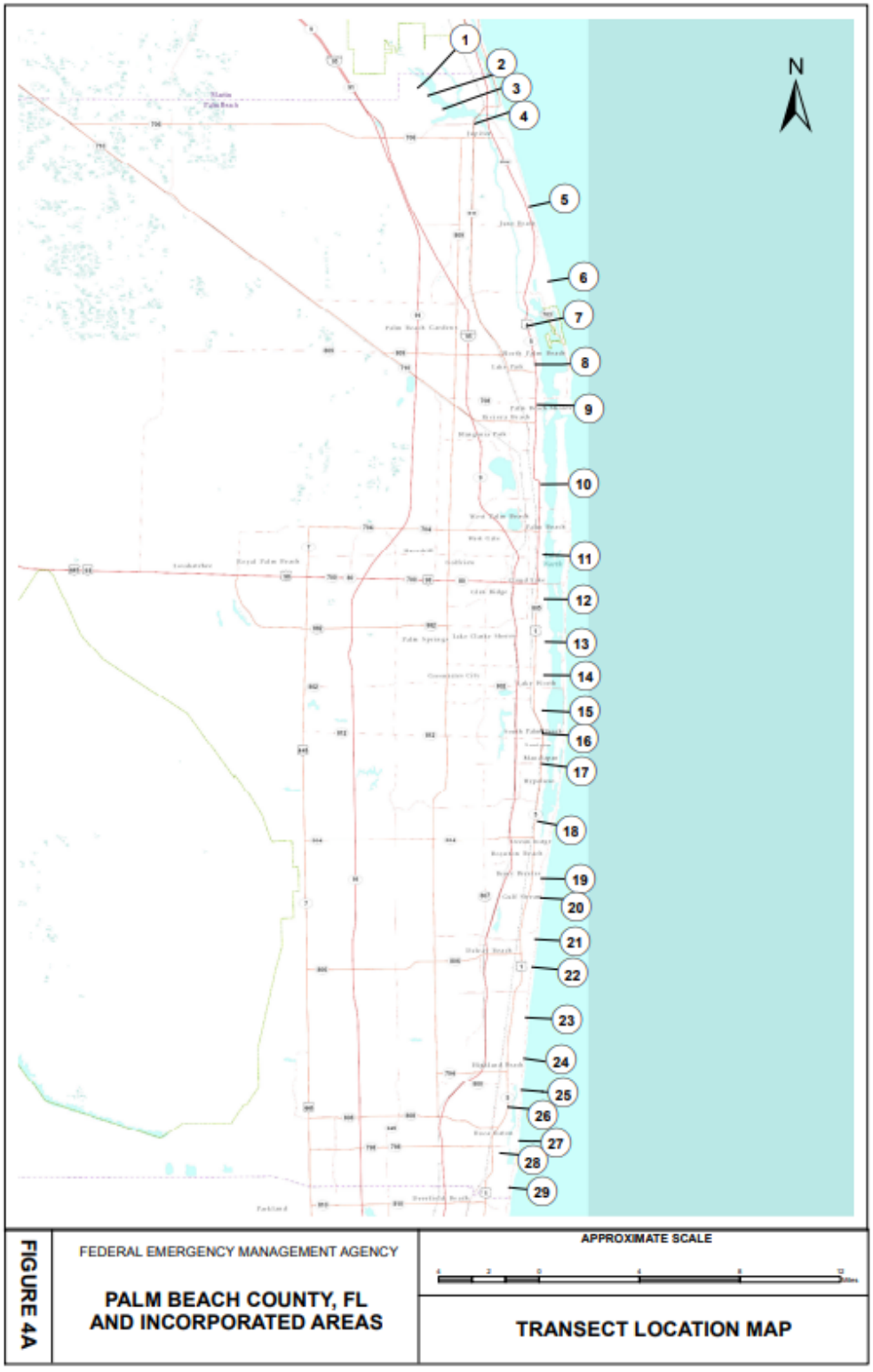
*Data not available

Stillwater Elevations[11]

The transects taken from the Flood Insurance Study are integral to the HAZUS-MH framework, which is designed to estimate storm surge and its potential impacts by modeling how surges of varying heights could affect both natural landscapes and urban development. The transects are used in the model to establish the stillwater elevations for the modeling to project surge. This process, depicted in Figure 36, is critical for urban planners and emergency management professionals as it aids in anticipating the extent of possible flooding and crafting preemptive measures. While HAZUS-MH offers robust modeling capabilities, it does not factor in elements such as landscape friction, the carrying capacity of stormwater systems, the protective effects of shoreline armoring or the effects of employing nature-based shoreline resilience strategies — all variables that can dampen the real-world effects of storm surge. Consequently, the tool may present an overestimated scope of surge impact, highlighting the importance of contextual adaptation of its findings. Despite this, the results from HAZUS-MH provide valuable insights for vulnerability assessments, laying the groundwork for informed, risk-conscious planning and the evolution of resilient infrastructure strategies.

[11] Stillwater elevations refer to the level of water in a body of water, such as a lake or river, under conditions of no wave action or minimal disturbance. This measurement is crucial in understanding water levels for purposes like flood prediction, navigation safety, and water resource management. It represents the height of the water surface when it is not affected by wind or tidal forces, providing a baseline for gauging water levels and their potential impacts.

Figure 36 - Transect Location Map



Stillwater elevations across the coastal transects identified within the FEMA 2017 Palm Beach County Flood Insurance Study ("2017 Palm Beach County FIS") were also averaged and adjusted by both NOAA Intermediate Low (NIL) and Intermediate High (NIH) Sea level change. Baseline stillwater elevations for the various return interval flood events (10-, 50-, 100-, and 500-year) were sourced from the 2017 Palm Beach County FIS.

Table 10 - Critical Average Stillwater Elevations

Planning Horizon	100-Year (feet NAVD88)	500-Year (feet NAVD88)
Present Day Average Stillwater	5.63	6.72
NIL 2040 Adjusted Average Stillwater	6.34	6.80
NIL 2070 Adjusted Average Stillwater	6.90	8.50
NIL 2100 Adjusted Average Stillwater	7.42	9.10
NIH 2040 Adjusted Average Stillwater	7.06	8.70
NIH 2070 Adjusted Average Stillwater	8.93	11.00
NIH 2100 Adjusted Average Stillwater	11.65	14.30

Using the outputs from the HAZUS-MH software, depth grids representing the maximum surge elevation (and corresponding flood depth) were created for a comparative overlay analysis with the critical asset inventory. Critical elevations used with the coastal floodplain module of HAZUS-MH are provided in Table 10 above.

Exposure: Depth of Current and Future Storm Surge Flooding

These maps identify the areas at increased risk from the combined effects of storm surges and sea level rise, combining the 2040, 2070, and 2100 NIH SLR projections with 100-year (1.0% annual chance) and 500-year (0.2% annual chance) storms. In the figures below, by 2070, flooding from even the 100-year storm inundates most of West Palm Beach at a depth of 4 feet or more.

Figure 37 - NIH 2040 SLR + 100-Year Storm Surge

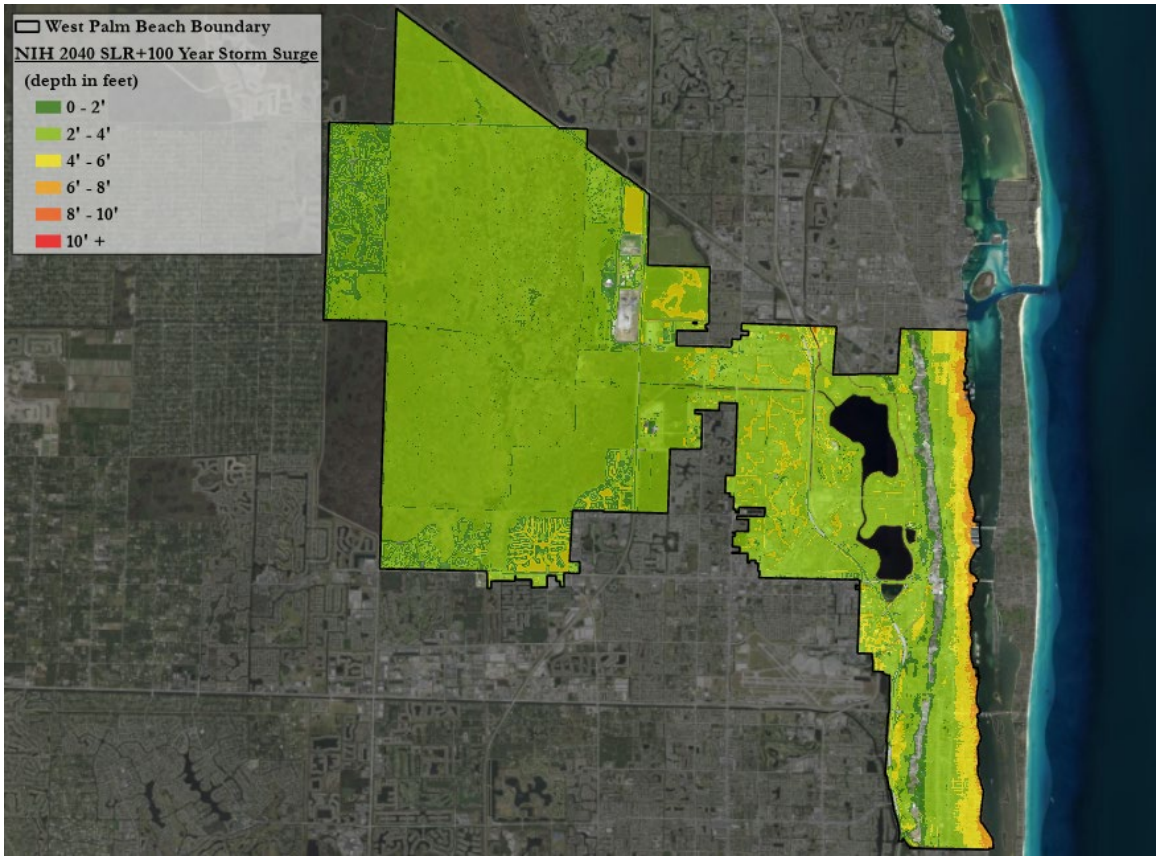
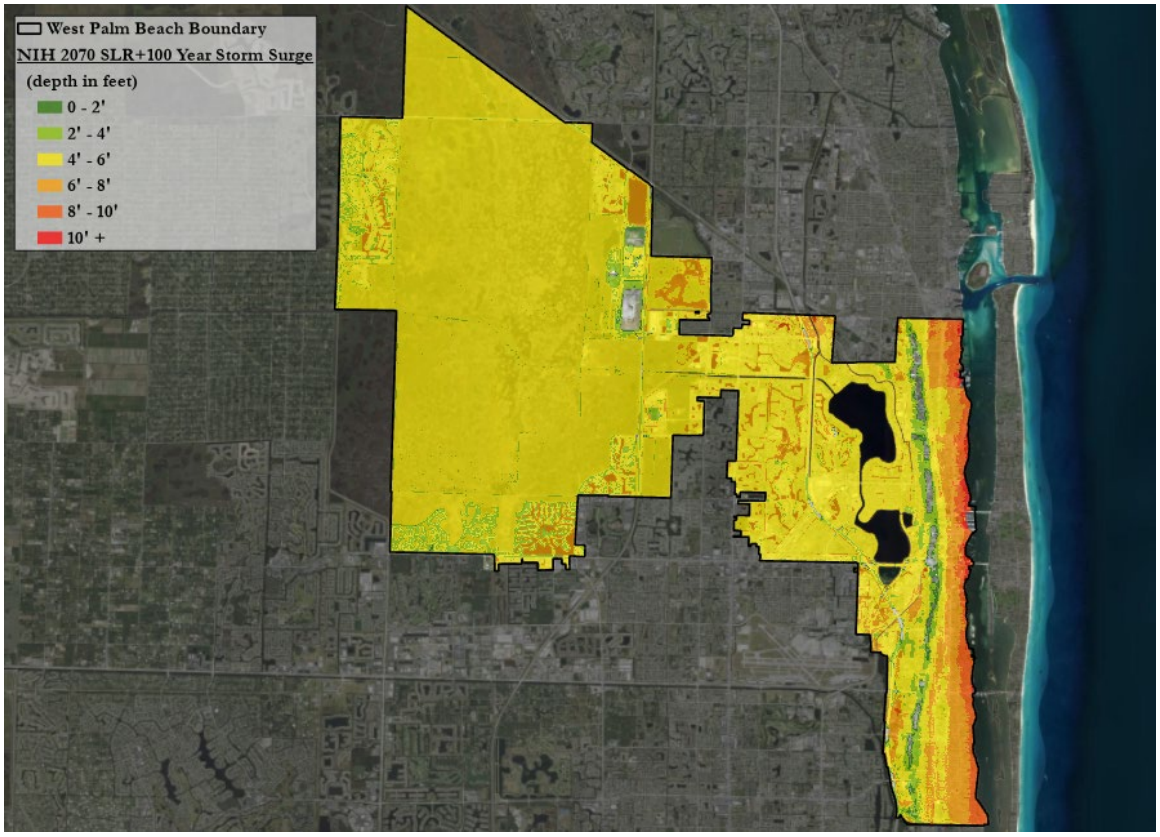


Figure 38 - NIH 2070 SLR + 100-Year Storm Surge



100-Year Storm Surge Scenario

The 100-year storm surge scenario encapsulates a storm event that has a 1% chance of occurring in any given year. This scenario is instrumental in determining the maximum expected storm surge flooding level over the planned horizons, providing a crucial benchmark for urban planning and infrastructure resilience. By integrating this scenario with future sea level rise projections, the assessment illuminates the compounded effects of climate change on storm surge risks. The analysis leverages FEMA's storm surge data and employs the HAZUS-MH software, adjusted for future sea level rise projections, to predict the depth and extent of flooding across various parts of the City. This scenario serves as a foundation for designing flood defense systems, updating building codes, and developing evacuation plans to mitigate the impacts of such extreme events on the community and critical infrastructure.

500-Year Storm Surge Scenario

Expanding the scope of the analysis, the 500-year storm surge scenario examines the impacts of a more severe but less frequent storm event, with a 0.2% chance of occurring in any given year. This scenario is crucial for stress-testing the City's

resilience against catastrophic storm surge events, offering insights into potential worst-case flooding scenarios. Similar to the 100-year scenario, this analysis incorporates adjustments based on projected sea level rises, employing advanced modeling techniques to provide detailed projections of storm surge depths and inundation extents. The outcome of this scenario analysis aids in the strategic placement of critical infrastructure, the design of more robust flood protection measures, and the prioritization of areas for targeted resilience enhancements.

Both the 100-year and 500-year storm surge scenarios are essential components of a comprehensive risk assessment framework, enabling West Palm Beach to proactively plan for and mitigate the risks associated with storm surge flooding. By accounting for these scenarios in conjunction with tidal flooding and sea level rise projections, the assessment offers a holistic view of the City's flood risk landscape. This approach ensures that resilience planning is informed by a thorough understanding of the range and severity of potential flooding events, guiding investments in infrastructure, emergency preparedness, and community resilience initiatives. Ultimately, by preparing for these scenarios, West Palm Beach can enhance its ability to withstand and recover from storm surge events, safeguarding the well-being of its residents and the integrity of its critical assets against the challenges posed by a changing climate.

Exposure: Rainfall

The rainfall analysis in the Vulnerability Assessment employs HEC-RAS software for rainfall simulation and runoff computation. This part of the assessment integrates NOAA's Atlas 14 data and SFWMD change factors to create baseline rainfall depth grids, aligning with legislative requirements without relying on developing entirely new hydrologic and hydraulic (H&H) modeling. This comprehensive approach makes it possible to understand and prepare for future climate impacts. This approach meets and exceeds the statutory requirements for rainfall evaluation in vulnerability assessments.

NOAA Atlas 14 provides high-quality data based on ongoing investigations of historical rainfall patterns across the United States. It offers site-specific rainfall distributions, which are essential for accurate hydrologic modeling. Compared to previous volumes, Atlas 14 estimates have longer periods of record and greater station density. NOAA Atlas 14 defines standard design rainfall distributions based on nesting high-intensity short durations within longer, lower-intensity durations. These distributions are used in hydrologic models to estimate rainfall intensity for specified durations and annual exceedance probabilities (Figure 39). The NOAA Atlas 14 serves as a guideline to assess flood potential in waterways and design stormwater infrastructure. The accuracy of rainfall data provided by NOAA Atlas 14 allows engineers and planners to make informed decisions when designing and managing infrastructure.

This document delineates the process of model development, touching upon terrain modeling, design storms, infiltration, runoff dynamics, soil conditions, boundary conditions, and the resultant analysis outputs.

Figure 39 - NOAA Atlas 14 Rainfall Time Series Table for West Palm Beach

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.511 (0.411-0.643)	0.586 (0.471-0.739)	0.709 (0.568-0.896)	0.810 (0.646-1.03)	0.949 (0.732-1.24)	1.06 (0.796-1.41)	1.16 (0.849-1.59)	1.27 (0.891-1.79)	1.41 (0.954-2.06)	1.52 (1.00-2.26)
10-min	0.748 (0.602-0.942)	0.858 (0.690-1.08)	1.04 (0.832-1.31)	1.19 (0.946-1.51)	1.39 (1.07-1.82)	1.55 (1.17-2.06)	1.70 (1.24-2.33)	1.86 (1.30-2.63)	2.06 (1.40-3.01)	2.22 (1.47-3.30)
15-min	0.912 (0.734-1.15)	1.05 (0.842-1.32)	1.27 (1.02-1.60)	1.45 (1.15-1.84)	1.70 (1.31-2.22)	1.88 (1.42-2.52)	2.07 (1.52-2.84)	2.26 (1.59-3.20)	2.52 (1.70-3.67)	2.71 (1.79-4.03)
30-min	1.42 (1.14-1.79)	1.62 (1.31-2.05)	1.96 (1.57-2.48)	2.24 (1.79-2.85)	2.62 (2.02-3.44)	2.92 (2.20-3.89)	3.21 (2.34-4.40)	3.51 (2.46-4.96)	3.90 (2.64-5.69)	4.19 (2.77-6.24)
60-min	1.89 (1.52-2.38)	2.12 (1.70-2.67)	2.52 (2.02-3.18)	2.87 (2.29-3.64)	3.39 (2.64-4.50)	3.82 (2.90-5.14)	4.27 (3.14-5.91)	4.75 (3.36-6.78)	5.43 (3.69-7.98)	5.97 (3.94-8.88)
2-hr	2.35 (1.91-2.94)	2.61 (2.11-3.26)	3.07 (2.47-3.85)	3.50 (2.80-4.42)	4.16 (3.27-5.51)	4.72 (3.62-6.34)	5.33 (3.95-7.36)	6.00 (4.27-8.54)	6.96 (4.77-10.2)	7.74 (5.15-11.5)
3-hr	2.58 (2.10-3.22)	2.84 (2.30-3.54)	3.34 (2.70-4.18)	3.83 (3.08-4.81)	4.61 (3.65-6.13)	5.30 (4.09-7.13)	6.07 (4.53-8.39)	6.93 (4.96-9.86)	8.18 (5.64-12.0)	9.22 (6.16-13.6)
6-hr	2.95 (2.41-3.65)	3.30 (2.70-4.09)	3.99 (3.25-4.96)	4.67 (3.78-5.84)	5.78 (4.62-7.67)	6.76 (5.25-9.06)	7.85 (5.90-10.8)	9.07 (6.55-12.9)	10.9 (7.55-15.8)	12.4 (8.31-18.1)
12-hr	3.34 (2.74-4.10)	3.90 (3.21-4.80)	4.96 (4.06-6.12)	5.96 (4.85-7.39)	7.51 (6.02-9.88)	8.85 (6.90-11.8)	10.3 (7.78-14.1)	11.9 (8.64-16.7)	14.3 (9.95-20.6)	16.2 (10.9-23.5)
24-hr	3.97 (3.28-4.84)	4.64 (3.83-5.66)	5.89 (4.86-7.22)	7.09 (5.81-8.73)	8.96 (7.23-11.7)	10.6 (8.31-14.0)	12.4 (9.39-16.8)	14.3 (10.5-20.0)	17.2 (12.1-24.7)	19.5 (13.3-28.2)
2-day	4.94 (4.12-5.99)	5.48 (4.55-6.64)	6.58 (5.45-8.00)	7.71 (6.36-9.43)	9.60 (7.85-12.6)	11.3 (8.98-14.9)	13.3 (10.2-18.0)	15.5 (11.4-21.5)	18.7 (13.3-26.8)	21.5 (14.7-30.8)
3-day	5.51 (4.61-6.66)	6.03 (5.03-7.28)	7.11 (5.91-8.62)	8.24 (6.82-10.0)	10.1 (8.31-13.2)	11.8 (9.44-15.6)	13.8 (10.6-18.6)	16.0 (11.9-22.2)	19.3 (13.8-27.6)	22.1 (15.2-31.6)
4-day	5.97 (5.00-7.18)	6.49 (5.43-7.82)	7.58 (6.32-9.16)	8.71 (7.22-10.6)	10.6 (8.71-13.7)	12.3 (9.83-16.1)	14.3 (11.0-19.1)	16.5 (12.2-22.8)	19.7 (14.1-28.1)	22.5 (15.5-32.1)
7-day	7.17 (6.04-8.58)	7.70 (6.48-9.22)	8.79 (7.37-10.6)	9.91 (8.26-12.0)	11.8 (9.68-15.1)	13.4 (10.8-17.4)	15.3 (11.9-20.4)	17.5 (13.0-23.9)	20.6 (14.8-29.1)	23.3 (16.2-33.0)
10-day	8.19 (6.92-9.77)	8.78 (7.41-10.5)	9.96 (8.37-11.9)	11.1 (9.30-13.4)	13.0 (10.7-16.5)	14.7 (11.8-18.9)	16.5 (12.8-21.8)	18.6 (13.9-25.4)	21.7 (15.6-30.4)	24.2 (16.9-34.2)
20-day	11.0 (9.32-13.0)	12.0 (10.2-14.2)	13.7 (11.6-16.3)	15.2 (12.8-18.2)	17.4 (14.3-21.6)	19.2 (15.4-24.2)	21.1 (16.4-27.4)	23.1 (17.2-30.9)	25.8 (18.6-35.7)	28.0 (19.6-39.4)
30-day	13.4 (11.4-15.8)	14.8 (12.6-17.4)	17.0 (14.4-20.1)	18.8 (15.9-22.4)	21.4 (17.5-26.3)	23.3 (18.7-29.2)	25.3 (19.7-32.5)	27.3 (20.4-36.2)	29.9 (21.6-41.0)	31.9 (22.5-44.7)
45-day	16.7 (14.3-19.6)	18.5 (15.8-21.7)	21.3 (18.2-25.1)	23.6 (20.0-27.9)	26.6 (21.8-32.3)	28.8 (23.1-35.7)	30.9 (24.0-39.4)	32.9 (24.7-43.4)	35.5 (25.7-48.3)	37.4 (26.4-52.1)
60-day	19.7 (16.9-23.0)	21.8 (18.7-25.5)	25.0 (21.4-29.4)	27.6 (23.5-32.6)	31.0 (25.4-37.5)	33.4 (26.9-41.2)	35.7 (27.8-45.3)	37.9 (28.4-49.6)	40.5 (29.3-54.9)	42.3 (30.0-58.8)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

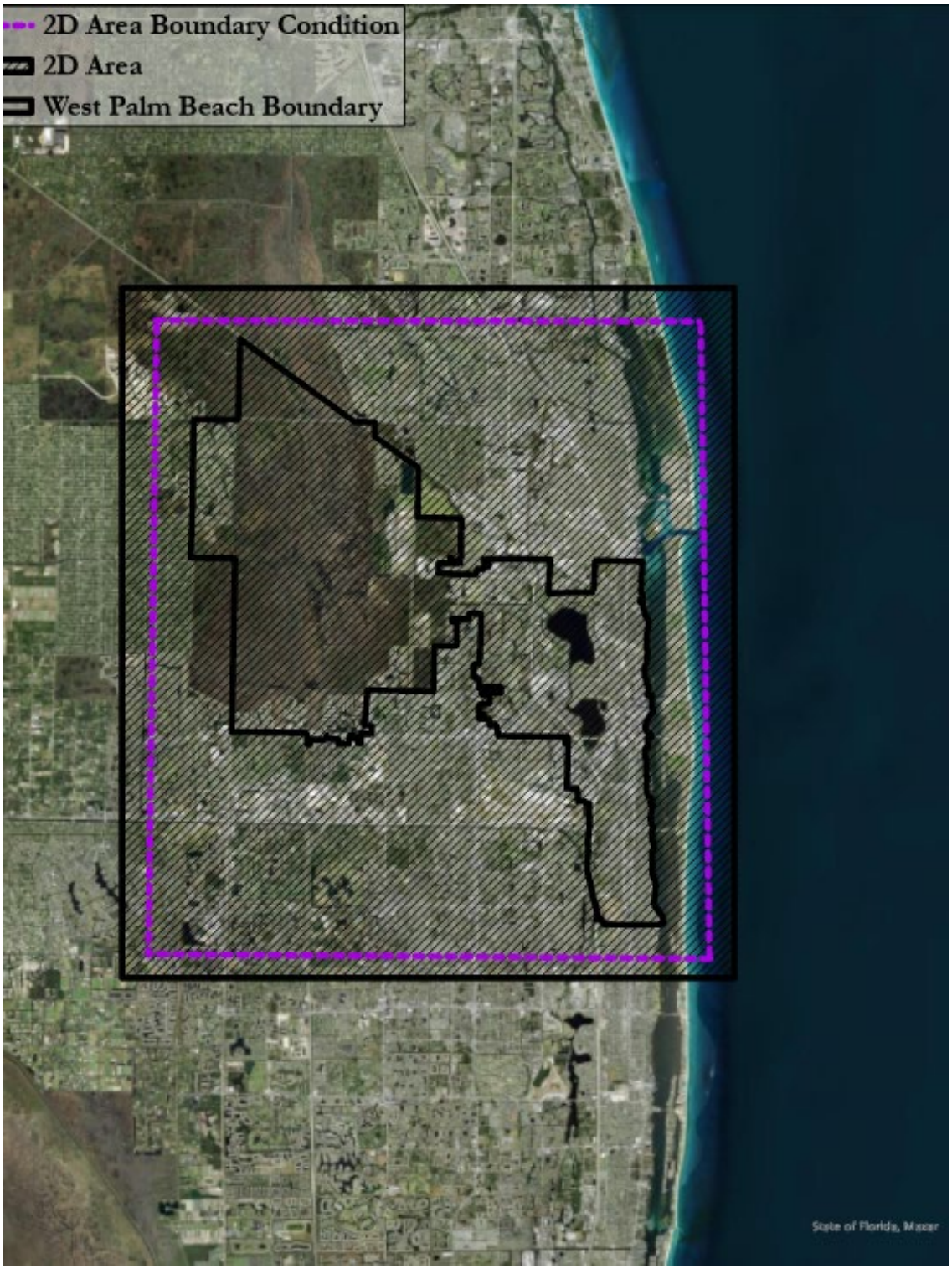
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Terrain

Digital elevation models (DEMs) were constructed to accurately capture the nuances of the terrain's elevation and slope. These DEMs serve as a foundational element in mapping and understanding the area's physical characteristics. The elevation data within these models adhere to the North American Vertical Datum of 1988 (NAVD88). Figure 40 is the outline of the 2D DEM area and the boundary condition lines used in conjunction with the DEM as terrain inputs in the modeling environment.

Figure 40 - LiDAR Data Extent and Boundary Condition Lines for N, S, E, and W Boundaries



Design Storms

The Precipitation Data files were generated using Intensity/Precipitation curves derived from the FDOT Drainage manual for 24-hour design storms. The design storms represent current (2023) rainfall patterns: 500-, 100-, 50-, and 25-year return interval 24-hour rainfall events and the rainfall depths representing each 24-hour hypothetical storm event were taken from National Oceanic and Atmospheric Administration (NOAA) Atlas 14 annual maxima series to represent 2023 rainfall patterns (NOAA, 2023). Future rainfall depths were computed using the current precipitation depths in Table 11, deriving the intensity for the respective future conditions by using the South Florida Water Management District (SFWMD) change factors to arrive at the projected precipitation in Table 12. The current and projected precipitation depths are then subjected to the storm design criteria in Table 13 below to arrive at a storm design that is suitable for varying present and future conditions.

Table 11 - Precipitation for 24-Hour Storm Duration - Present Day

Year	Scenario	Precipitation (inches)[12]
Present Day	25-Year	8.96
Present Day	50-Year	10.6
Present Day	100-Year	12.4
Present Day	500-Year	17.2
Present Day	1000-Year	19.5

Table 12 - Projected Precipitation for 24-Hour Storm Duration

Year	Scenario	Precipitation (inches)
2040	25-Year	10.04
2040	100-Year	13.89

[12] [1] (NOAA, 2023)

Year	Scenario	Precipitation (inches)
2070	25-Year	10.93
2070	100-Year	15.13
2100	25-Year	12.01
2100	100-Year	16.62

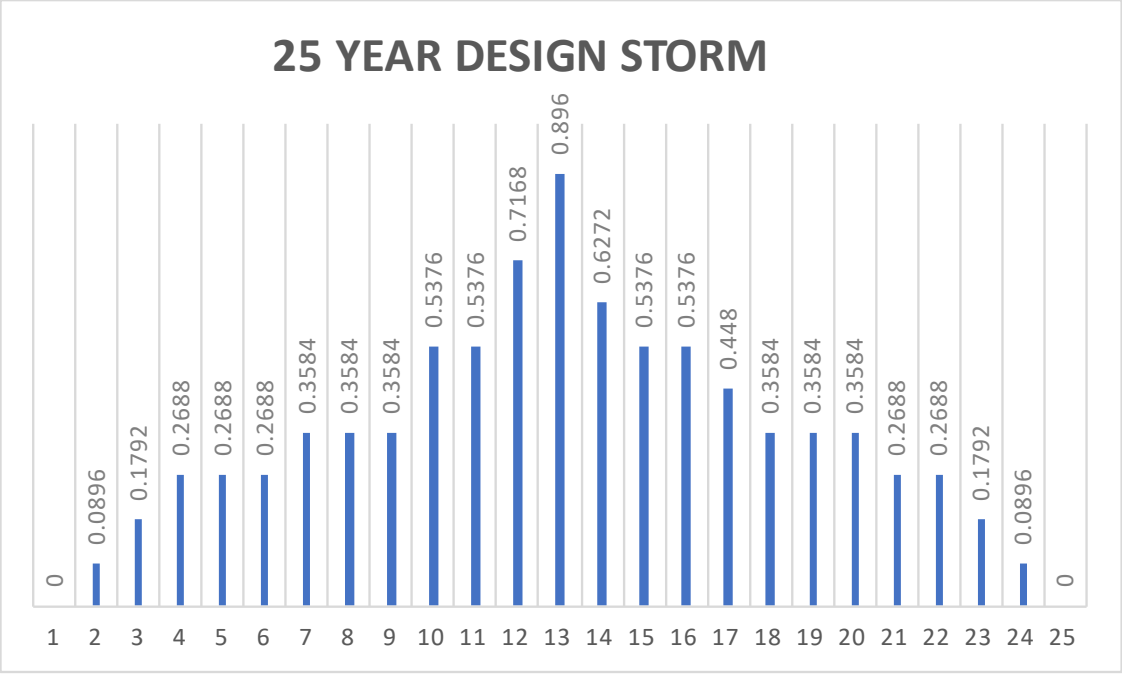
Table 13 - Rainfall Design Storm Criteria for Varying Storm Events[13]

T hours	I/P Total	25-Year Intensity	50-Year Intensity	100-Year Intensity	500-Year Intensity
0	0	0	0	0	0
1	0.01	0.12	0.14	0.17	0.23
2	0.02	0.24	0.28	0.33	0.46
3	0.03	0.36	0.43	0.50	0.68
4	0.03	0.36	0.43	0.50	0.68
5	0.03	0.36	0.43	0.50	0.68
6	0.04	0.48	0.57	0.66	0.91
7	0.04	0.48	0.57	0.66	0.91
8	0.04	0.48	0.57	0.66	0.91
9	0.06	0.72	0.85	1.00	1.37
10	0.06	0.72	0.85	1.00	1.37
11	0.08	0.96	1.14	1.33	1.82
12	0.10	1.20	1.42	1.66	2.28
13	0.07	0.84	0.99	1.16	1.60
14	0.06	0.72	0.85	1.00	1.37
15	0.06	0.72	0.85	1.00	1.37

[13] FDOT drainage manual for design storms, https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/roadway/drainage/files/idfcurves.pdf

T hours	I/P Total	25-Year Intensity	50-Year Intensity	100-Year Intensity	500-Year Intensity
16	0.05	0.60	0.71	0.83	1.14
17	0.04	0.48	0.57	0.66	0.91
18	0.04	0.48	0.57	0.66	0.91
19	0.04	0.48	0.57	0.66	0.91
20	0.03	0.36	0.43	0.50	0.68
21	0.03	0.36	0.43	0.50	0.68
22	0.02	0.24	0.28	0.33	0.46
23	0.01	0.12	0.14	0.17	0.23
24	0	0	0	0	0

Figure 41 - 25-Year Design Storm Criteria for West Palm Beach



Infiltration and Runoff

The infiltration method employed in this HEC-RAS model utilizes the Soil Conservation Service (SCS) Curve Number (CN) method, designed to estimate direct

runoff and infiltration rates from rainfall events. This approach is particularly suitable for varying soil conditions, and land use offering a comprehensive understanding of how different terrains respond to precipitation.

The SCS CN method is based on empirical data, correlating soil type and land use to a curve number that represents the potential for runoff. This method simplifies the calculation of effective rainfall (precipitation that contributes to runoff) by considering the initial abstraction and potential maximum retention after runoff begins.

Infiltration rates are dynamically adjusted for each simulation. This adaptation ensures the model's responsiveness to varying hydrological conditions, offering a more nuanced depiction of infiltration and runoff dynamics within the study area. Manning's n roughness and percent impervious values were assigned to each USGS National Land Cover Database (NLCD) land cover category representing 2021 conditions (USGS, 2023a) (Figure 43). Manning's n roughness ranges were taken from the HEC-RAS technical reference guide (USACE, 2021). Table 15 shows the land cover categories, Manning's n roughness, percent impervious, and area within the modeled 2D flow area.

Soil Classification

The Gridded Soil Survey Geographic (gSSURGO) Database was used to identify the soil texture and hydrologic soils group for soils within the 2D flow area (USDA-NRCS, 2023). Figure 42 shows the gSSURGO soil map classifications in the 2D flow area. The most dominant soil texture throughout the City is primarily fine sand. Aside from sandy soil classifications there was also a notable presence of muck soils. In the model, muck soils are treated as poorly drained soils where there is limited capacity to transmit water because of the shallow depth of the water table. Typically, these muck soils carry dual hydrologic soil groups with soil group A or B applying to the drained condition and soil group. The sandy soils are considered well drained and without frequent ponding with a hydrologic soil group classification of A indicating low runoff potential.

Table 14 - Extent of Soil Textures

Soil Texture	Acres
Gravelly Sand	71.43
Fine Sandy Loam	108.72
Muck	2,837.52
Sand	9,456.29
Fine Sand	21,832.51

Figure 42 - Soil Texture Categories

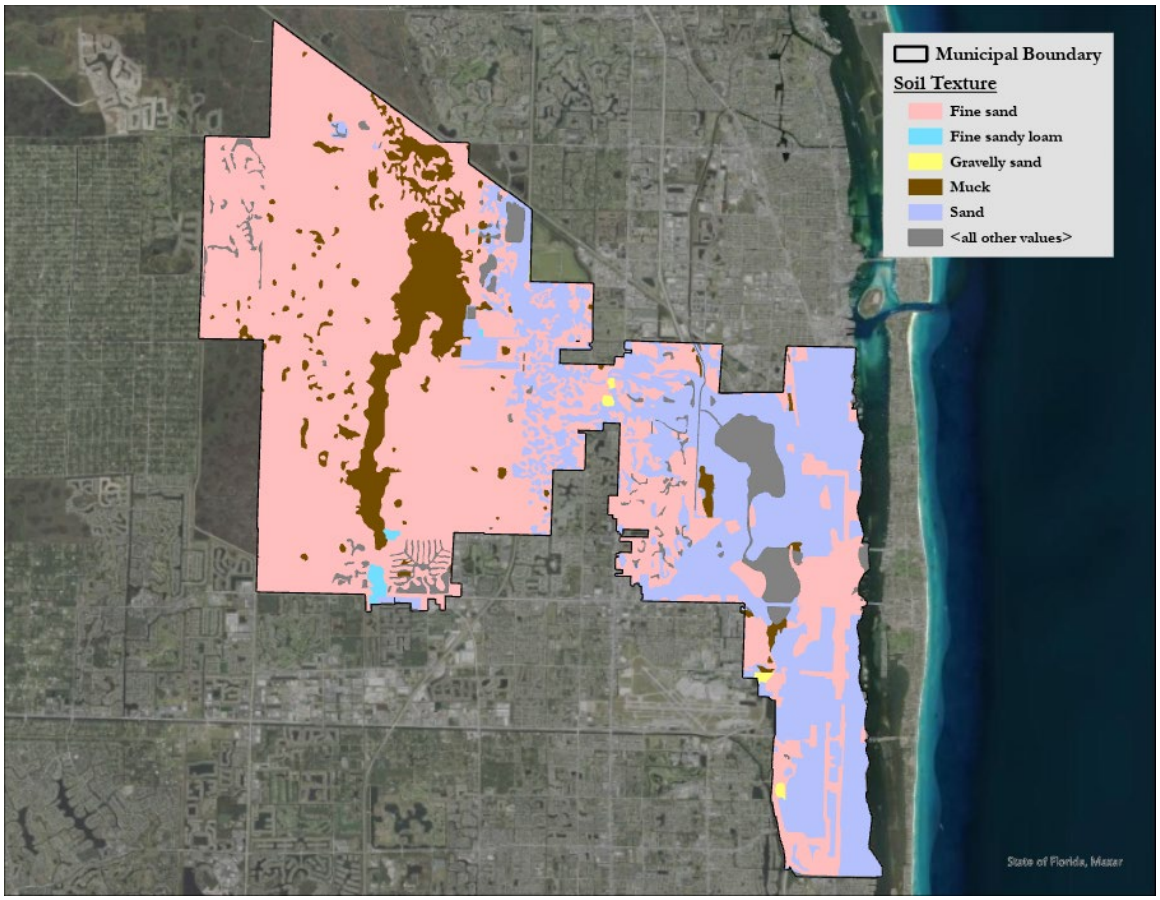
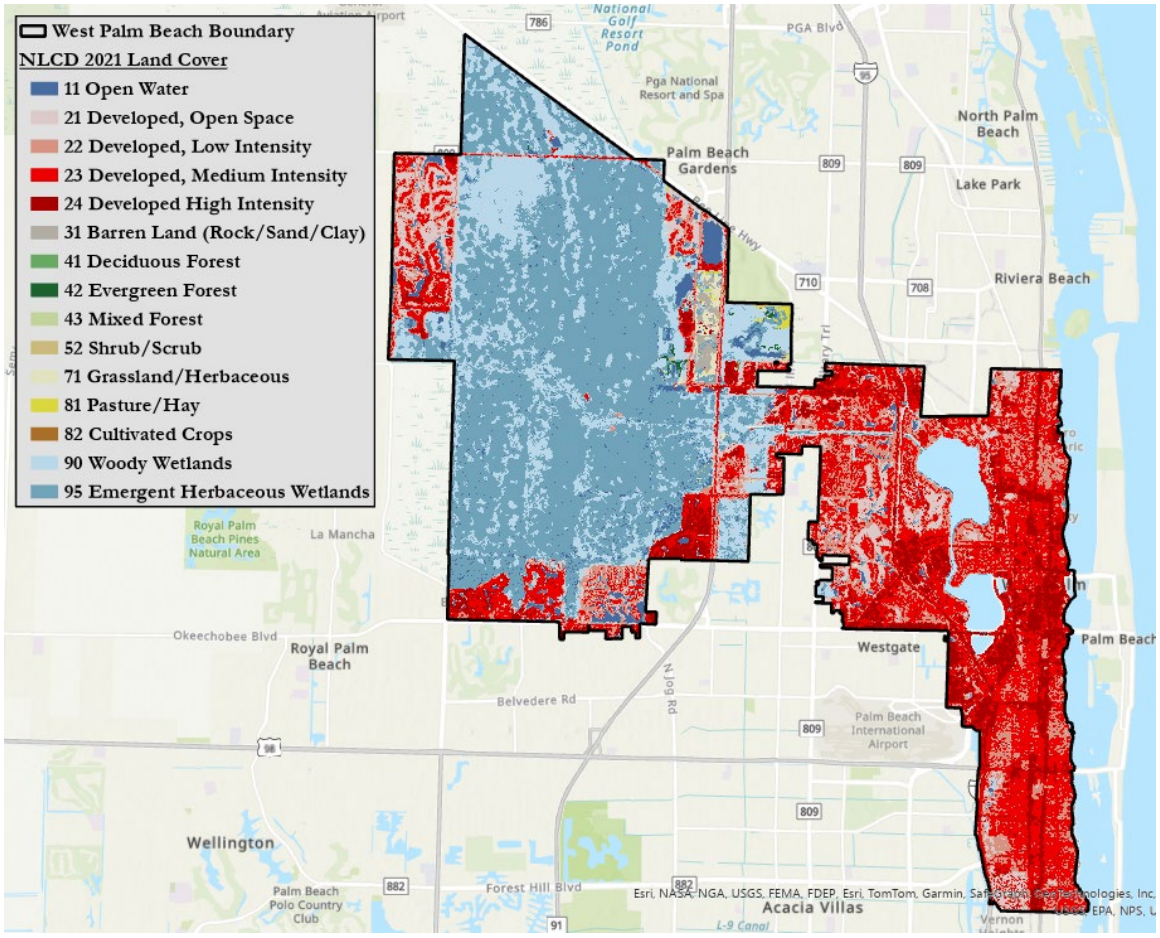


Figure 43 - Land Cover Categories



This map illustrates the 2021 land cover of West Palm Beach using the National Land Cover Dataset (NLCD), a crucial input for HEC-RAS modeling in rainfall and flooding analysis. The diverse landscape depicted includes urban areas (shades of red), water bodies (dark blue), and natural habitats. The large light blue area in the northwest represents the Grassy Waters Preserve, a critical wetland ecosystem that plays a significant role in the city's hydrology and stormwater management.

The NLCD provides broad-scale land cover information used to determine Manning's n roughness coefficients and impervious surface percentages, which are essential for accurate runoff and infiltration calculations in flood modeling. While generally accurate, some local discrepancies may occur in the NLCD classification. For instance, small areas of development (red) shown within the Grassy Waters Preserve, particularly along the M Canal, are known misclassifications. In reality, some of these areas are undeveloped, maintaining the Preserve's natural state.

This land cover representation serves as a key component in hydrological modeling, informing how different areas of the city respond to rainfall events and contribute to

potential flooding scenarios. The accuracy of this data directly influences flood risk assessments and adaptation planning strategies.

Table 15 - Land Cover Category - Manning's N Roughness and Impervious Surface[14]

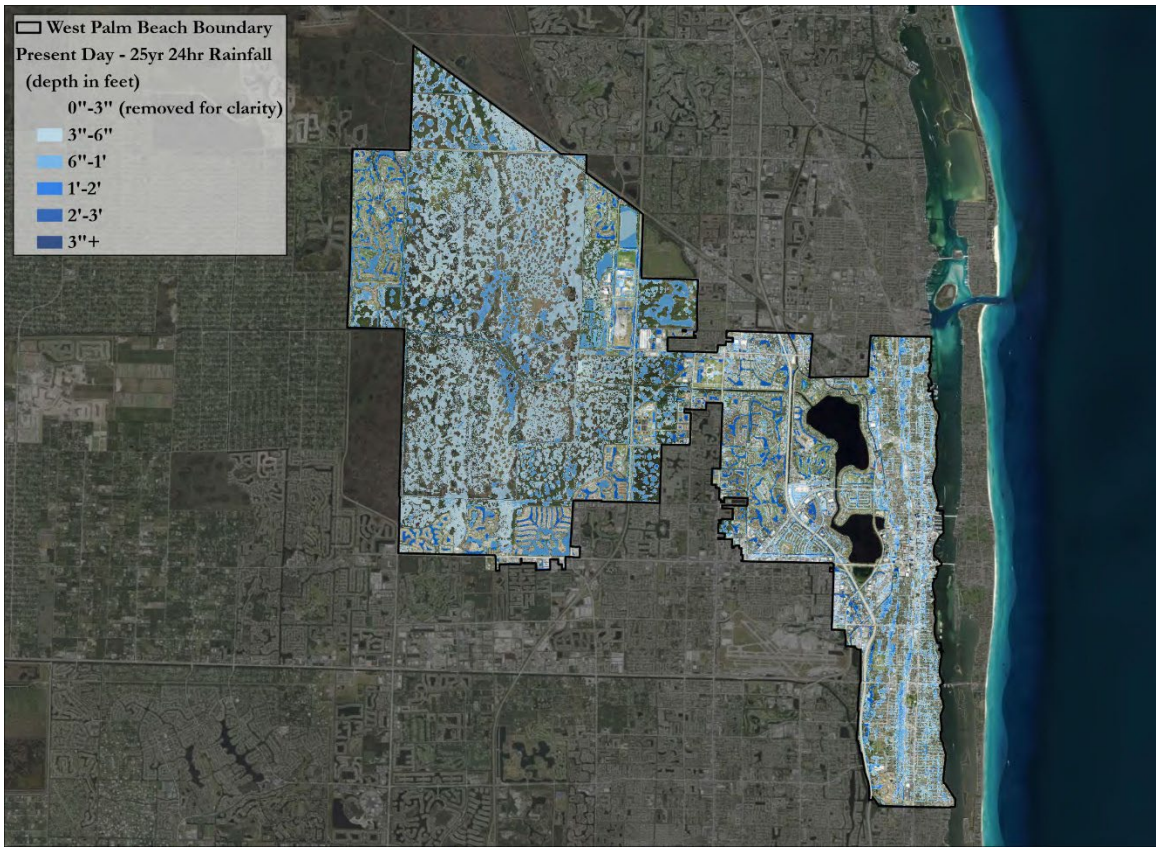
ID	Name	Manning's n Range[1]	Mannings n[2]	Impervious[3] %
31	Barren Land Rock-Sand-Clay	0.023-0.030	0.030	0
82	Cultivated Crops	0.020-0.050	0.050	0
24	Developed, High Intensity	0.120-0.200	0.150	80
22	Developed, Low Intensity	0.060-0.120	0.080	40
23	Developed, Medium Intensity	0.080-0.160	0.120	60
21	Developed, Open Space	0.030-0.050	0.035	0
95	Emergent Herbaceous Wetlands	0.050-0.085	0.070	75
42	Evergreen Forest	0.080-0.160	0.150	0
71	Grassland-Herbaceous	0.025-0.050	0.040	0
43	Mixed Forest	0.080-0.200	0.120	0
11	Open Water	0.025-0.050	0.035	100
81	Pasture-Hay	0.025-0.050	0.045	0
52	Shrub-Scrub	0.070-0.160	0.080	0
90	Woody Wetlands	0.045-0.150	0.100	50

[14] USACE Creating Land Cover, Manning's N Values, and % Impervious Layers (USACE, 2021).

Baseline Rainfall-Induced Flooding

The modeling approach uses generally accepted analysis and modeling techniques, which meet and exceed the requirements of Section 380.093(3)(d)2.c., F.S. Rainfall precipitation data sourced from NOAA's Atlas 14 provides the baseline rainfall depth grids and depth duration hydrographs for different storm events (25-year, 50-year, 100-year, and 500-year).

Figure 44 - 25-Year 24-Hour Rainfall - Present Day



25-Year 24-Hour Scenario

This scenario models a storm event with a 4% chance of happening in any given year. It provides insights into moderate but significant flooding risks that can disrupt daily life and damage less resilient infrastructure. The analysis of this frequency helps in identifying flood-prone areas that require improved drainage, enhanced stormwater management systems, and community flood preparedness programs.

50-Year 24-Hour Scenario

Elevating the analysis, the 50-year 24-hour scenario, with a 2% annual occurrence probability, examines the impacts of more intense rainfall. This scenario assists in evaluating the adequacy of existing flood defenses and identifying critical infrastructure that might be at risk during such events. It also underscores the need for robust emergency response strategies and infrastructure resilience against more severe flooding.

100-Year 24-Hour Scenario

A cornerstone of flood risk management, the 100-year 24-hour scenario represents a severe storm event with a 1% chance of occurring in any given year. This scenario is crucial for urban planning and development, guiding the design standards for flood mitigation infrastructure, zoning regulations, and insurance requirements. It highlights areas where strategic investments can significantly reduce flood risks and enhance community resilience.

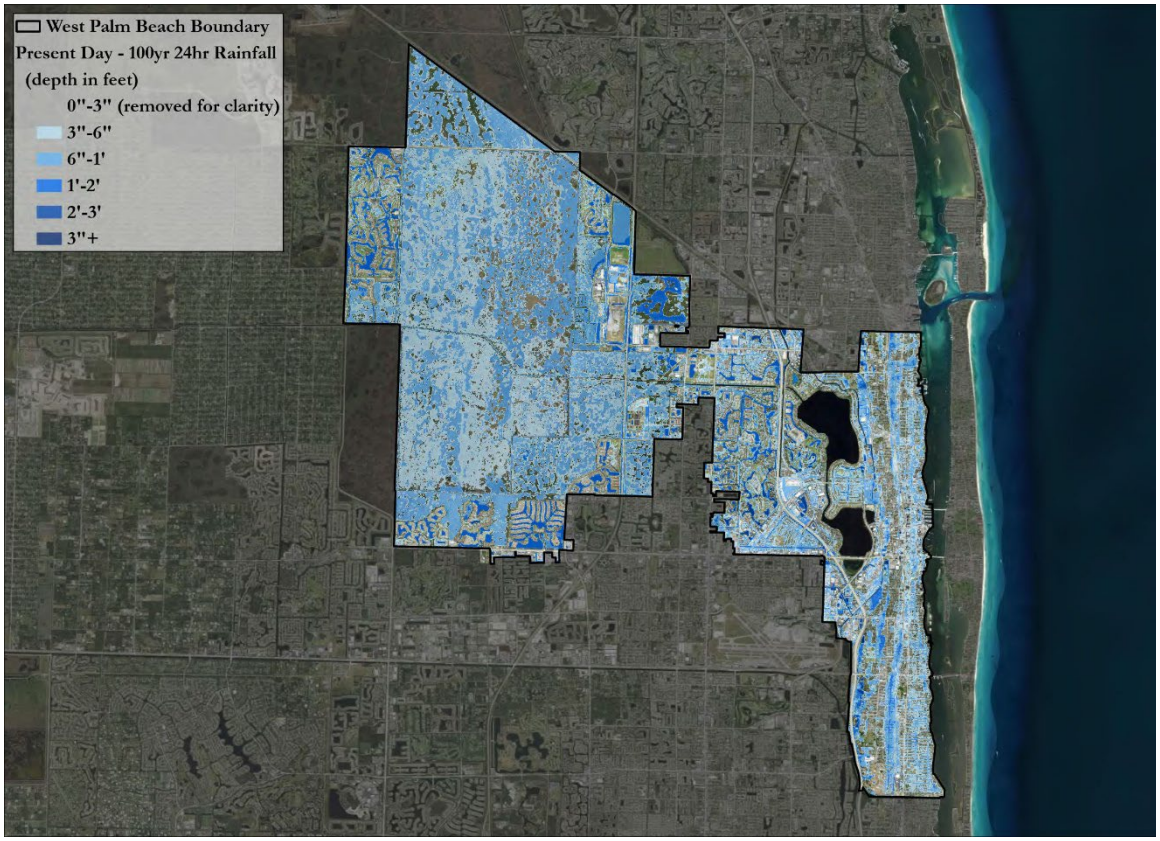
500-Year 24-Hour Scenario

The 500-year 24-hour scenario represents an extreme rainfall event with a 0.2% chance of occurring in any given year. This scenario is crucial for understanding the upper limits of flood risk, highlighting areas and infrastructure that could be subjected to unprecedented water levels. The potential for catastrophic flooding under this scenario demands comprehensive planning and robust mitigation strategies, far beyond the routine flood management measures.

1,000-Year 24-Hour Scenario

This scenario represents an exceptionally rare and extreme rainfall event with a 0.1% chance of occurring in any given year, offering a detailed examination of the potential for catastrophic flooding. The 1,000-year scenario is critical for comprehensive risk assessment and planning, necessitating advanced preparedness and mitigation strategies to safeguard lives, property, and critical infrastructure. The profound implications of such an event underscore the importance of forward-looking, resilient urban planning and the development of robust emergency management systems to handle potential catastrophic impacts.

Figure 45 - 100-Year 24-Hour Rainfall - Present Day



Stormwater Management and Drainage Considerations

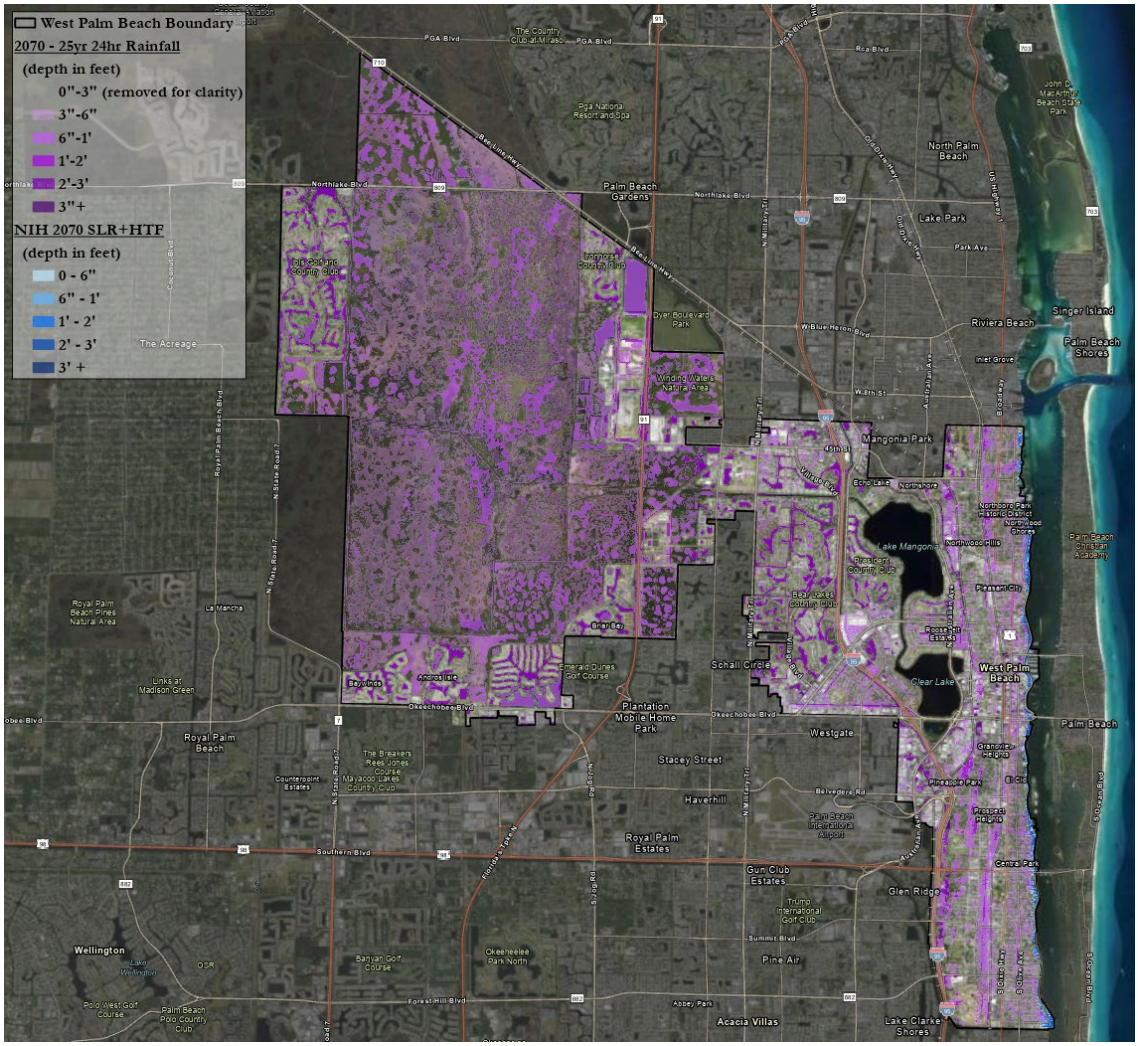
Grassy Waters Preserve (GWP), a critical water source for West Palm Beach, plays a key role in stormwater management during extreme rainfall events. Historically, during periods of intense precipitation, GWP has contributed to surface runoff that crosses major roads, including Northlake Boulevard. This highlights the need for enhanced drainage systems to manage water overflow effectively. While this assessment does not include detailed hydrological simulations of specific stormwater system responses, it is important to recognize that inadequate drainage, combined with rising water levels and increased rainfall intensity projected for 2040, 2070, and 2100, could exacerbate flooding risks in adjacent areas.

Improving drainage infrastructure around GWP, such as upgrading culverts and expanding stormwater retention basins, could mitigate these risks. Moreover, strategic placement of check-valves and pumps along key drainage points, particularly in low-lying areas prone to water overflow, should be considered to prevent roadway flooding.

Future Rainfall-Induced Flooding

These baseline depth grids are then adjusted by the sea level rise projection data based on NOAA's Intermediate Low (NIL) and Intermediate High (NIH) projections for the respective timeframes and rainfall precipitation by the SFWMD's published change factors. These predict approximately 1.12 times more rain in 2040 than present day conditions, 1.22 times more rain in 2070, and 1.34 times more rain in 2100. It should be noted that coastal communities are not required to include rainfall-induced flooding in their vulnerability assessments per Section 380.093(3), F.S. However, non-coastal communities must perform a rainfall-induced flooding assessment.

Figure 46 - NIH 2070 SLR + 25-Year 24-Hour Rainfall



Adjusted 25-Year and 100-Year 24-Hour Scenarios

Recognizing the influence of climate change on weather patterns, the Assessment includes adjusted scenarios for the 25-year and 100-year events. These adjusted models take into account the anticipated increase in rainfall intensity and frequency, offering a forward-looking perspective on flood risks. By integrating climate change projections, these scenarios provide a more accurate reflection of future flood hazards, guiding the development of adaptive infrastructure and policies that are resilient to changing climatic conditions.

Together, these rainfall-induced flooding scenarios form a critical component of West Palm Beach's comprehensive flood risk assessment. By encompassing a broad range of event frequencies and intensities, the analysis equips City planners, policymakers, and community leaders with the data necessary to make informed decisions about flood mitigation, emergency preparedness, and climate adaptation strategies. The detailed examination of both standard and adjusted scenarios ensures that the City's resilience planning remains dynamic and responsive to both current and future flood risks, safeguarding the well-being of the community and the sustainability of its development in the face of increasing rainfall events.

Compound Modeling

The compound modeling section of the Vulnerability Assessment focuses on assessing the combined impacts of various flooding scenarios. This includes high tide flooding, storm surge, and rainfall-induced flooding. The methodology involves overlaying depth grids from each scenario to identify compounded flood heights at a well-defined scale. The approach provides a comprehensive understanding of the potential cumulative impacts of different flooding events simultaneously occurring, aiding in effective planning and mitigation strategies. This planning process, however, does not simulate the hydrologic interactions between these events or the stormwater management system's response. However, this type of simulation could be performed with a more complex engineering-based model.

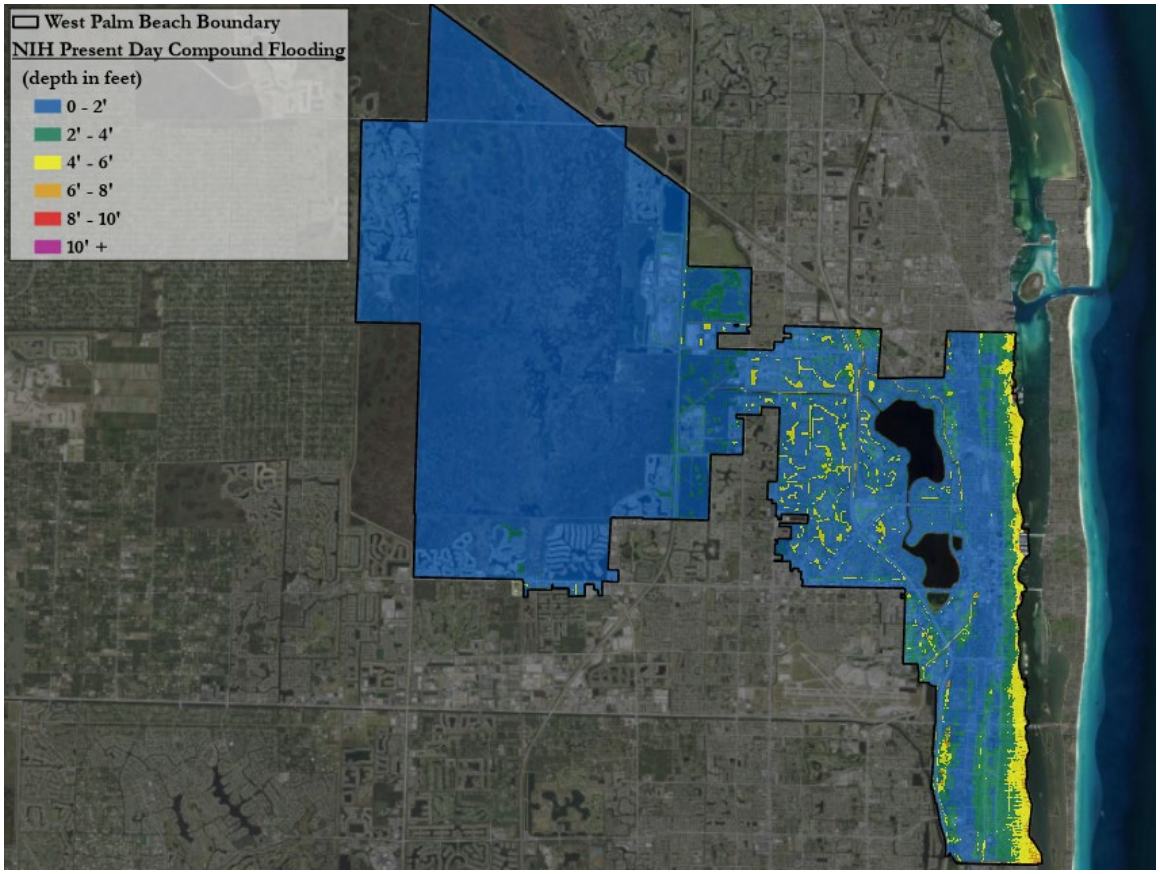
Sea level rise inundation modifies the “coastline,” representing an approximate new coastal boundary under mean higher high water (MHHW) or the highest high tide of the day. Stormwater structures along coastal waters, inundated by sea level rise are expected to no longer function and exacerbate flooding. Surge impacts are large but temporary in nature, caused by the force of storm pushing water onto the terrain.

Table 16 - NOAA Intermediate Low and High Combined Flood Scenario Water Rise Impacts

Sea Level Rise Scenario	Surge Scenario	Rainfall Scenario	Combined Water Rise (ft)
Present Day	100-Year	25-Year 24-Hour	6.4
Present Day	100-Year	100-Year 24-Hour	6.7
Present Day	500-Year	25-Year 24-Hour	7.5
Present Day	500-Year	100-Year 24-Hour	7.8
NIL 2040	100-Year	25-Year 24-Hour	7.2
NIL 2040	100-Year	100-Year 24-Hour	7.5
NIL 2040	500-Year	25-Year 24-Hour	7.7
NIL 2040	500-Year	100-Year 24-Hour	8.0
NIH 2040	100-Year	25-Year 24-Hour	7.9
NIH 2040	100-Year	100-Year 24-Hour	8.3
NIH 2040	500-Year	25-Year 24-Hour	9.6
NIH 2040	500-Year	100-Year 24-Hour	9.9
NIL 2070	100-Year	25-Year 24-Hour	7.8
NIL 2070	100-Year	100-Year 24-Hour	8.1
NIL 2070	500-Year	25-Year 24-Hour	9.4
NIL 2070	500-Year	100-Year 24-Hour	9.7
NIH 2070	100-Year	25-Year 24-Hour	9.8
NIH 2070	100-Year	100-Year 24-Hour	10.2
NIH 2070	500-Year	25-Year 24-Hour	11.9
NIH 2070	500-Year	100-Year 24-Hour	12.2
NIL 2100	100-Year	25-Year 24-Hour	8.3
NIL 2100	100-Year	100-Year 24-Hour	8.6
NIL 2100	500-Year	25-Year 24-Hour	10.0
NIL 2100	500-Year	100-Year 24-Hour	10.3
NIH 2100	100-Year	25-Year 24-Hour	12.5
NIH 2100	100-Year	100-Year 24-Hour	12.9

Sea Level Rise Scenario	Surge Scenario	Rainfall Scenario	Combined Water Rise (ft)
NIH 2100	500-Year	25-Year 24-Hour	15.2
NIH 2100	500-Year	100-Year 24-Hour	15.5

Figure 47 - Present Day SLR + 100-Year Storm Surge + 25-Year Rainfall



Sea Level Rise + 100-Year Storm Surge with 25-Year + 100-Year Rainfall Scenarios

This scenario amalgamates the risks of significant sea level rise, a century-scale storm surge, and both moderate and severe rainfall events, offering a detailed perspective on flooding risks over a broad spectrum of frequencies and intensities.

Sea Level Rise + 500-Year Storm Surge with 25-Year + 100-Year Rainfall Scenarios

By considering a more extreme storm surge event alongside the same rainfall probabilities within the context of rising sea levels, this scenario highlights the

utmost extents of potential flooding impacts, emphasizing the critical need for robust resilience planning.

Sea Level Rise with 100-Year + 500-Year Storm Surge Scenarios

This scenario focuses on the compounded effects of sea level rise and both the 100-year and 500-year storm surge events, providing a stark overview of the most extreme surge events' potential amplification due to rising sea levels.

Sensitivity: Ranked Prioritization in Hot Spots

The sensitivity analysis helps prioritize resilience adaptation efforts based on how the various sea level rise projections affect critical assets within key geographic areas in the City of West Palm Beach. The Assessment should guide land use regulations, building codes, land development policies, emergency response strategies and inform various justice, equity, diversity and inclusion (JEDI) initiatives[15] that are associated with climate resilience adaptation planning.

The information provided by this Assessment allows decision makers to implement measures that reduce vulnerability and mitigate future harms in stages. The Vulnerability Assessment also aims to facilitate collaboration between communities in pursuit of the long-term goals of sustainable coastal management and environmental conservation. Regions that are highly exposed to multiple flood scenarios are identified as flooding “hot spot” areas. These hot spots contain a mix of government facilities, commercial areas, critical transportation hubs, and residential neighborhoods where there is a high concentration of publicly-owned assets. By mapping these hot spots and prioritizing the assets within them, resources can be focused where multiple risks intersect, both identifying highly vulnerable assets and enabling an adaptation plan that is prioritized by geographic area and immediate need.

Ranked Flood Exposure Tiers

To add context to the flood exposure analysis, the team developed the following table in tandem with City officials. It defines the flood thresholds used to assign no, low, medium, high, and very high flood exposure levels based on the GIS modeling.

[15] https://www.cdc.gov/climateandhealth/JEDI.htm

Table 17 - Exposure Descriptions

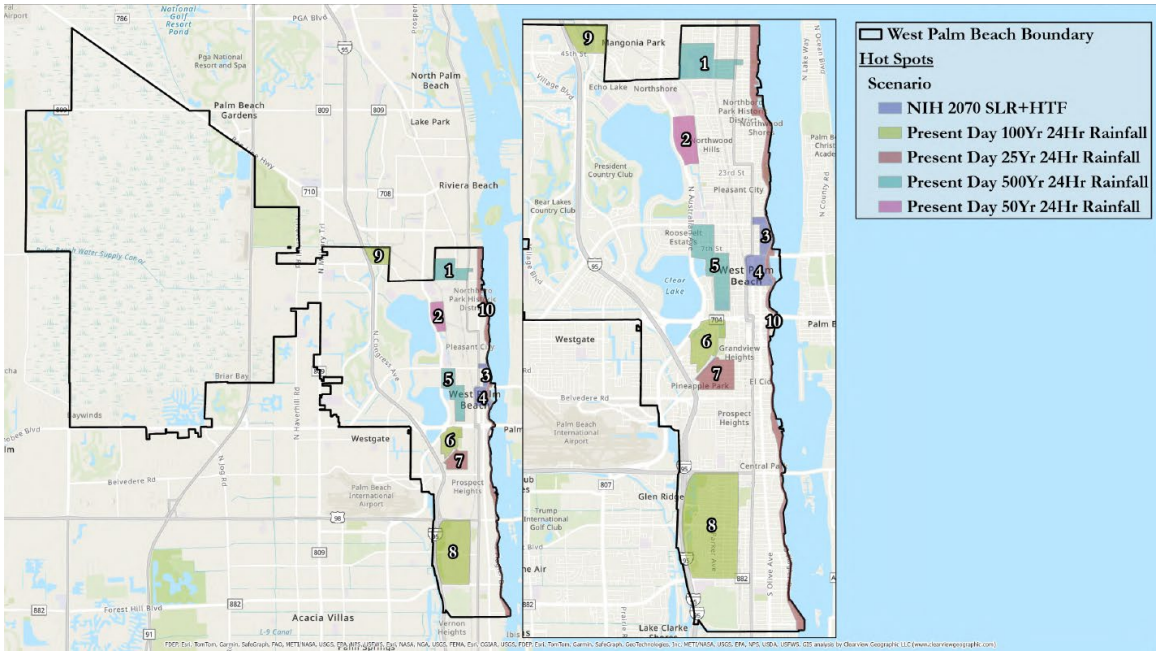
Flood Depth	Exposure Ranking	Description
0 feet	No Exposure	No flooding detected. Areas with no impact from sea level rise or flooding.
0 to 0.5 feet	Low Exposure	Minor flooding. Shallow inundation typically causing minimal impact.
0.5 feet to 1.0 foot	Medium Exposure	Moderate flooding. Likely to impact structures and disrupt daily life.
1.0 foot to 3.0 feet	High Exposure	Significant flooding. Serious degree of inundation causing damage and major disruptions.
More than 3.0 feet	Very High Exposure	Severe flooding. Extensive inundation posing critical threats and causing extensive damage.

Table 17 above outlines West Palm Beach's determined exposure levels for this project. These ranking levels enable evaluation of the potential consequences of rising sea levels and overall flooding impact in West Palm Beach's specific context.

Identifying High-Risk Areas with Hot Spots

Identification of high-risk areas and assets is a cornerstone of this Vulnerability Assessment. Based on modeling and the concentration of critical assets, high-risk areas within West Palm Beach have been identified, as reflected in Figure 48, Hot Spot Map of West Palm Beach. This map series reflects the areas where 1) there are aggregations of critical assets and 2) are subject to some level or multiple levels of flood risk. The map is color coded to reflect the type of flood risk and the approximate year that area will be impacted by that flood risk. A summary table is embedded that shows each hot spot breakdown and which flood scenarios impact that hot spot. The hot spots are numbered according to their priority of impact based on need and geography as defined in FDEP's Vulnerability Assessment Checklist and by statute.

Figure 48 - Hot Spot Map of West Palm Beach



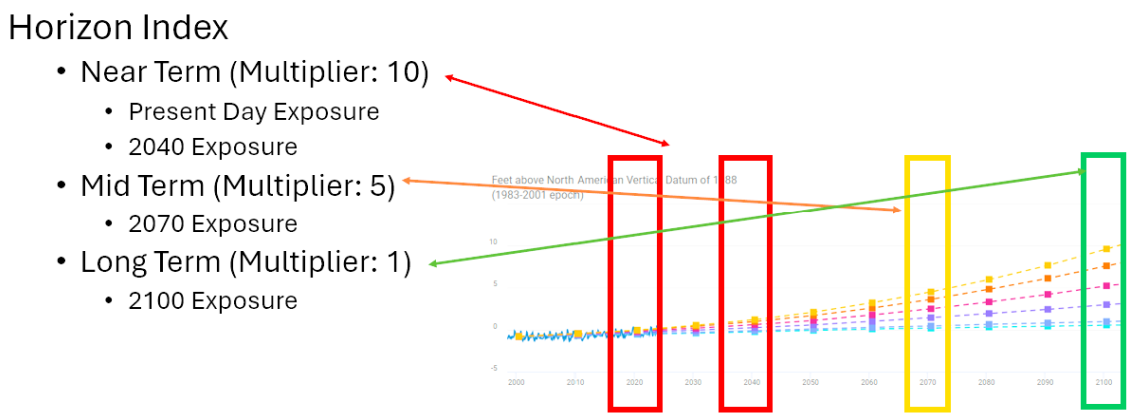
Modeling Impact to Assets

Within the highest risk areas, quantitative analysis was performed on the critical assets to assign the flood depths derived from the exposure modeling directly to the assets within the underlying data tables. This impact modeling contributes directly to the method of prioritization discussed later in this section and aligns with FDEP Vulnerability Assessment Checklist criteria and the methodologies outlined in the assessment framework, ensuring a meticulous and precise identification process for asset risk and enables the identification of specific flood scenarios each asset is impacted by.

Prioritizing Based on Planning Horizon

The planning horizons are categorized into near-term (approximately 0-20 years), mid-term (~20-50 years), and long-term (~50-100 years). The Horizon Index reflects this temporal segmentation, using a multiplier system to emphasize the criticality of impacts in the near term. Assets are ranked based on their Horizon Index scores, a derived metric that segments out the modeling into near term, mid-term, and long term, with a multiplier system identifying those with the nearest term impacts. It helps in making informed decisions about near-term planning, adaptation measures, and risk management related to flooding. It also serves as a guide for prioritizing investments in infrastructure and formulating policy responses to the challenges posed by sea level rise and climate change.

Figure 49 - Planning Horizon Prioritization



Prioritizing Based on Flood Risk

Assets are ranked based on their Flood Risk Index scores, with a tiered system identifying those at highest risk. This prioritization informs resource allocation and intervention strategies by delineating areas of high vulnerability where adaptation strategies can be the most impactful.

Table 18 - Flood Risk Metric Weighting

Metric	Weight
Rain and Sea Level Rise Combo	0.35
Sea Level Rise Impact	0.25
Rain, Sea Level Rise, and Storm Surge	0.15
Number of Times Asset is Exposed	0.10
Average Flood Depth	0.10
Average Flood Depth Percentile Rank	0.05
Total	**1.00**

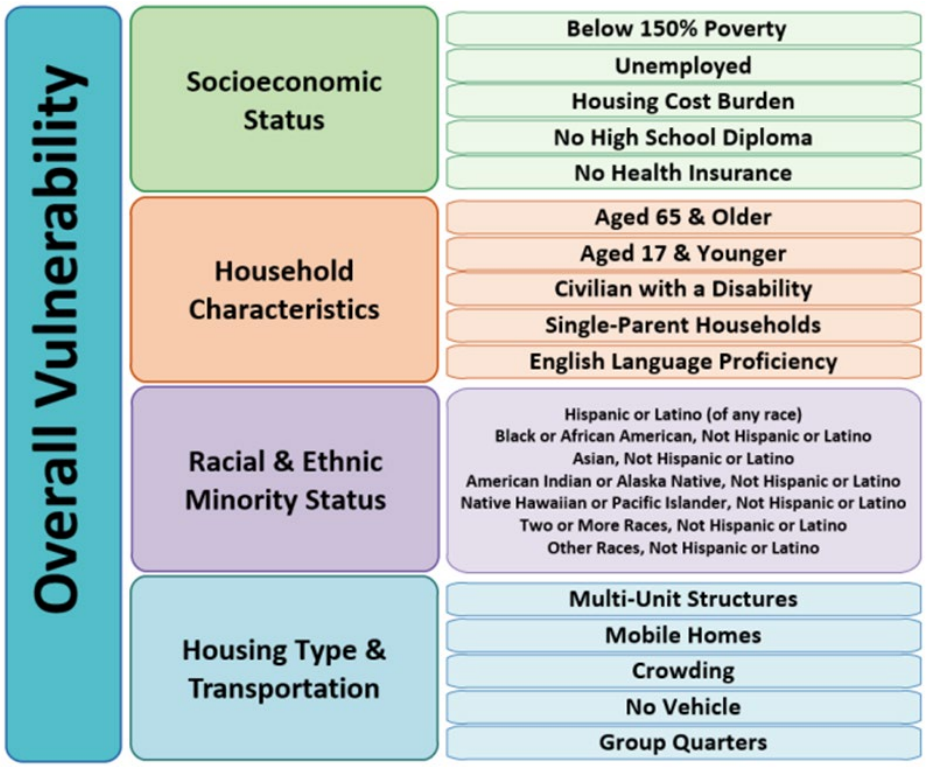
Prioritizing Based on Social Vulnerability

This assessment recognizes that social vulnerability significantly affects how communities experience and recover from flood events. Hence, integrating these factors ensures that resilience strategies are inclusive and equitable. Assets are ranked based on their Social Index scores, a derived metric that helps support

prioritization of more socially vulnerable census tracts, integrating the CDC Social Vulnerability Index and the HUD Location Affordability Index, each with its own set of values and corresponding multipliers, reflecting the severity of social vulnerability and housing affordability issues, respectively.

In the CDC Social Vulnerability Index, values range from 0.25 to 1.00, with higher values indicating greater vulnerability, and are assigned multipliers from 1 to 4. It assesses aspects like socioeconomic status, household composition and disability, minority status and language, and housing and transportation.

Figure 50 - CDC Social Vulnerability Index Metrics



The HUD Location Affordability Index considers housing affordability in various household profiles, ranging from median-income families to dual-professional families, in relation to the median household income (MHHI) for a given area. Similar to the CDC index, values assigned to each profile range from 0.25 to 1.00, with associated multipliers from 1 to 4.

Table 19 - HUD LAI's Household Profile Median Household Income Thresholds

Household Profile	MHHI (Median Household Income for a Given Area)
1. Median-Income Family	MHHI
2. Very Low-Income Individual	National Poverty Line
3. Working Individual	50% of MHHI
4. Single Professional	135% of MHHI
5. Retired Couple	80% of MHHI
6. Single-Parent Family	50% of MHHI
7. Moderate-Income Family	80% of MHHI
8. Dual-Professional Family	150% of MHHI

By combining these factors, the Social Index creates a weighted sum that helps to identify and prioritize intervention areas where people may be more affected by socioeconomic and housing-related challenges. This tool is particularly useful for policy makers and planners to direct resources and efforts to improve the resilience and support of communities that are most at risk.

Prioritizing within the Composite Index

Each of the components described above assesses different aspects of risk and vulnerability and is assigned a specific weight within the Composite Index.

1. **Horizon Index**: This measures the potential future impact of flooding, considering the planning horizon or the timeframe within which the impacts are expected. It is given a weight of 0.659, indicating that it accounts for more than half of the Composite Index value, recognizing the importance of long-term flood risk projections in overall risk assessment but focusing on the immediacy of near-term impacts.

2. **Flood Risk Index**: It evaluates the current exposure to flood risks, including the frequency and depth of potential flooding events. This index has a weight of 0.34, suggesting that immediate flood risks are also a significant factor in the overall assessment but less so than long-term projections.

3. **Social Index**: It incorporates socioeconomic factors into the risk evaluation, with a weight of 0.001. This reflects the understanding that the social context,

including the socioeconomic vulnerabilities of affected populations, plays a crucial role in how impacts are felt and managed.

The final metric, the Composite Index, offers a holistic measure of flood-related risk by combining these weighted components. It provides a more comprehensive assessment that can guide decision-making in urban planning, emergency preparedness, resource allocation, and other critical areas of public policy and infrastructure development. This Composite Index is essential to this toolkit, allowing various risk factors to be overlaid and identifying where they converge to create heightened risk profiles. It is not just a measure but a strategic guide for directing efforts effectively. By factoring in both the likelihood and potential severity of flood events, as well as the social dimensions of vulnerability, the Composite Index serves as a robust tool for prioritizing actions and investments to mitigate flood risks.

Identifying Most At-Risk Assets Based on Three-Tiered Prioritization

Employing the composite index described above, the hot spot prioritization analysis assigned a priority 1 through 5, or not prioritized, ranking based on the indexed score. Table 20 below provides the index thresholds of utilized to assign the priorities.

Table 20 - Composite Risk Index Scores and Prioritization

Composite Index Score Threshold	Assigned Priority
Top 5% Highest Values	1
5-10%	2
10-15%	3
15-25%	4
25-50%	5
Below 50%/Median Value – Not Prioritized	0

These derived outputs, together, provide the prioritized asset inventory when linked back to the critical asset inventory and the assets unique identifier. This prioritization is a critical step in linking strategic planning with on-the-ground realities, ensuring that responses are not only theoretically sound, but also practically actionable.

To carry the prioritization process into the various high-risk areas and provide numerical calculations that harmonize various Resilient Florida Grant criteria, the

analysis results were then re-ordered by the overall risk determination, assigned based on percentages of land area inundated and the number of critical assets affected in the identified hot spots, as described in Table 21. This final step of this analysis harmonizes the various assessment criteria to produce a coherent risk profile for each hot spot. It ensures that both the spatial extent of the flood risk and the density of critical assets are factored into the overall risk determinations.

Table 21 - Hot Spot Risk Assessment Criteria

Overall Risk Assessment	Land Area Inundated (% of Census Tract or Neighborhood)	Critical Assets Affected (% of Total Assets or Within Each Asset Category)
None	0%	0%
Low	Less than 25%	<25%
Medium	25-50%	25-50%
High	50-75%	50-75%
Very High	>75%	>75%

Results and Analysis

This Vulnerability Assessment extends beyond numerical projections and embraces the intricacies of West Palm Beach's unique physical landscape. Guided by the FDEP Vulnerability Assessment Checklist, this comprehensive Vulnerability Assessment considers specific data related to West Palm Beach and its critical assets. West Palm Beach's geographical location along the Lake Worth Lagoon near the Atlantic Ocean makes it particularly susceptible to a range of climate-related hazards.

Flood Vulnerability

The elevation profile provided below is designed to assist with the visualization process in applying critical elevations to coastal planning. This profile is an essential tool for understanding the varying heights and depths that characterize coastal landscapes, offering insights into how different elevations can impact both natural and built environments. By examining these profiles, planners and developers can make informed decisions about where and how to construct infrastructure, considering factors such as flood risk, sea level rise, and coastal erosion. The goal is to promote resilient coastal development that accounts for the unique challenges

posed by critical elevations, ensuring that communities are better prepared to face the impacts of climate change and protect valuable ecosystems.

Figure 51 – Northwood Gardens Shoreline Profile

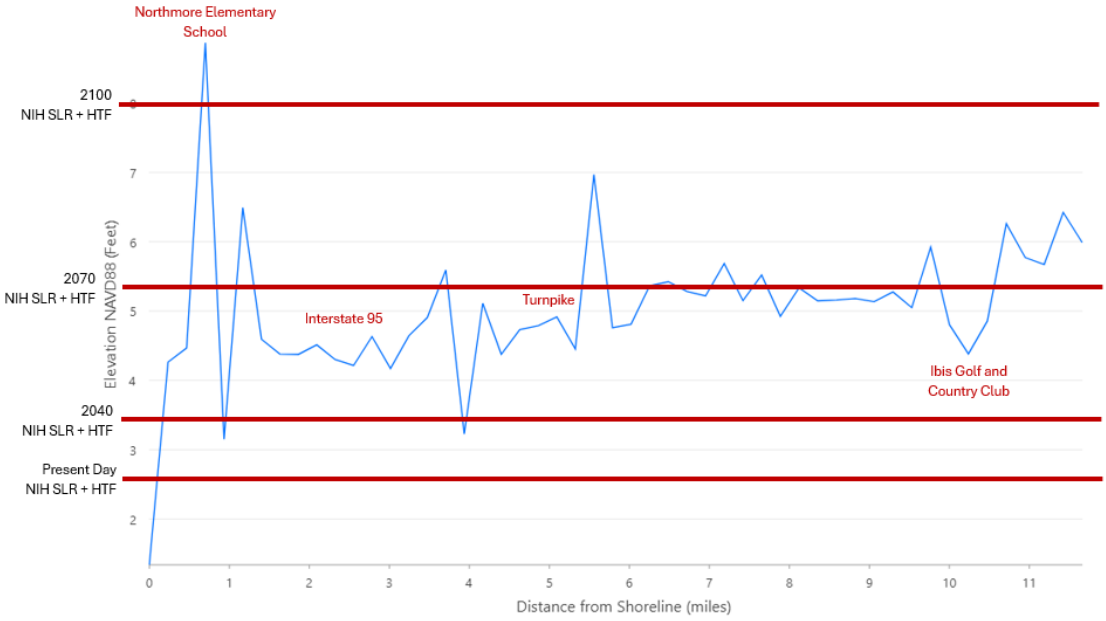
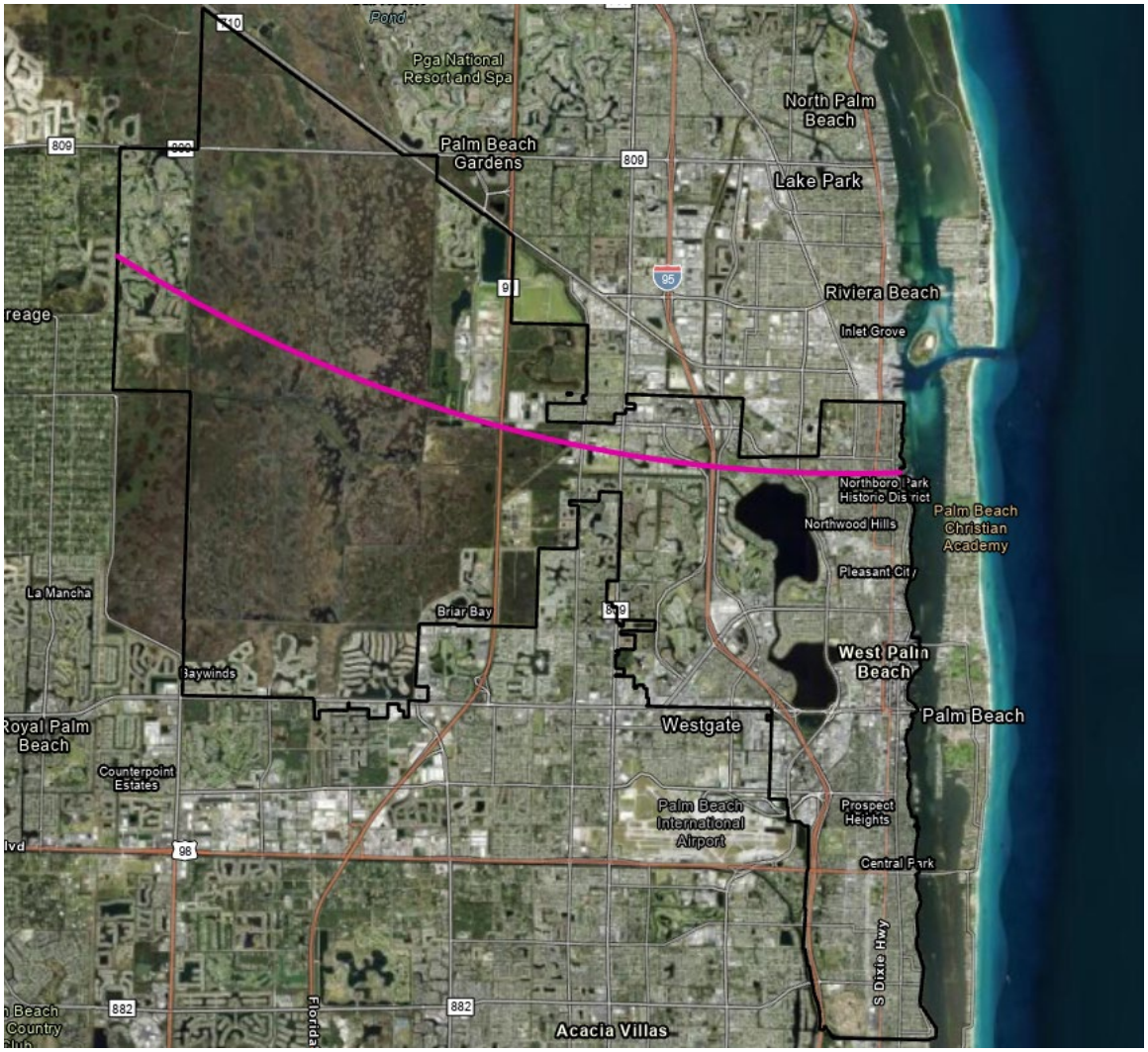


Figure 52 – Northwood Gardens Shoreline Profile Location



The analysis described above, utilizing the NOAA Intermediate High projection, was applied to the land area within West Palm Beach utilizing the sea level rise and high tide flooding thresholds and the elevation at which the tides for the given year are anticipated to be at for at least 90 days throughout the planning horizons to determine the acres of landward inundation that West Palm Beach is expected to experience based on future sea level rise projections.

Table 22 - Area of Inundation

Based on SLR and Tide Extent 90 Days of Year

Projection	NIL SLR + High Tide Flooding (in acres)	NIL 90 days of High Tide Flooding (in acres)	NIH SLR + High Tide Flooding (in acres)	NIH 90 Days of High Tide Flooding (in acres)
2040	9.5	8.1	25.6	9.6
2070	14.7	9.3	219.8	155.1
2100	42.3	13.6	558.8	477.2

Sea Level Rise (SLR) and High Tide Flooding (HTF) in Table 22 above are both terms used in the context of climate change and its impact on coastal and low-lying areas. However, they refer to slightly different phenomena:

- **Sea Level Rise (SLR)** is a gradual increase in the average level of the world's oceans. It is caused by factors such as the melting of ice sheets and glaciers, and the thermal expansion of seawater as it warms. SLR is a long-term change that occurs over years and decades, contributing to the permanent alteration of coastal landscapes. It can exacerbate coastal erosion, increase the risk of coastal flooding, and lead to the loss of habitat for plants, animals, and even humans.
- **High Tide Flooding (HTF)**, sometimes referred to as "nuisance flooding" or "sunny day flooding," occurs when tides reach two feet above the mean higher high water via FDEP Threshold and begin to flood onto streets or flood areas that are historically dry. It is more immediate and often associated with specific high tide events that can cause flooding in coastal areas even in the absence of storms or rainfall. HTF is becoming more frequent in many areas as sea levels rise and can disrupt daily life by flooding roads, overwhelming drainage systems, and damaging property.
- **90 Days of Tidal Inundation** refers to a specific metric used to assess the impact of SLR and HTF, indicating the number of days within a given year when tidal levels exceed a certain threshold, leading to flooding conditions. This metric is useful for understanding how often an area might experience tidal flooding under current and future sea level conditions. It helps in planning and preparing for increased flooding events, identifying vulnerable infrastructure, and implementing adaptation strategies.

In summary, SLR is about the long-term increase in sea levels affecting coastlines and oceans globally, while HTF deals with the more immediate effects of unusually

high tides leading to flooding. The 90 days of tidal inundation metric helps quantify the extent and frequency of HTF and its potential increase due to SLR, providing crucial data for resilience planning and mitigation efforts.

Critical and Prioritized Assets in Flooding Hot Spots

This section of the Vulnerability Assessment systematically analyzes and provides recommendations to address critical vulnerabilities identified within West Palm Beach, Florida. Following a detailed evaluation of flood risk models, historical data, and geographical assessments, this document outlines specific interventions required to mitigate flood risks in designated hot spots where critical assets are significantly threatened.

The City of West Palm Beach, celebrated for its cultural scene, thriving economy, and location on the Lake Worth Lagoon (part of the Intracoastal Waterway), faces unique challenges that necessitate tailored, proactive measures. By pinpointing various vulnerability hot spots, each with unique assets and inherent risks, the assessment prioritizes actions and strategies to bolster collective resilience. This exploration covers four critical domains: transportation infrastructure, critical infrastructure, critical community and emergency facilities, and the preservation of natural, cultural, and historical resources.

The City is actively working on a number of resilience planning and infrastructure projects, including a Stormwater Master Plan and a Watershed Master Plan. These activities are part of a comprehensive effort by the City to address the challenges of climate change.

The objective for the Stormwater Master Plan project is to develop a clear, comprehensive, and forward-looking strategy that encompasses the City's stormwater management program, presents a detailed investigation into key components of stormwater as it is related to the City of West Palm Beach, establishes goals, and provides a foundation for future policy decisions. The Stormwater Master Plan update will help the City guide its stormwater management program for the next 10 or more years. The Plan will utilize these plans to update and create a Stormwater Master Plan addressing water quality, climate change and re-development, and growth to allow for a more livable West Palm Beach for the future.

1. Transportation Infrastructure

To keep the transportation system functional during extreme weather events, several strategic measures are necessary. Elevating and reinforcing bridges and culverts in flood-prone areas will prevent disruptions and structural failures. Improving drainage

systems along major roadways will manage runoff more effectively, reducing the risk of flooding. Developing elevated pathways for critical evacuation routes will ensure they remain passable during flood events.

Assets Impacted:

- **Roadways,** particularly those serving as primary evacuation routes and critical access points to essential services.
- **Bridges and culverts** that are crucial for maintaining connectivity but are at risk during flooding events.

2. Critical Infrastructure

Ensuring the resilience of critical infrastructure is vital for public health and safety. Flood-proofing water treatment facilities and sewage systems by implementing barriers and elevated structures will prevent contamination and service disruptions. Securing and elevating electrical infrastructure, such as substations and critical components of the distribution network, will ensure continuity of service during floods.

Assets Impacted:

- **Potable water treatment facilities** that supply the City with clean water for drinking, bathing, and other necessities.
- **Wastewater lift stations** that allow for sewage to be properly disposed of.
- **Stormwater drainage systems,** which aim to prevent flooding and associated damage.
- **Electrical substations,** an integral part of the system that supplies the City with energy.

3. Critical Community and Emergency Facilities

Public buildings must be resilient to serve as shelters and critical service centers during disasters. Strengthening the infrastructure of hospitals and emergency facilities will ensure they can withstand flood events. Equipping these facilities with reliable emergency power sources, such as generators, will maintain operations during power outages. Developing and implementing comprehensive flood response plans, including evacuation strategies and service continuity protocols, will enhance readiness and response capabilities.

Assets Impacted:

- **Hospitals and healthcare facilities** must remain operational to provide emergency services during disaster situations.

- **Fire stations and police departments**, which are crucial for disaster response and recovery efforts.
- **Government facilities,** including emergency management centers.

4. Preservation of Natural, Cultural, and Historical Resources

Preserving natural, cultural, and historical resources is essential for maintaining the City's ecological balance and heritage. Protective landscaping techniques, such as natural and engineered solutions, will safeguard parks and natural habitats from erosion and flooding. Elevating structures and installing barriers around cultural and historical sites will protect them from flood damage. Engaging the community in preservation efforts and educating them about the importance of protecting these resources will foster a collective sense of responsibility and action.

Assets Impacted:

- **Parks** allow for green space that simultaneously aids in stormwater drainage and builds a sense of community for residents.
- **Shorelines** play a vital role in the City's ecological balance but are susceptible to damage from flooding.
- **Cultural and historical landmarks**, which contribute to the city's heritage and require protection from flood damage.

This vulnerability assessment emphasizes the importance of a targeted approach to infrastructure resilience. By prioritizing critical assets in transportation, water management, emergency services, and cultural preservation, West Palm Beach can significantly enhance its flood preparedness and safeguard essential services. A focus on community engagement and continuous monitoring will be critical to the success of these efforts. Public education campaigns on resilience measures, along with regular emergency drills, will ensure that residents remain informed and prepared for flood events.

Successful implementation of these resilience measures requires active community engagement and continuous monitoring. Launching educational programs will inform residents about resilience measures and encourage their participation. Conducting regular emergency response drills will ensure community readiness. Deploying sensors and monitoring systems to track environmental conditions and infrastructure performance will provide valuable data for ongoing improvements. This proactive approach will foster effective adaptation and responses to changing climate conditions.

Figure 53 - Hot Spot 1: St. Mary's Medical Center Area



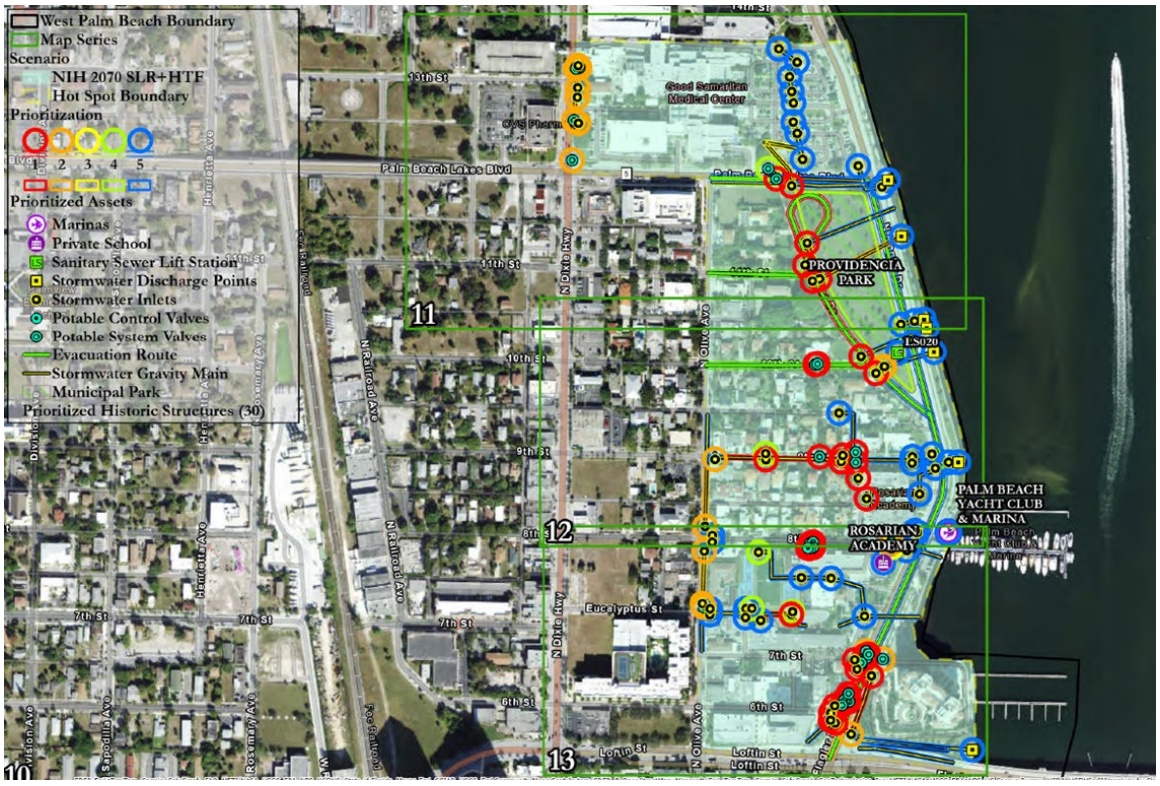
Hot Spot 1 includes multiple health facility assets such as the St. Mary's Medical Center, a hospice center, the Jerome Golden Center for Behavioral Health, and two other medical facilities, all of which are essential for the health and well-being of citizens. The prioritization results of the analysis indicated that the stormwater infrastructure encompassed within this hot spot could be vulnerable to intense rainfall events. The functionality of these structures is essential for mitigating flood impacts, such as damage to property and inaccessibility of transportation routes. Other prioritized assets include potable water infrastructure and a disaster debris management site. Based on the results of the exposure analysis, this hot spot is projected to be moderately impacted by a 500-year 24-hour rainfall event.

Figure 54 - Hot Spot 2: 26th Street to 25th Street



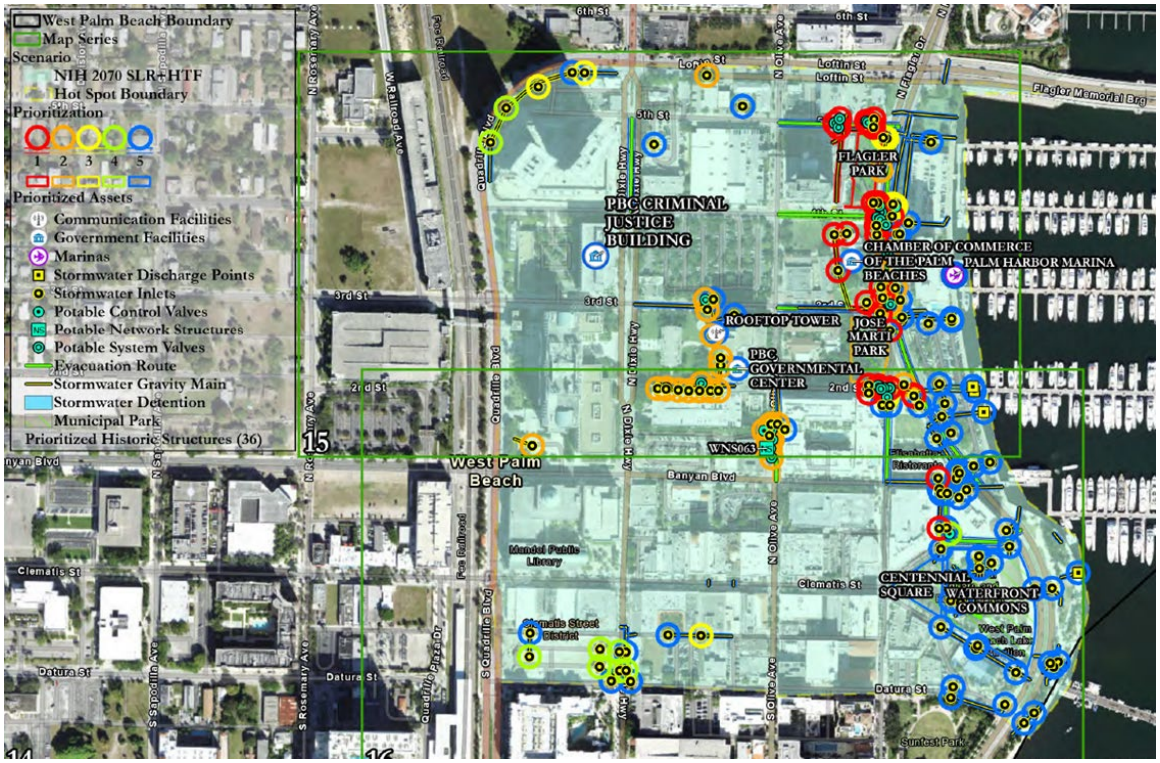
There is a high frequency of infrastructure assets located in this hot spot with a high to low prioritization, including potable water infrastructure, stormwater infrastructure, and a sanitary sewer lift station. Lake Magnolia Park is expected to be minimally impacted. Electronics Way may be moderately affected by flooding due to the prioritization of the surrounding stormwater structures and roadways. The Seaboard Coast Line railroad sits on the edge of the hotspot. This hot spot is likely to be impacted by a 50-year 24-hour rainfall event.

Figure 55 - Hot Spot 3: Good Samaritan Medical Center to Loftin Street



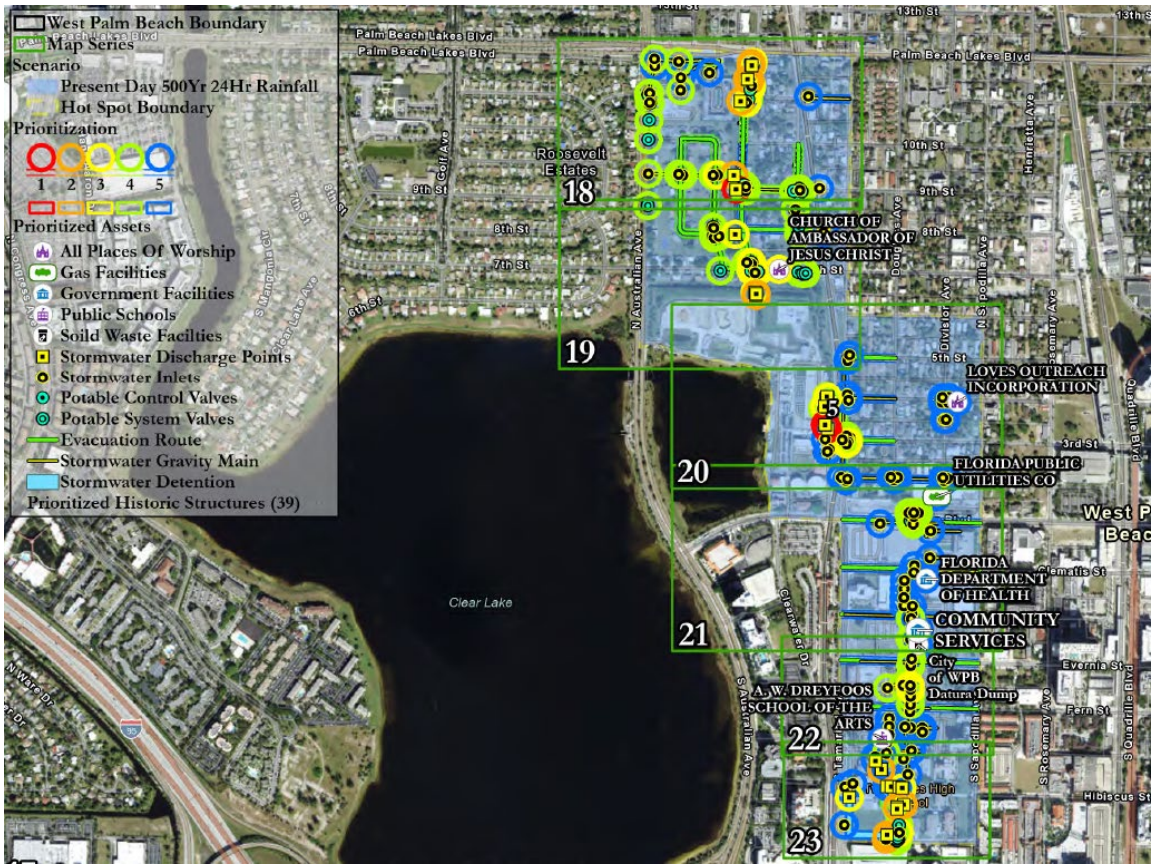
Hot Spot 3 encompasses multiple community and emergency assets, such as a hospital, municipal park, childcare facility, assisted living facility, and private school. These assets may not be directly impacted by rainfall, sea level rise, and storm surge, but the surrounding stormwater infrastructure and roadways are expected to be highly to moderately impacted, causing secondary impacts to surrounding assets. Potable water infrastructure is also expected to be highly to moderately impacted. This area may be impacted by sea level rise and high tide flooding given the NOAA Intermediate High scenario for 2070.

Figure 56 - Hot Spot 4: Loftin Street to Datura Street



Loftin Street to Datura Street has a high density of governmental assets, including West Palm Beach City Hall, the Palm Beach County Governmental Center, the Palm Beach County Criminal Justice Building, and the Palm Beach Chamber of Commerce headquarters, all of which are integral to the proper functioning of systems within the City. A fire station, communication towers, Centennial Square and Fountain Park, and Saint Ann Catholic School are also contained within this hot spot. The majority of the prioritized assets within this hot spot are stormwater infrastructure, roadways, potable water infrastructure, municipal parks, and a select few governmental facilities. It is expected that this area will be affected by sea level rise and high tide flooding, under the NOAA Intermediate High scenario for 2070.

Figure 57 - Hot Spot 5: Palm Beach Lakes Blvd to Jessamine Street



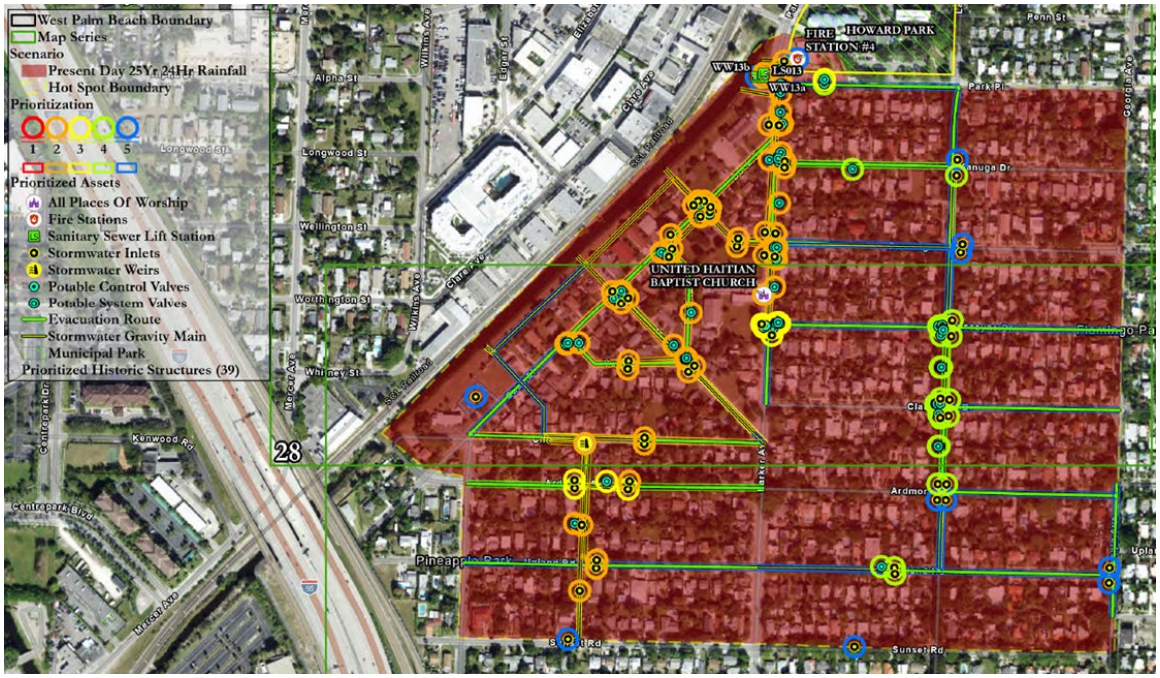
Hot Spot 5 encompasses a high density of prioritized infrastructure assets, such as the City of West Palm Beach Datura Dump, a fuel station, stormwater infrastructure, and potable water infrastructure. Prioritized community assets include government facilities, such as the Florida Department of Health office, Community Services building, and the AW Dreyfoos School of Arts, though they are not expected to be heavily impacted. Streets connected to Carver Avenue may be moderately affected by flooding. The Seaboard Coast Line railroad runs through Hot Spot 5 but is not prioritized. This hot spot may be impacted by a 500-year 24-hour rainfall event.

Figure 58 - Hot Spot 6: S Australian Ave to the SCL Railroad



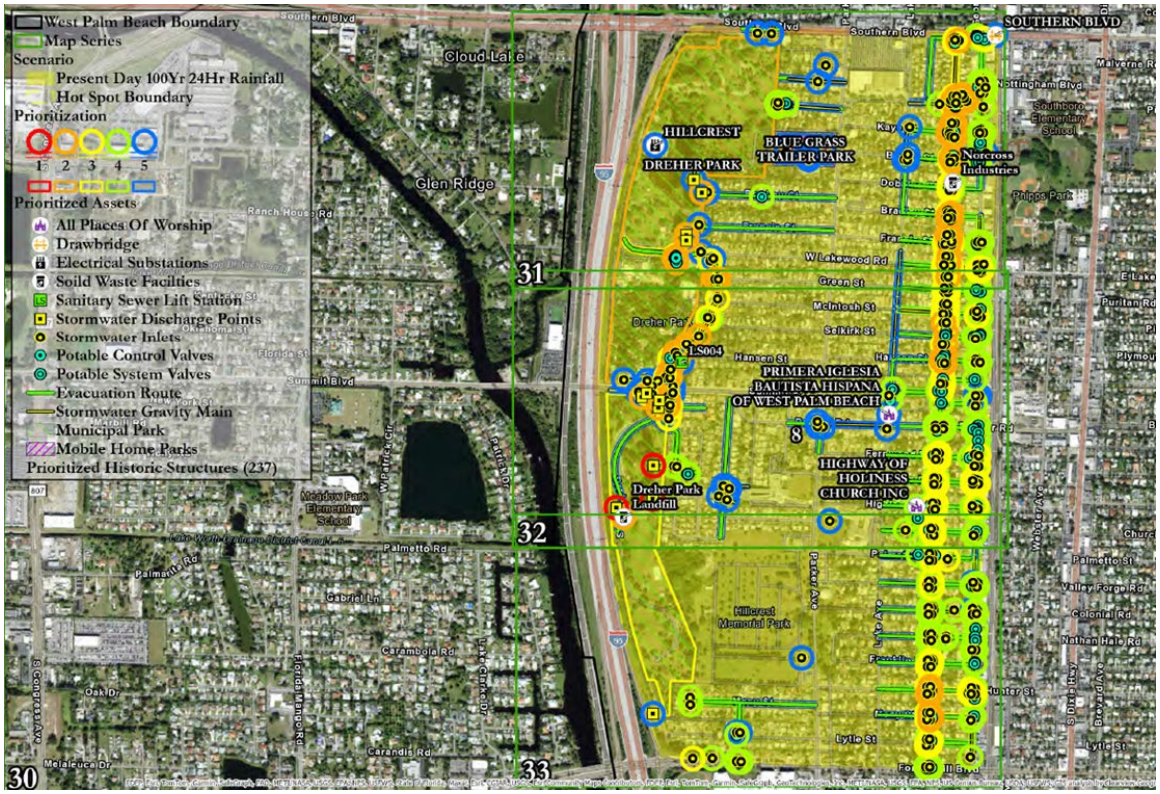
Hot Spot 6 has a high density of infrastructure assets of varying priority, including an electrical substation, sanitary sewer lift stations, stormwater infrastructure, and potable water infrastructure. Caroline Street and Elizabeth Avenue are given medium to low priority. The Seaboard Coast Line railroad runs through Hot Spot 6 as well, and State Highway 704 sits at the hotspot's edge. A 100-year 24-hour rainfall event could impact assets within Hot Spot 6.

Figure 59 - Hot Spot 7: Park Place to Sunset Road



Hot Spot 7 has a high density of infrastructure assets, including sanitary sewer lift stations, stormwater infrastructure, and potable water infrastructure. Fire Station 4 is a low priority. Howard Park and most streets within the hot spot are medium priority. However, areas of Parker Avenue, York Street, Market Street, Dock Street, and Delphia Street are expected to be heavily impacted by a 25-year 24-hour rainfall event.

Figure 60 - Hot Spot 8: Southern Blvd to Forest Hill Blvd



This region contains a high density of infrastructure assets, including potable water infrastructure, an electric substation, and stormwater infrastructure. Dreher Park is given medium priority, and several road segments are given a medium to low priority. Blue Grass Trailer Park is listed as a low priority. U.S. Highway 98, an evacuation route, sits at the north end of Hot Spot 8. Hot Spot 8 may be impacted by a 100-year 24-hour rainfall event.

Figure 61 - Hot Spot 9: West Palm Hospital Area



Assets within Hot Spot 9 include a hospital and supplemental medical facilities—namely CL Brumback Primary Care Clinic and Atlantic Kidney Centers. The primary care facility was given a low priority, while the surrounding stormwater infrastructure has high to low priority scores.

Figure 62 - Hot Spot 10: Flagler Drive (1 of 5)



Figure 63 - Hot Spot 10: Flagler Drive (2 of 5)



Figure 64 - Hot Spot 10: Flagler Drive (3 of 5)

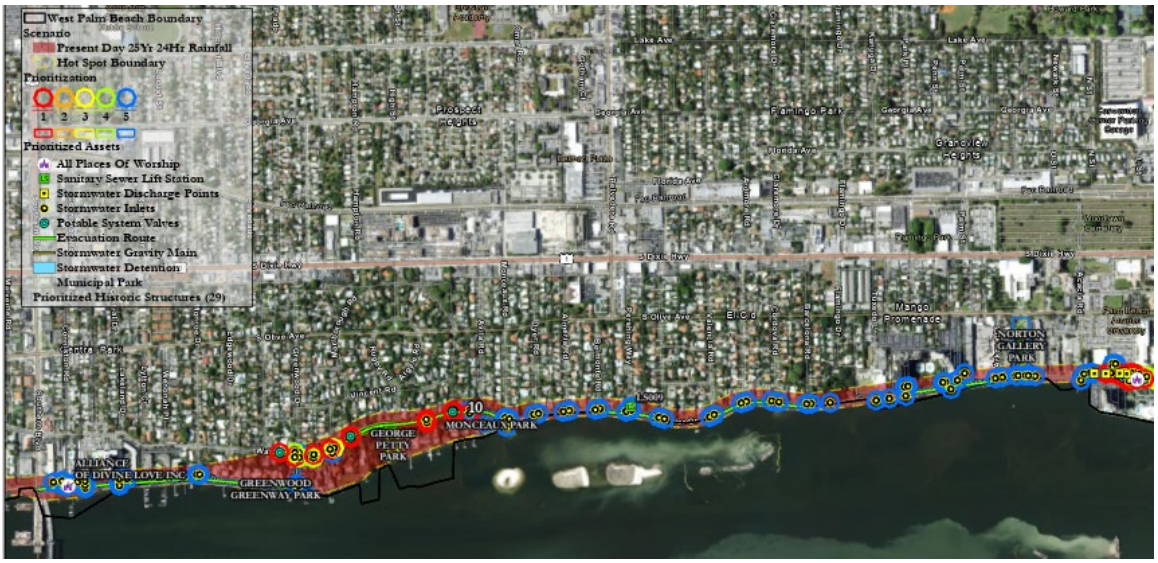


Figure 65 - Hot Spot 10: Flagler Drive (4 of 5)

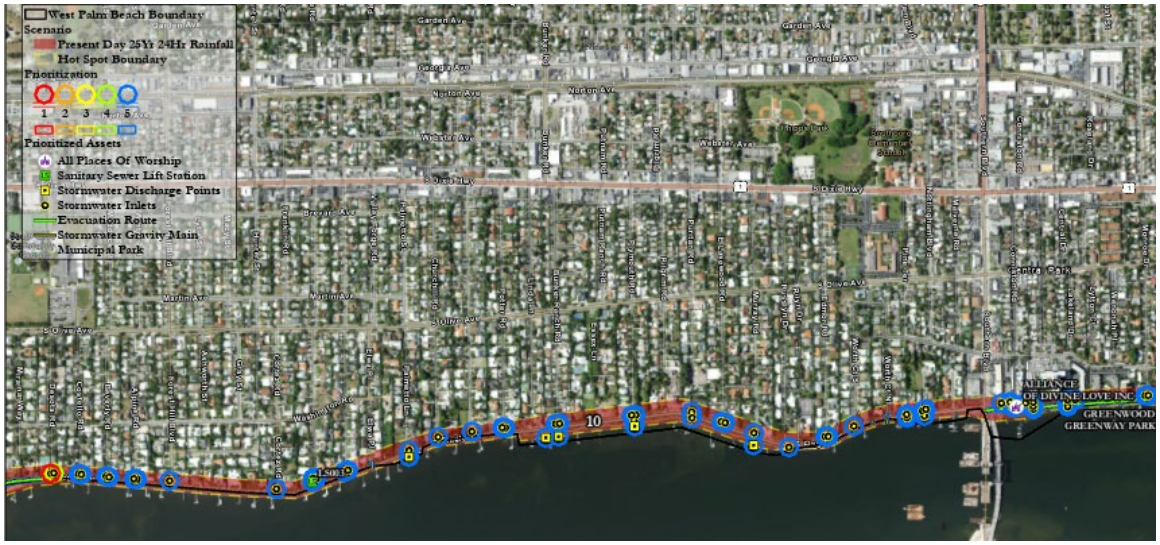


Figure 66 - Hot Spot 10: Flagler Drive (5 of 5)



Hot Spot 10 contains many assets, such as a critical roadway, parks, shorelines, potable water infrastructure and stormwater infrastructure. Among the high priority assets and areas are Gettler Park, North Flagler Drive, South Flagler Drive, 23rd Street, Washington Road, and the shoreline in front of Summa Street. Lower and medium priority assets include Ingham Shores Marina, Currie Park, Palm Beach Yacht Club and Marina, A1A, Centennial Square, Palm Beach Atlantic University, Palm Beach Day Academy, and several sections of shoreline. These assets may be impacted by a 25-year 24-hour rainfall event.

Habitat Change Due to Sea Level Rise

West Palm Beach is projected to experience significant habitat changes driven by sea-level rise (SLR), which threatens its ecological stability. The Sea Level Affecting Marshes Model (SLAMM) was used to assess long-term impacts on tidal habitats such as saltwater marshes, mangroves, and wetlands. Unlike other models, SLAMM integrates hydrological functions and ecosystem data, forecasting habitat shifts based on parameters like elevation and land cover.

Projections were informed by data from the South Florida Water Management District's Land Cover database and the most recent available LiDAR derived digital elevation models. The NOAA Intermediate Low (NIL) and Intermediate High (NIH) SLR scenarios for 2040, 2070, and 2100 were employed to assess changes in key habitats and their role in providing flood resilience and carbon sequestration. This scientific evaluation highlights how habitat loss or transformation could diminish ecosystem services that are vital for flood defense, biodiversity, and climate mitigation in West Palm Beach.

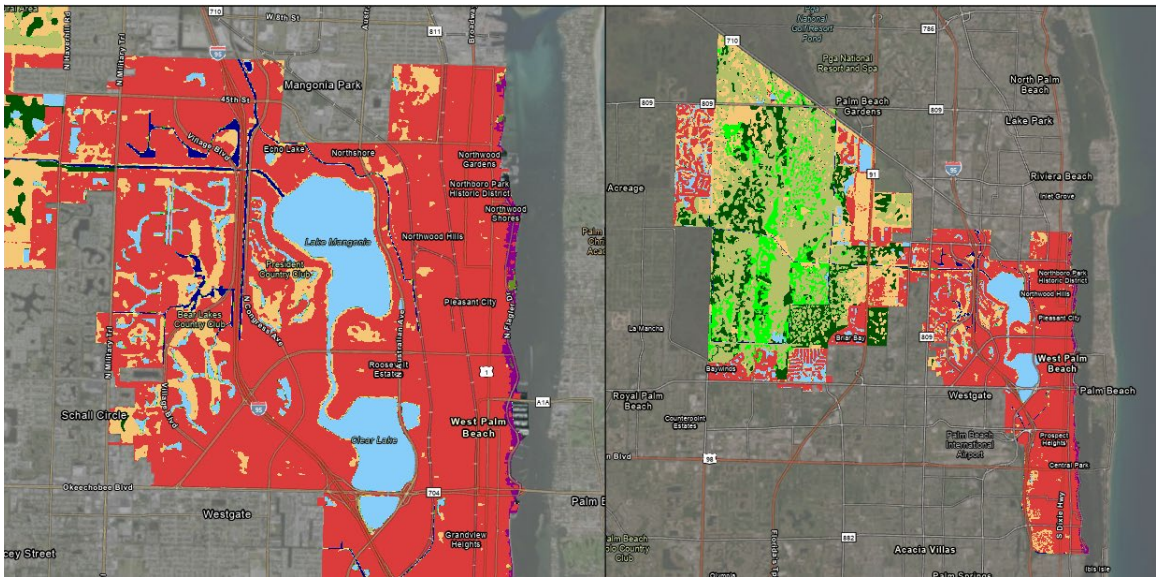
The SLAMM model reveals that coastal wetlands will be increasingly subjected to tidal inundation, leading to the potential loss or migration of habitats like freshwater marshes and mangroves, which play a key role in storm protection and carbon storage. Additionally, urban areas are expected to experience gradual flooding, further emphasizing the need for proactive habitat conservation and adaptive management strategies to mitigate the impact of SLR.

Figure 67 - SLAMM Map Legend



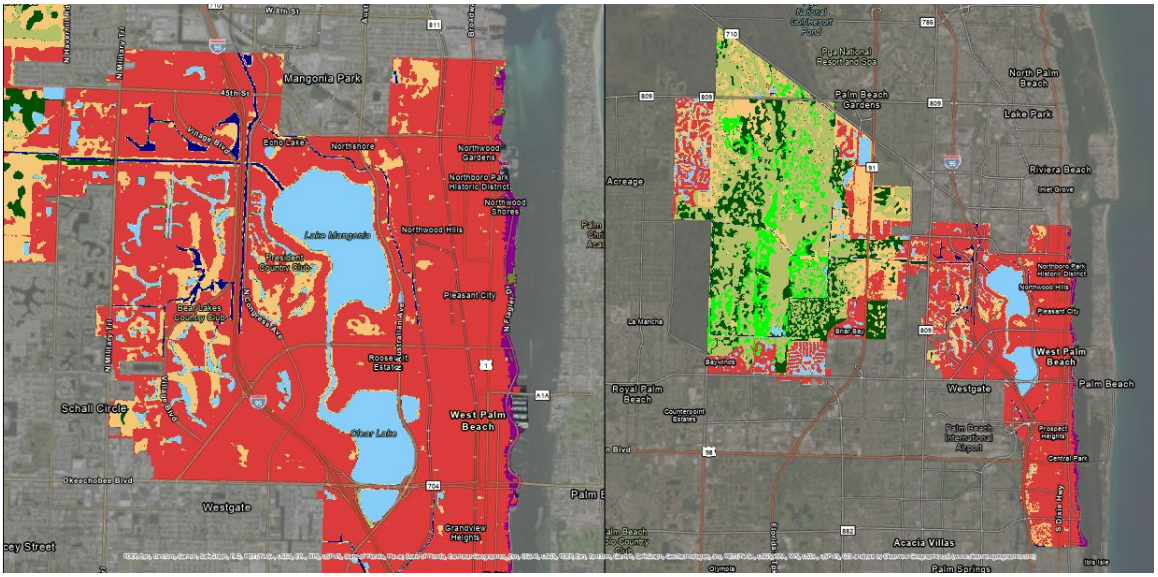
This legend corresponds to a map created using the Sea Level Affecting Marshes Model (SLAMM). It categorizes various land and water types that are affected by sea level changes. The legend includes a range of terrestrial environments, such as developed and undeveloped dry land, different types of swamps and marshes (including tidal and non-tidal varieties), and various coastal and marine environments like beaches, tidal flats, and open water bodies. It also indicates areas that may become flooded due to sea level rise, such as "Flooded Developed Dry Land" and "Flooded Forest."

Figure 68 - NIH SLAMM – Present Day Overview Map



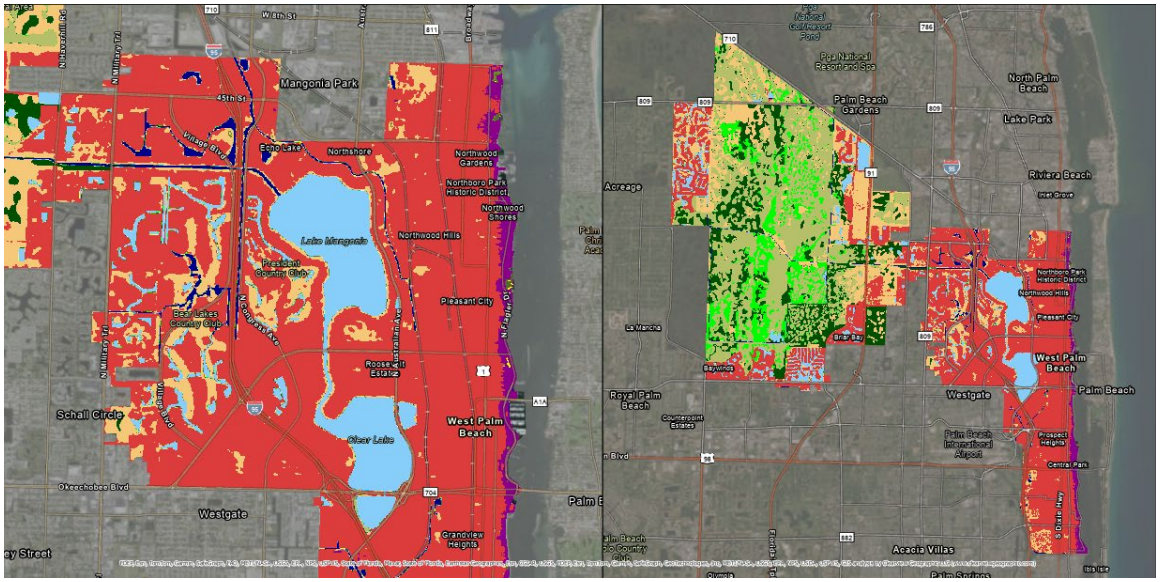
This map illustrates the current land use and environmental features of a coastal area in West Palm Beach. The left portion shows extensive urban development (red) with large water bodies, while the right section displays a more diverse landscape. The prominent green area on the right represents Grassy Waters Preserve, a significant natural habitat. Urban areas (red) and other land types are interspersed throughout, particularly near the coast.

Figure 69 - NIH 2040 SLAMM Map



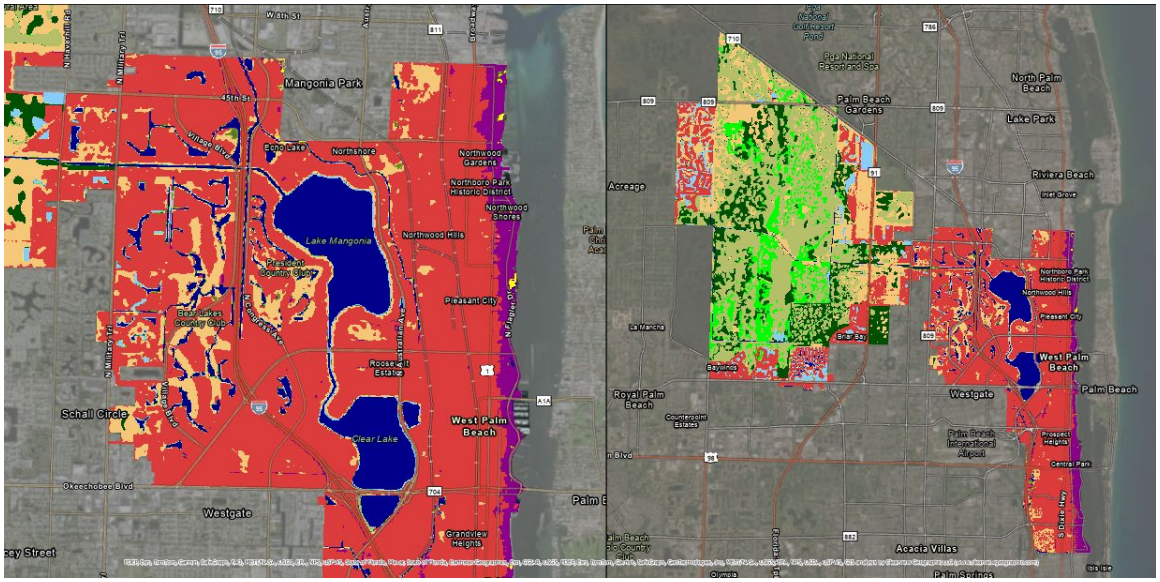
This map depicts projected land use and environmental changes in West Palm Beach by 2040. Compared to the present-day scenario, several subtle but notable changes are visible. The urban areas (red) remain largely consistent, indicating the persistence of developed infrastructure. However, there are slight increases in blue areas, particularly along the edges of water bodies and in low-lying regions, suggesting minor expansions of water coverage due to sea level rise. The Grassy Waters Preserve (large green area) appears to maintain its overall integrity, though some minor shifts in vegetation types may occur. Small patches of purple, representing flooded developed dry land, begin to appear in some coastal and low-elevation areas, indicating the early stages of sea level rise impacts on urban infrastructure. These changes, while not dramatic, highlight the gradual transformation of the landscape as it responds to rising sea levels over the next two decades.

Figure 70 - NIH 2070 SLAMM Map



The 2070 projection map for West Palm Beach reveals more pronounced changes due to sea level rise. Urban areas (red) still dominate much of the landscape, but there is a noticeable increase in purple areas, particularly along the coastline and around water bodies, indicating a significant expansion of flooded developed dry land. The blue areas representing water bodies and coastal waters have expanded further inland, suggesting increased inundation of low-lying areas. The Grassy Waters Preserve (large green area) appears to maintain its overall structure, though some changes in vegetation composition may be occurring due to altered hydrology. Yellow areas, likely representing transitional or altered ecosystems, have become more prominent in some regions. This map illustrates the accelerating impact of sea level rise on the urban and natural landscapes of West Palm Beach over a 50-year timeframe, highlighting the increasing challenges for both infrastructure and ecosystem management.

Figure 71 - NIH 2100 SLAMM Map



The 2100 projection map for West Palm Beach illustrates dramatic changes to the landscape due to significant sea level rise. The most striking difference is the extensive increase in dark blue areas, particularly visible in Lake Mangonia and Clear Lake, which have greatly expanded and likely merged with rising coastal waters. This indicates a substantial intrusion of seawater into formerly freshwater systems. The purple areas representing flooded developed dry land have proliferated, especially along the eastern coastline and around inland water bodies, signifying widespread inundation of urban areas. While large portions of developed land (red) still persist, they are increasingly fragmented and surrounded by water. The Grassy Waters Preserve (green area) appears to maintain much of its extent, though likely with altered ecological characteristics due to changing hydrology. This map vividly illustrates the potential consequences of sea level rise on West Palm Beach's urban and natural landscapes by the end of the century, highlighting the critical need for adaptive planning and management strategies.

Tables 23 and 24 present the projected changes in habitat types under the NOAA Intermediate Low (NIL) and NOAA Intermediate High (NIH) sea level rise scenarios, respectively. These tables show the total hectares for each habitat type at present day, 2040, 2070, and 2100, as well as the percent change from the baseline year. The "Change from Present Day" columns indicate habitat loss or gain, with negative values representing a decrease in area due to sea level rise or loss of a particular habitat due to a shift. Comparing the two scenarios, the NIH projections generally show more significant habitat losses than the NIL projections, reflecting the more severe impacts of higher sea level rise rates on the landscape.

Table 23 - Habitat Change under NOAA Intermediate-Low SLR Scenario

SLAMM Category	**Present Day Hectares**	**2040 Hectares**	**2070 Hectares**	**2100 Hectares**	**Change from Present Day to 2040**	**Change from Present Day to 2070**	**Change from Present Day to 2100**
Developed Dry Land	5,465.07	5,450.74	5,426.57	5,403.95	-0.26%	-0.70%	-1.12%
Undeveloped Dry Land	2,126.05	2,125.55	2,124.65	2,123.81	-0.02%	-0.07%	-0.11%
Swamp	1,388.33	1,388.32	1,388.32	1,388.31	<-0.01%	<-0.01%	<-0.01%
Cypress Swamp	982.29	982.29	982.29	982.21	0.00%	0.00%	-0.01%
Inland-Fresh Marsh	3,425.78	3,425.78	3,425.84	3,425.85	0.00%	<0.01%	<0.01%
Tidal-Fresh Marsh	15.91	15.91	15.90	15.89	0.00%	-0.06%	-0.13%
Transitional Salt Marsh	18.52	18.92	19.53	19.67	2.16%	5.45%	6.21%
Regularly Flooded Marsh	14.84	14.76	14.99	15.68	-0.54%	1.01%	5.66%
Mangrove	14.53	14.53	14.52	14.50	0.00%	-0.07%	-0.21%
Estuarine Beach	15.27	15.27	15.27	15.27	0.00%	0.00%	0.00%
Tidal Flat	14.73	14.89	14.73	14.70	1.09%	0.00%	-0.20%
Ocean Beach	15.43	15.43	15.41	15.40	0.00%	-0.13%	-0.19%
Ocean Flat	16.45	16.45	16.44	16.44	0.00%	-0.06%	-0.06%
Rocky Intertidal	18.68	18.68	18.67	18.67	0.00%	-0.05%	-0.05%
Inland Open Water	859.71	859.38	858.23	855.43	-0.04%	-0.17%	-0.50%
Riverine Tidal	6.64	6.63	6.63	6.63	-0.15%	-0.15%	-0.15%
Estuarine Open Water	109.83	110.2	111.56	114.44	0.34%	1.57%	4.20%
Tidal Creek	0	0	0.03	0.04	N/A	N/A	N/A
Flooded Developed Dry Land	94.55	108.86	133.02	155.66	15.13%	40.69%	64.63%
Flooded Forest	0.10	0.10	0.10	0.18	0.00%	0.00%	80.00%

Table 24 - Habitat Change under NOAA Intermediate-High SLR Scenario

SLAMM Category	**Present Day**	**2040 Hectares**	**2070 Hectares**	**2100 Hectares**	**Change from Present Day to 2040**	**Change from Present Day to 2070**	**Change from Present Day to 2100**
Developed Dry Land	5,465.07	5,430.59	5,338.52	5,152.72	-0.63%	-2.32%	-5.72%
Undeveloped Dry Land	2,126.05	2,124.86	2,121.51	2,055.05	-0.06%	-0.21%	-3.34%
Swamp	1,388.33	1,388.33	1,388.50	1,413.28	0.00%	0.01%	1.80%
Cypress Swamp	982.29	982.29	982.07	981.62	0.00%	-0.02%	-0.07%
Inland-Fresh Marsh	3,425.78	3,425.81	3,425.98	3,449.44	<0.01%	0.01%	0.69%
Tidal-Fresh Marsh	15.91	15.9	15.84	15.81	-0.06%	-0.44%	-0.63%
Transitional Salt Marsh	18.52	19.29	18.76	30.32	4.16%	1.30%	63.71%
Regularly Flooded Marsh	14.84	15.04	17.59	18.51	1.35%	18.53%	24.73%
Mangrove	14.53	14.52	14.47	14.44	-0.07%	-0.41%	-0.62%
Estuarine Beach	15.27	15.27	15.24	15.15	0.00%	-0.20%	-0.79%
Tidal Flat	14.73	14.84	15.7	19.68	0.75%	6.59%	33.60%
Ocean Beach	15.43	15.41	15.4	15.33	-0.13%	-0.19%	-0.65%
Ocean Flat	16.45	16.44	16.44	16.4	-0.06%	-0.06%	-0.30%
Rocky Intertidal	18.68	18.67	18.66	18.64	-0.05%	-0.11%	-0.21%
Inland Open Water	859.71	858.39	845.82	402.43	-0.15%	-1.62%	-53.19%
Riverine Tidal	6.64	6.63	6.58	6.25	-0.15%	-0.90%	-5.87%
Estuarine Open Water	109.83	111.3	124.25	569.65	1.34%	13.13%	418.66%
Tidal Creek	0	0.03	0.04	0.15	N/A	N/A	N/A
Flooded Developed Dry Land	94.55	129.03	221.08	407.1	36.47%	133.82%	330.57%
Flooded Forest	0.1	0.1	0.32	1.68	0.00%	220.00%	1580.00%

Summary of Habitat Changes

The Sea Level Affecting Marshes Model (SLAMM) projections for West Palm Beach reveal significant habitat changes by 2100 due to sea-level rise. This analysis, supported by Tables 23 and 24 and the corresponding maps, illustrates key habitat transformations under both NOAA Intermediate Low (NIL) and NOAA Intermediate High (NIH) sea level rise scenarios. These changes will profoundly affect the region's ecosystems and require comprehensive planning to mitigate impacts on biodiversity, water resources, and human infrastructure.

1. Developed Dry Land:

- **Present Day**: 5,465.07 hectares.
- **Projected Losses**:
    - **2040**: Minor loss of 0.60% (NIH) and 0.30% (NIL).
    - **2100**: Substantial loss of **6.00% (NIH)** and **1.00% (NIL)**.

Impact on habitat: West Palm Beach's urbanized areas are expected to undergo gradual flooding, particularly in low-lying zones near the coast. The projected reduction of developed dry land by 2100 reflects the increasing pressure on urban environments from coastal inundation. As a result, residential, commercial, and industrial spaces will transition toward flood-prone or permanently flooded regions, potentially increasing the need for elevated structures, flood defenses, or managed retreat.

Suggested response: resilient infrastructure planning. Invest in flood-proof infrastructure, such as elevated buildings, seawalls, and drainage systems, to prevent large-scale damage in frequently flooded areas. Where flooding is unavoidable, implement managed retreat by relocating communities to safer, higher ground to minimize disruption and loss of property.

2. Undeveloped Dry Land:

- **Present Day**: 2,126.05 hectares.
- **Projected Losses**:
    - **2100**: Losses of **up to 3.00% (NIH)**.

Impact on habitat: These natural, undeveloped areas are increasingly at risk of conversion to flood-prone zones. As sea levels rise, portions of these lands will either be submerged or transition into more aquatic habitats, reducing the availability of dry uplands critical for biodiversity. The loss of undeveloped dry land will further shrink buffer zones that currently act as natural flood defenses for inland areas, exacerbating flooding risks for both human and natural environments.

3. Inland Freshwater Ecosystems:

- **Inland Fresh Marsh**: Remains stable or shows slight increases by 2100.
- **Inland Open Water**: Drastic **53% reduction** by 2100 (NIH).

Impact on habitat: Freshwater systems in West Palm Beach, particularly Clear Lake and Lake Mangonia, are at significant risk of salinization due to rising sea levels. The projected 53% loss of inland open water is especially concerning for West Palm Beach, as these lakes are critical components of the city's surface water supply system.

Clear Lake and Lake Mangonia, which are clearly visible in the present-day map (Figure 68) as large blue areas in the urban landscape, show dramatic changes in the 2100 projection (Figure 71). These lakes appear to have expanded and darkened, indicating a likely transition from freshwater to brackish or estuarine conditions. This transformation would not only alter the local ecology, but could also severely impact the city's drinking water supply.

The conversion of these freshwater bodies to more saline environments would significantly alter the hydrology and ecology of the region. This change would reduce biodiversity adapted to freshwater conditions and impair the city's ability to store and supply freshwater for both ecosystem and human use. The potential loss of these freshwater resources is particularly critical for West Palm Beach, where they play a vital role in providing drinking water, supporting local agriculture, and maintaining healthy urban and natural ecosystems.

Suggested response: Given the crucial importance of Clear Lake and Lake Mangonia to West Palm Beach's water supply, specific strategies should be developed to protect these water bodies from saltwater intrusion. This may include:

1. Enhancing barriers or installing salt-water intrusion prevention systems around these lakes.
2. Developing alternative freshwater storage solutions further inland.
3. Implementing advanced water treatment technologies capable of handling increasingly saline water.
4. Creating buffer zones around these water bodies to allow for natural filtration and gradual transition of ecosystems.

These targeted approaches, specific to West Palm Beach's unique water supply situation, will be essential for maintaining the city's water security in the face of rising sea levels.

4. Tidal-Fresh Marsh and Transitional Salt Marsh:

- **Tidal-Fresh Marsh**: Expected to decrease slightly by 0.60% under NIH

projections by 2100.

- **Transitional Salt Marsh**: Significant **64% increase by 2100** under NIH.

Impact on habitat: The loss of tidal-fresh marshes suggests that these areas are particularly vulnerable to rising seas and increasing salinity, which can convert them into salt marshes or brackish wetlands. The projected 64% increase in transitional salt marsh represents a major shift in the landscape, in which previously freshwater systems become saltwater-dominated ecosystems. This transformation will alter nutrient cycling and hydrology and may affect nearby agricultural zones, as saltwater intrusion reduces the soil's suitability for farming. Additionally, salt marshes play a crucial role in carbon sequestration, and their expansion could help mitigate some climate impacts, though at the cost of displacing other critical habitats.

Suggested response: Expand wetland and marsh conservation. Bolster the restoration of wetlands and marshes to enhance natural flood defenses. These areas not only protect coastal communities by absorbing floodwaters but also sequester carbon, thus mitigating some effects of climate change. Active restoration and protection of marsh ecosystems can prevent excessive habitat loss in other areas.

5. Regularly Flooded Marshes:

- **Projected Increase**: From 14.84 hectares to 18.51 hectares by 2100, showing a **25% growth** (NIH).

Impact on habitat: Regularly flooded marshes will expand inland as tidal waters encroach into areas that were previously less affected by tidal flooding. These marshes provide essential ecosystem services, such as storm buffering, flood mitigation, and habitat for aquatic species. The 25% growth of this habitat type indicates how tidal influence will reshape the coastal landscape, potentially providing natural flood barriers that protect urban areas. However, the expansion of flooded marshes could reduce available land for both natural and human uses, requiring a strategic balance between conservation and development.

6. Mangroves:

- **Present Day**: 14.53 hectares.
- **Projected Loss**: Minor **0.60% decrease** by 2100 (NIH).

Impact on habitat: Mangrove forests, known for their resilience to tidal changes and storm surges, are projected to experience a minor decrease in area by 2100. While mangroves can migrate inland with rising sea levels, their growth is constrained by developed land or areas with steep topography. A slight decrease in mangroves could diminish their ability to act as natural storm barriers and reduce the shoreline protection they provide. Mangrove conservation efforts will be key to ensuring that these critical habitats can continue to perform their ecological functions in the face

of sea-level rise.

Suggested response: Create buffer zones that allow for the inland migration of mangroves and other tidal ecosystems. Securing areas for mangroves to move landward will ensure their continued protection against storm surges and erosion and maintain their role as a critical flood defense.

7. Estuarine and Tidal Habitats:

- **Tidal Flat**: Increase of **34% by 2100** under NIH.
- **Estuarine Open Water**: Drastic expansion by **419% by 2100** under NIH.

Impact on habitat: The significant increase in tidal flats and estuarine open water highlights the transformation of coastal regions into more water-dominated environments. These habitats are essential for fisheries and marine biodiversity, supporting complex food webs. The expansion of estuarine open waters—from 109.83 hectares to 569.65 hectares—will dramatically reshape the coastal landscape, converting what were previously terrestrial or freshwater zones into estuarine systems. This shift will improve habitats for some species but reduce the availability of terrestrial space and freshwater ecosystems, thus altering the balance of the overall landscape.

8. Flooded Developed Land:

- **Present Day**: 94.55 hectares.
- **Projected Increase**:
    - **2100**: Flooded developed land is expected to expand by **330%**, reaching 407.1 hectares (NIH).

Urban areas will see a sharp rise in flood-prone or permanently submerged zones, particularly in coastal and low-lying regions of West Palm Beach. This increase signals a profound reduction in options for land use, with many developed areas becoming unsuitable for long-term habitation or infrastructure. The increase in flooded developed land also suggests that pressure on inland ecosystems will grow as human populations retreat from coastal zones, potentially leading to further encroachment on natural habitats like marshes and swamps.

The series of maps from present day to 2100 provides a visual narrative of these changes, clearly showing the gradual inundation of coastal areas, the expansion of water bodies, and the transformation of freshwater systems to brackish or saline environments. The striking expansion of dark blue areas (estuarine open water) and purple regions (flooded developed land) in the 2100 map underscores the urgent need for adaptive strategies.

Suggested response: These projections highlight the critical importance of integrated

adaptation measures, including:

1. Expanding wetland and marsh conservation to enhance natural flood defenses.
2. Implementing urban resilience plans, including flood-proofing infrastructure and managed retreat from high-risk areas.
3. Creating habitat buffer zones to allow for the inland migration of coastal ecosystems.
4. Protecting and managing freshwater resources to mitigate saltwater intrusion.

By combining the quantitative data from the tables with the visual representation in the maps, West Palm Beach can develop targeted strategies to address the specific challenges posed by sea-level rise, ensuring the long-term resilience of both its urban and natural environments.

To address the significant changes projected by the SLAMM model and illustrated in both the tables and maps, West Palm Beach must adopt a comprehensive and forward-thinking approach to adaptation. The dramatic shifts in habitat composition, particularly the expansion of estuarine open water and flooded developed areas, coupled with the reduction of inland freshwater systems, necessitate a multi-faceted strategy. This strategy should aim to protect existing natural buffers, manage urban development in vulnerable areas, and ensure the resilience of both ecosystems and infrastructure in the face of rising sea levels. The following integrated adaptation recommendations provide a framework for addressing these challenges, balancing the needs of urban development with ecological preservation, and enhancing the overall resilience of West Palm Beach to the impacts of climate change and sea-level rise.

Integrated adaptation recommendations:

1. **Expand wetland and marsh conservation**: Protect and restore **expanding marshes** and **mangroves** to reinforce **natural flood defenses** and **carbon sequestration**. These habitats are critical in reducing storm surges, absorbing floodwaters, and mitigating the impacts of climate change.
2. **Freshwater resource protection**: Prioritize strategies to preserve **inland freshwater ecosystems**, including the use of **freshwater buffer zones** to protect against **saltwater intrusion**. Sustainable water management will be crucial for maintaining freshwater availability as sea levels rise.
3. **Urban adaptation plans**: Implement forward-thinking **urban resilience plans** by **flood-proofing** new developments and **elevating vulnerable infrastructure**. Proactively managing **land use** in coastal and low-lying areas will reduce long-term economic impacts and protect critical infrastructure

from rising seas.

4. **Habitat buffer zones**: Create **migration corridors** for habitats such as **mangroves, marshes**, and **wetlands**, allowing them to adapt to **changing water levels** and prevent habitat squeeze between urban development and rising waters.

Proactive management, habitat conservation, and resilient urban design will be essential for protecting both human communities and the rich diversity of ecosystems in this vulnerable coastal region.

Shoreline Assessment

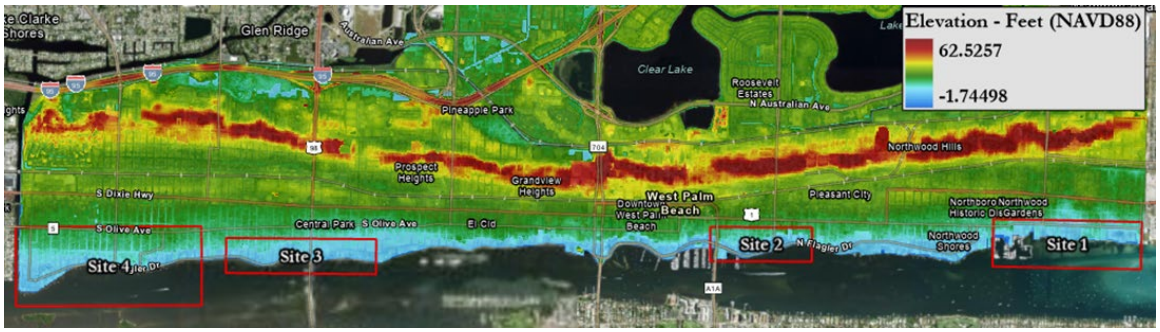
Shorelines conditions can have major implications on the health and safety of natural and developed areas. Shorelines provide the first line of defense against tidally influenced flooding such as storm surge and high tide flooding. However, shorelines are also the most impacted by tidal flooding events, therefore the stability and resiliency of a community's shoreline is essential for a community's protection and recovery in the event of a storm.

This Assessment is aimed at determining areas where West Palm Beach's shoreline may benefit from the installation of living shorelines or the raising and armoring of seawall infrastructure to protect evacuation routes and other infrastructure that is expected to be impacted based on storm surge and future high tide flooding projections.

Through analysis of available Light Detecting and Ranging (LiDAR) data, the shoreline composition of West Palm Beach, and NOAA sea level rise trends, the team identified four sites that are at an increased risk of being impacted by tidally influenced flood events and may be suitable for the implementation of living shorelines.

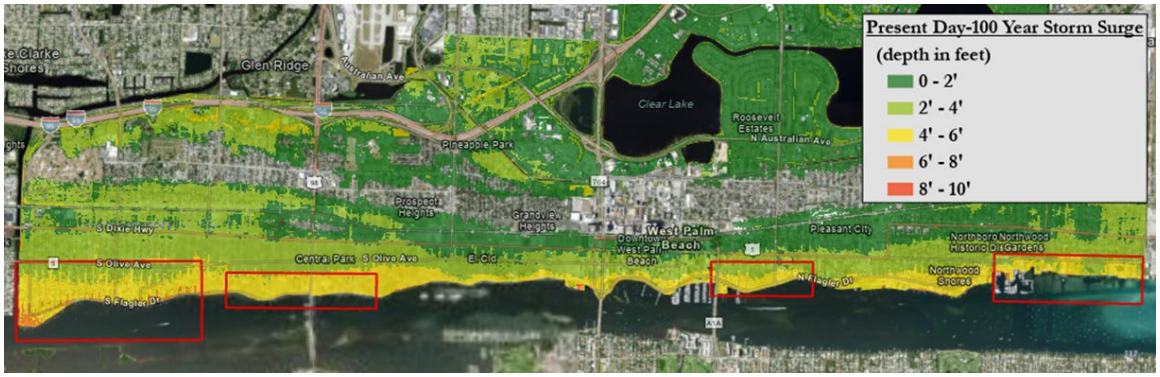
By employing the latest LiDAR Digital Elevation Models, detailed topographical contours and shorelines in the lowest elevation zones and those with the most direct exposure to coastal forces were mapped. These areas, often nearest to the coastal waters, emerged as the most at risk to the perils of storm surges and high tide flooding. This identification process is vital in developing strategic interventions to fortify these critical zones against the increasing threats of flooding and coastal erosion.

Figure 72 - Elevation Map of West Palm Beach with Shoreline Resilience Sites 1-4



Based on present day 100-year storm surge projections, the full length of West Palm Beach's shoreline is expected to experience 4-6 feet (yellow) to 6-8 feet (orange) of flooding during a storm of this magnitude. Because the entire shoreline is expected to be impacted by current storm surge, the project team selected areas that may be suitable for the implementation of living shoreline features and where shoreline restoration projects have not already been implemented.

Figure 73 - Storm Surge Flooding Frequency



Based on data provided by the City of West Palm Beach, the project team determined the composition of the shoreline: mostly comprised of seawall, with some beach and natural areas. Identifying the composition of the shoreline in parallel with the shoreline's elevation and its susceptibility to storm events can assist in determining for which areas restoration projects or seawall improvement may be best suited.

Figure 74 – Shoreline Composition Site 1



Figure 75 - Shoreline Composition Site 2



Figure 76 - Shoreline Composition Site 3



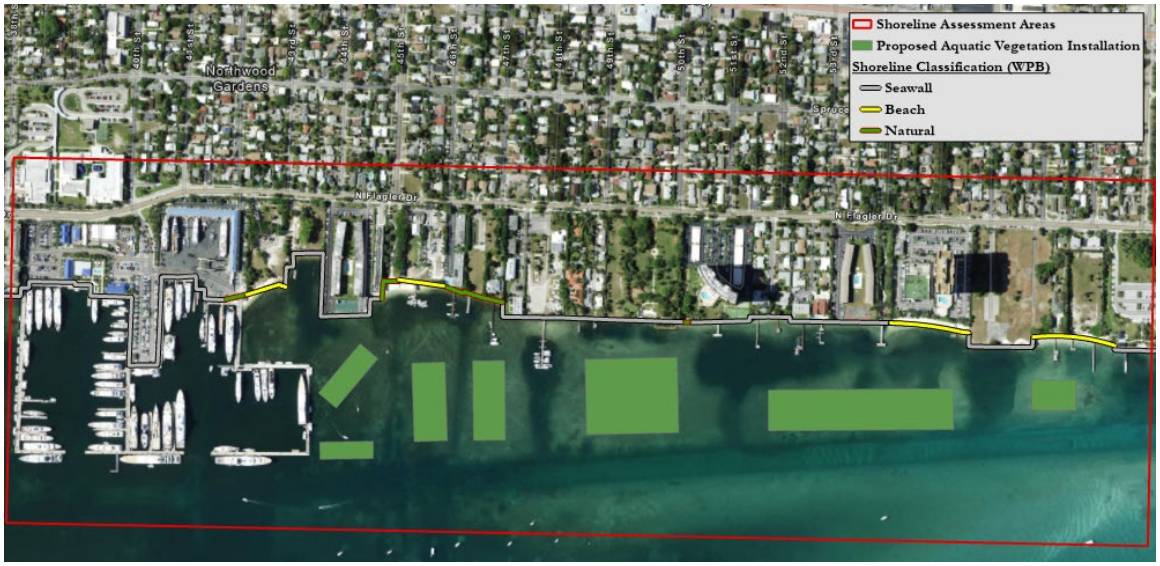
Figure 77 – Shoreline Composition Site 4



Multiple natural restoration projects have already been implemented in the Lake Worth Lagoon along the shoreline of West Palm Beach, such as the South Cove and El Cid intertidal islands, as well as the improvement of seawalls and implementation of intertidal wetland planters. Below the project team presents potential shoreline restoration improvements.

Based on aerial observation of Site 1, the bathymetry is relatively shallow, with dredged channels to allow for the movement of boats. The project team proposes the installation of native aquatic vegetation in the shallow areas to absorb wave energy from surge events, stabilize dredged channel banks, and increase aquatic habitat.

Figure 78 - Site 1 Proposed Shoreline Restoration



Based on projected storm surge and future high tide flooding projections, Site 2 is expected to be heavily impacted, especially Flagler Drive, an important roadway in the West Palm Beach. Based on aerial observation of Site 2, the bathymetry appears to be quite deep. Therefore, the project team suggests two potential options for shoreline protection. Option 1 would raise or armor current seawalls and update discharge points with backflow preventers for more immediate shoreline protection. Option 2 would create intertidal islands similar to the South Cove and El Cid shoreline projects and install mangroves just north of the One Watermark Place to provide protection against storm surge events.

Figure 79 - Site 2 Proposed Shoreline Restoration Option 1

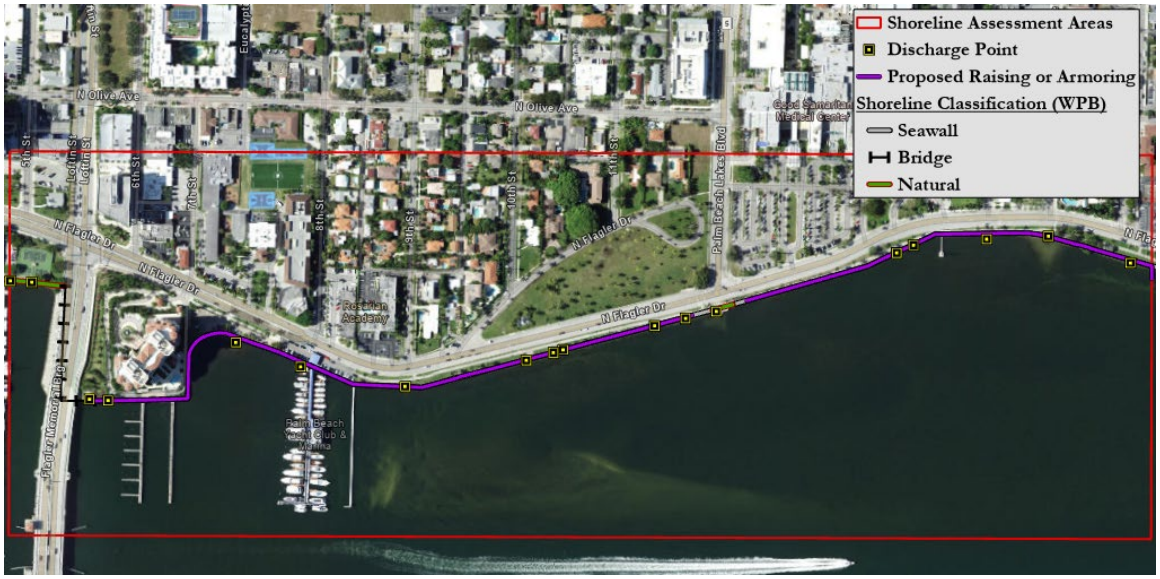


Figure 80 - Site 2 Proposed Shoreline Restoration Option 2



Based on data provided by the City of West Palm Beach, Site 3's shoreline is entirely comprised of seawall and Flagler Drive run right along this shoreline. Due to the concentration of private docks, the narrowness of the Lake Worth Lagoon at this location, and the lack of natural shoreline, the project team suggests two potential options. Option 1 proposes raising or armoring of the seawalls and updating discharge points with backflow preventers for more immediate protection to the shoreline and Flagler Drive. Option 2 proposes the installation of mangroves or intertidal wetland beds along the shoreline to provide protection from storm surge

and erosion. The City might consider looking into a buy-back system in order to acquire more shoreline and expand mangrove implantation.

Figure 81 - Site 3 Proposed Shoreline Restoration Option 1

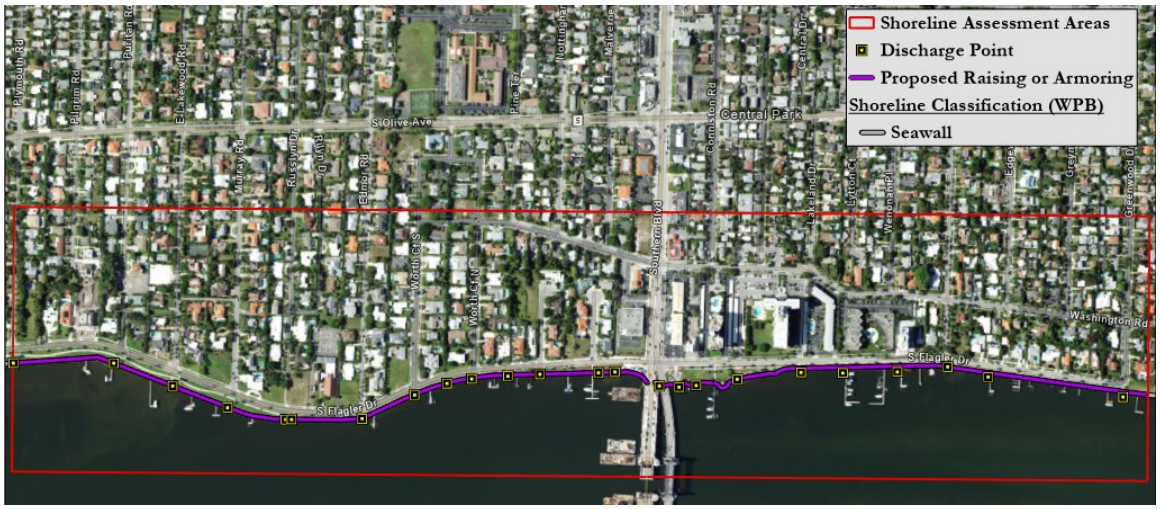
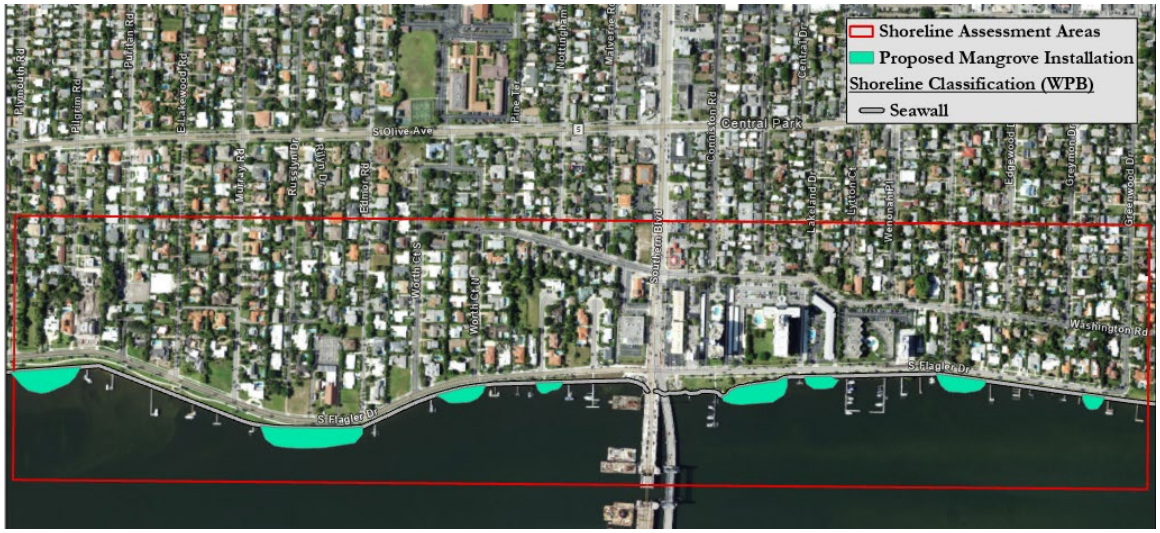


Figure 82 - Site 3 Proposed Shoreline Restoration Option 2



Based on projected 100-year storm surge, Site 4 is expected to be heavily impacted, especially along Flagler Drive. Site 4 is in a densely populated residential area and the majority of the shoreline is comprised of seawall, while a small portion is natural. Because of the concentration of docks in this area, there is limited space to install vegetation along the shoreline; therefore, the project team suggests two shoreline improvement options. Option 1 proposes raising or armoring of the seawalls, updating discharge points with backflow preventers, and installing rip rap along the

natural shoreline for more immediate protection to the shoreline and Flagler Drive. Option 2 would create smaller intertidal islands adjacent to the shoreline to reduce water energy caused by storm surge, but maintain free movement for boating activity, and to install mangroves along the natural shoreline to reduce erosion and protect againTst storm surge.

Figure 83 - Site 4 Proposed Shoreline Restoration Option 1

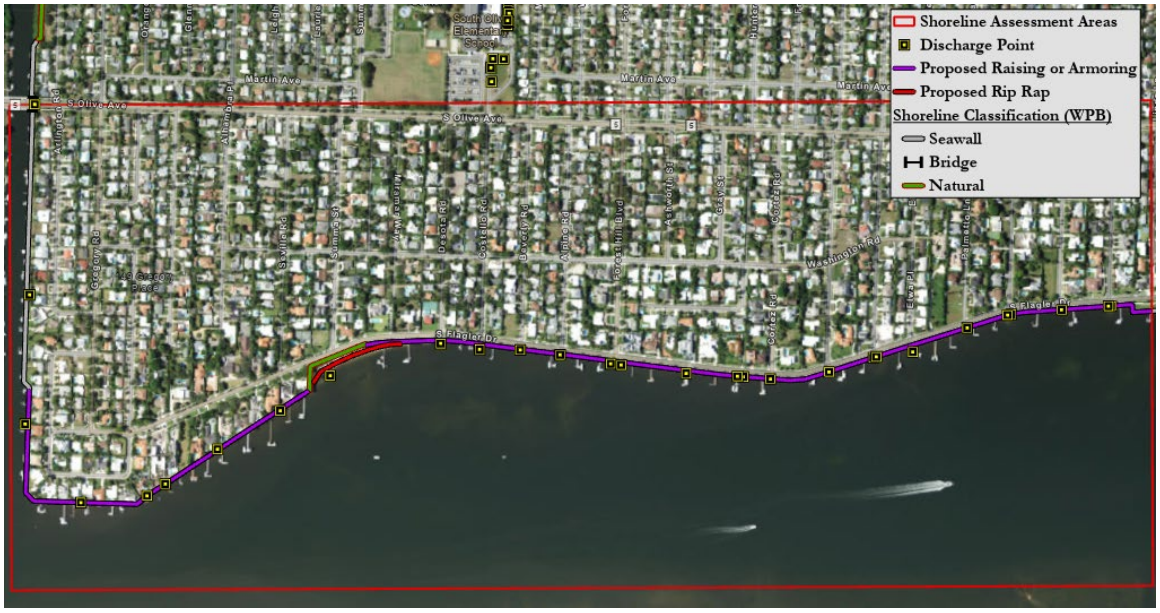


Figure 84 - Site 4 Proposed Shoreline Restoration Option 2



Socioeconomic Vulnerability

A comprehensive vulnerability assessment encompasses not only physical factors but also socioeconomic considerations. These considerations reveal the increased risks faced by a community's most vulnerable communities.

This section presents an analysis aimed at understanding the impact of flood vulnerability on the City's people. Spanning both urban and suburban communities, special attention is paid to identifying vulnerable populations. Those with limited resources or access to essential services require additional focus and call for special delineation of resources. Tailoring effective flood mitigation strategies specifically for these groups is critical.

A census tract is a geographic region defined for population study. Census tracts are used in this analysis to identify particularly vulnerable populations within flooding hot spots.

Description of Analysis

The exploration of West Palm Beach's flood risk planning through the lens of socioeconomic vulnerability uncovers the nuanced challenges faced by the City's most exposed communities. This approach, centered around the Social Vulnerability Index (SVI) and Location Affordability Index (LAI), emphasizes the importance of tailored flood mitigation strategies.

Incorporating LAI into the analysis adds depth, revealing how housing and transportation costs impact the financial stability of various household profiles. From very low-income individuals to moderate-income families, each group's economic reality underscores the importance of integrated planning that considers both flood risks and affordability. This comprehensive approach ensures that flood resilience measures are not only effective in reducing physical vulnerabilities but also in supporting the economic well-being of West Palm Beach's residents.

The findings underscore the critical need for West Palm Beach to adopt a multi-faceted approach to flood risk planning. By acknowledging the intersection of physical vulnerabilities with socioeconomic factors, the City can develop more inclusive and sustainable strategies. These strategies should aim to not only protect infrastructure and property but also to enhance the resilience of communities, particularly those who are most vulnerable to the adverse effects of flooding. Through targeted interventions and supportive policies, West Palm Beach can work towards a future where all residents, regardless of their economic status, are safeguarded against the impacts of climate change and sea-level rise.

Efforts to address these vulnerabilities must consider the complex interplay of factors that contribute to the community's risk, prioritizing strategies that support the most affected populations through financial assistance, social services, and inclusive policymaking. This targeted approach is essential for improving quality of life and ensuring equitable access to resources and support in the face of climate change and flood risks.

Social Vulnerability Index

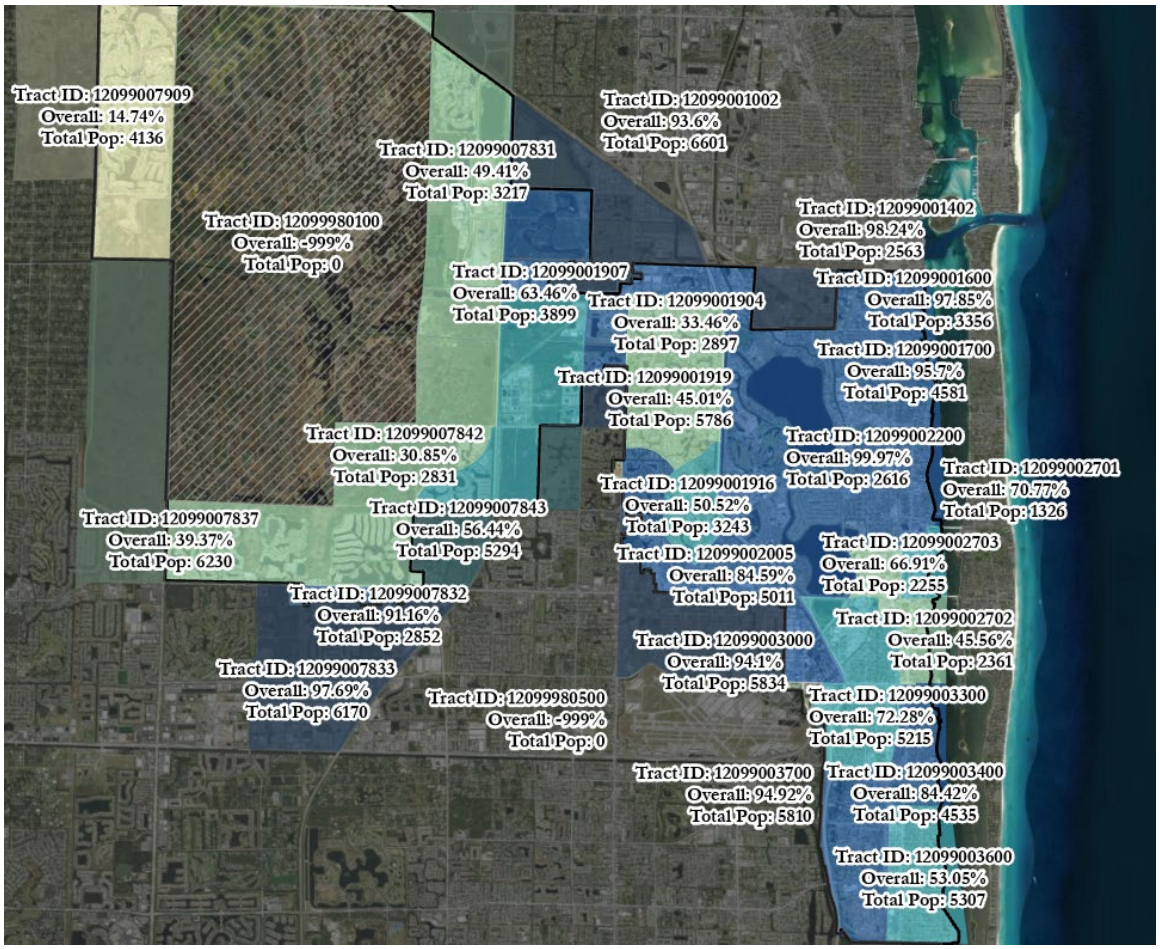
The City of West Palm Beach consists of 38 census tracts, a detailed study of each area tract helps in identifying populations that are especially vulnerable to flood risk. Vulnerability is based on the overall composite ranking within the Social Vulnerability Index, where values of 50% (or .50) or greater are prioritized higher than lower values. Table 25 provides the census tracts within West Palm Beach that have a SVI Composite Index greater than 50%. Higher values indicate a higher susceptibility to flood-related adversities and other stressors. This detailed breakdown serves as a critical tool for prioritizing action and directing resources towards the most vulnerable sectors of the population. Ensuring that mitigation efforts are both efficient and equitable is crucial for protecting vulnerable communities.

Table 25 - Census Tracts in West Palm Beach with SVI Index Greater than 50%

Census Tract	Land Area (in square miles)	SVI Composite Index
12099001002	1.63	90% (.904)
12099001402	0.69	97% (.970)
12099001600	0.41	97% (.969)
12099001700	0.69	94% (.940)
12099001801	1.22	82% (.816)
12099001802	1.99	83% (.833)
12099001907	2.21	54% (.541)
12099001917	0.80	79% (.790)
12099001921	0.48	83% (.829)
12099002005	0.89	81% (.809)
12099002006	0.88	95% (.946)
12099002100	0.94	97% (.966)
12099002200	0.33	99% (.998)

Census Tract	Land Area (in square miles)	SVI Composite Index
12099002300	0.64	80% (.800)
12099002400	0.28	91% (.909)
12099002701	0.17	63% (.629)
12099002703	0.15	64% (.643)
12099002800	0.93	62% (.621)
12099002900	0.19	98% (.979)
12099003000	0.33	92% (.923)
12099003300	0.95	72% (.716)
12099003400	0.77	79% (.786)
12099003700	1.60	94% (.943)
12099007832	0.13	87% (.867)
12099007833	0.03	96% (.964)

Figure 85 – Census Tracts with SVI Scores and Total Population

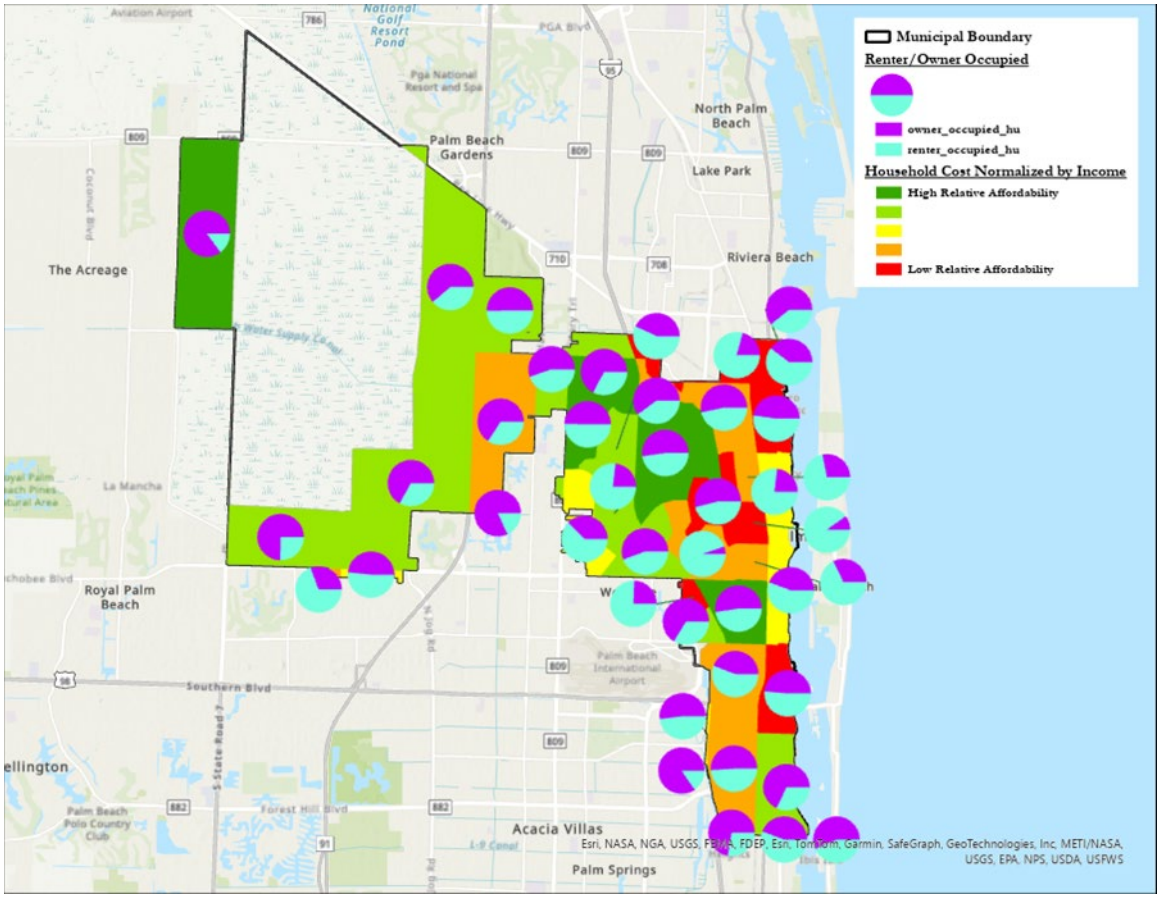


Location Affordability Index

The Location Affordability Index (LAI) provides a comprehensive view of the cost burdens of housing and transportation on different household profiles and analyzes them to determine the true cost of living, not just in terms of rent and/or mortgages but also commuting and travel expenses. This index is a key factor when analyzing the vulnerability of a community. Metrics for each household profile identified within the analyzed census tracts are detailed below.

Figure 86 - Location Affordability Index

Green denotes areas where housing and transportation costs are more affordable, relative to income; red and orange signify areas where incomes are less sufficient to cover housing and transportation costs; yellow is in between. Pie chart overlays represent the ratio of total owner-occupied housing in blue and renter-occupied housing in purple.



Household Profiles

The 2024 Vulnerability Assessment for West Palm Beach introduces several household profiles to better understand the socioeconomic fabric of the City and tailor resilience strategies accordingly. Each profile encapsulates distinct economic realities, from those barely making ends meet to families enjoying financial stability.

Very Low-Income Individuals: These are residents at the lowest economic tier within the community, earning significantly less than the majority. They represent the segment most in need of comprehensive support and intervention, reflecting

profound financial challenges that necessitate targeted assistance programs to ensure their well-being and societal integration. This suggests significant economic challenges and a potential need for targeted financial assistance and social services to improve their quality of life and economic stability.

Working Individuals: This group includes a broad spectrum of the workforce, from those employed full-time to part-time across various sectors. Their economic situation is somewhat stable, yet precarious, marked by a delicate balance between earnings and expenditure that could be easily disrupted by unforeseen financial demands or economic downturns. This group likely includes a mix of full-time and part-time workers in various sectors, possibly facing moderate financial constraints with some disposable income but also vulnerabilities to economic downturns or unexpected expenses.

Retired Couples: Enjoying the fruits of their lifelong labor, retired couples generally occupy a more comfortable economic position, buoyed by pensions, savings, or other retirement benefits. While they are less vulnerable to immediate financial shocks, they may require support with healthcare and aging-related services to maintain their quality of life. This suggests that they likely have a stable source of retirement income, such as pensions or savings, positioning them relatively comfortably in terms of economic security. This group may have fewer financial vulnerabilities but could still require services geared towards healthcare and aging.

Single-Parent Families: Single parents navigate the complexities of raising children on a single income, a challenge compounded by the costs associated with childcare and education. This group's economic positioning, while not at the bottom, is fraught with unique pressures that call for policies aimed at easing their financial and caregiving burdens. Despite being in the middle-income bracket, the demands of single parenting, including childcare and educational expenses, can strain their financial resources, highlighting the need for supportive policies that address childcare, education, and healthcare.

Moderate Income Families: Representing a relatively comfortable middle ground in the economic spectrum, families in this category have a stable income that supports a decent standard of living. However, they are not immune to financial strains, particularly regarding housing, education, and healthcare expenses, underscoring the need for adaptable support systems.

Table 26 - LAI Household Profiles of Interest and their Median Household Income

Household Profile	Median Household Income for a Given Area (MHHI)
2. Very Low-Income Individual	National Poverty Line
3. Working Individual	50% of MHHI
5. Retired Couple	80% of MHHI
6. Single-Parent Family	50% of MHHI
7. Moderate-Income Family	80% of MHHI

Each of these profiles plays a crucial role in shaping West Palm Beach's approach to building a resilient and inclusive community. By acknowledging the diverse economic realities of its residents, the City can devise targeted strategies that not only address immediate vulnerabilities but also lay the groundwork for sustainable development and prosperity.

Policy, Land Use and Development

The process of conducting a vulnerability assessment generates an immense amount of data and analysis, but what the community does with those resources is even more important than the information itself. Key mechanisms through which a community can make better decisions based on the outcomes of a vulnerability assessment include its budget, infrastructure design, and land use/land development policies. Each of these examples is discussed in this section.

Budget Implications

This Vulnerability Assessment can help the City target investments into priority areas by focusing on the flooding hot spots identified. The flooding hot spots show current and increasing flood risk based on the type of flooding. For hot spots subject to tidal flooding, shoreline defense strategies might include seawall improvements, living shorelines, or controlling other tidal impacts through backflow prevention on stormwater outfalls. These strategies can help protect the critical assets identified in those hot spots, as well as the property and business owners relying on those assets for their day-to-day quality of life. Hot spots where rainfall is the primary driver of current and future flood risk are generally already known to be flood-prone areas, so any updated, more advanced hydrological modeling will serve as a further check and balance on stormwater improvement priorities. Prioritizing investments in these

areas can maintain or improve stormwater levels of service defined with the City's Comprehensive Plan and Code and again assist in targeting investments to the areas that will be impacted the soonest. These prioritization strategies would essentially take place as part of the City's existing capital improvements and budgeting processes.

Infrastructure Design

When designing infrastructure in the City, there are two basic concepts: the actual design of a project and the level of service it provides. A couple of examples from the City's Code and Comprehensive Plan can demonstrate these concepts and how the outcomes of this Vulnerability Assessment can help shape those policies.

Stormwater

In Sec. 94-307 of the Code of Ordinances, the City requires design standards for stormwater management systems. Relevant provisions include:

> *All development shall provide for adequate drainage and stormwater management. Compliance with the stormwater management requirements of South Florida Water Management District F.A.C. 40E-4, shall constitute compliance with this provision and with the provisions of the city's comprehensive plan which relate to the aquifer recharge areas. Provided, however, that there shall be no new drainage outfalls into Lake Worth.*

Sec. 94-35.c.11 Site Plan review includes the following:

> *Stormwater control. Appropriate measures shall be taken to ensure that removal of stormwater will not adversely affect neighboring properties or the public storm drainage system. Provisions shall be made for the construction of facilities, including grading, gutters, piping and the treatment of turf, to accommodate stormwater and to prevent erosion and the formation of silt.*

Sec. 94-485.f includes the following provisions for parking and loading spaces:

> *Storm drainage for parking and loading spaces. Off-street parking and loading spaces shall be provided with drainage systems adequately designed and maintained as required by the following:*
>
> 1. *To prevent the accumulation of water from normal rainfall; and*
> 2. *To prevent the runoff of rainfall onto neighborhood property at rates greater than would result if the site were undeveloped. Drainage systems shall be designed in accordance with standards prescribed by the city engineering department.*

Sec. 94-579 of the Code of Ordinances also includes the following level of service

standards for concurrency determinations:

4. Drainage. Drainage facilities shall operate at the following LOS standards:

DRAINAGE TYPE	*LEVEL OF SERVICE*
Storm sewer systems	*3-year, 1-hour storm*
Canal systems	*25-year, 24-hour storm*

In the City's 2024 Comprehensive Plan, the level of service for drainage is as follows in Policy 1.1.1 of the Stormwater Management Sub-Element:

Policy 1.1.1: The City shall continue to fully implement the stormwater requirements set forth in the Zoning and Land Development Regulations and as specified by the South Florida Water Management District. The City shall continue to implement these regulations in order to meet the following:

a. Maintain and expand the storm management system as needed to maintain level of service design standards of a 3-year, 1-hour storm for the storm-sewer system and a 25-year, 24-hour storm for the canal system.

b. Require erosion and sedimentation controls during construction to avoid contamination of receiving waters.

c. Utilize retention/detention facilities where practical to provide water-quality treatment of stormwater runoff.

d. Install sedimentation basins and/or baffle systems to prevent pollutants from entering receiving water bodies.

e. Maintain the land around Clear Lake and Lake Mangonia in order to prevent stormwater runoff from entering this potable water source.

f. Require future development to limit post-development runoff rates to pre-development discharge rates.

g. Provide routine maintenance to the stormwater management facilities to ensure they are functioning properly and to prolong their service life.

h. Continue the City's vigorous street sweeping program that includes the daily sweeping of downtown streets and twice weekly sweeping of all streets outside of the downtown.

Policy 1.3.4 of the Capital Improvements Element of the Comprehensive Plan also includes the City's Drainage Level of Service as follows:

Drainage facilities shall operate at the following level of service standards:

Storm sewer systems:	*3-year, 1-hour storm*
Canal systems	*25-year, 24-hour storm*

The City is currently updating its Stormwater Master Plan and completing a Watershed Master Plan, per activity 452.b in the FEMA Community Rating System. Both efforts include more advanced hydrologic and hydraulic analysis and should be coordinated with the outcomes in this Vulnerability Assessment. Through these planning efforts, the City should also revisit its adopted level of service standards to determine if they are being met, if they need to be revised, and if there are differences in level of service achievement that have diminished over time due to increased tidal flooding impacts and reductions in stormwater outfall capacity.

Indeed, the existing development level of service for a 25-year, 24-hour storm may be a very low level of service. There are nevertheless opportunities to improve this level of service through new capital projects or larger redevelopment projects. The results of the Vulnerability Assessment indicate potentially higher volume rainfall events (1.12 times more rainfall in 2040 than present day, 1.22 times more in 2070, and 1.34 times more in 2100). The City may wish to reevaluate these adopted level of service standards in the Comprehensive Plan based upon the information in this Vulnerability Assessment.

Land Use / Land Development

Land use and land development policies generally control how communities develop and where. There is significant potential to improve level-of-service delivery for stormwater and flooding not only in new developments, but also through redevelopment opportunities. The City may wish to consider certain policies in response to increasing flood risk, including:

- General increases in onsite stormwater management and retention to address increasing stormwater quality and quantity requirements at the state and regional levels.
- This could include requiring enhanced pervious surfaces in the City's Landscaping requirements or other onsite management technologies. This may also include accounting for future groundwater conditions that reduce storage capacity onsite in certain types of development applications, for instance those located closer to tidal influence.
- The City's Floodplain Management Ordinance in Article VII, Floodplain Management in Chapter 18 of the Building Regulations under the Zoning and Land Development Regulations. Key provisions may include enhanced freeboard in certain areas of the City or for substantial improvements.
- Adopting a shoreline ordinance revision that harmonizes concepts of seawall heights, promoting living or hybrid shorelines in key locations and tying useful life of shoreline improvements to future flood risk. The City's Code currently does not appear to address directly shoreline improvements beyond the existing building permit process related to docks.

- The City’s stormwater assessment program is solely focused on traditional rainfall-driven stormwater. A trending policy response related to traditional stormwater utilities to expand the methodology to include general flooding / drainage improvements authorized under Chapter 170, F.S. and revisit how tidal flooding impacts are addressed in the overall system’s service and rate structure.

Conclusion

In summary, this Comprehensive Vulnerability Assessment has illuminated critical insights into West Palm Beach's susceptibility to climate change and sea-level rise. These findings underscore the urgent need for proactive measures to safeguard the City's communities, infrastructure, and environment.

By conducting an in-depth analysis of physical, socioeconomic, and environmental vulnerabilities specific to West Palm Beach, this Vulnerability Assessment equips decision-makers with a holistic understanding of the City's susceptibility to climate change impacts. This knowledge forms the basis for tailored mitigation and adaptation strategies aimed at enhancing the City's resilience and sustainability.

West Palm Beach's coastal location exposes it to the relentless forces of sea-level rise, storm surges, and high tide flooding. The potential impacts on critical infrastructure, communities, and the economy are significant and cannot be ignored. By further developing these types of adaptation strategy recommendations and working together, West Palm Beach can fortify its defenses against the growing threats of climate change.

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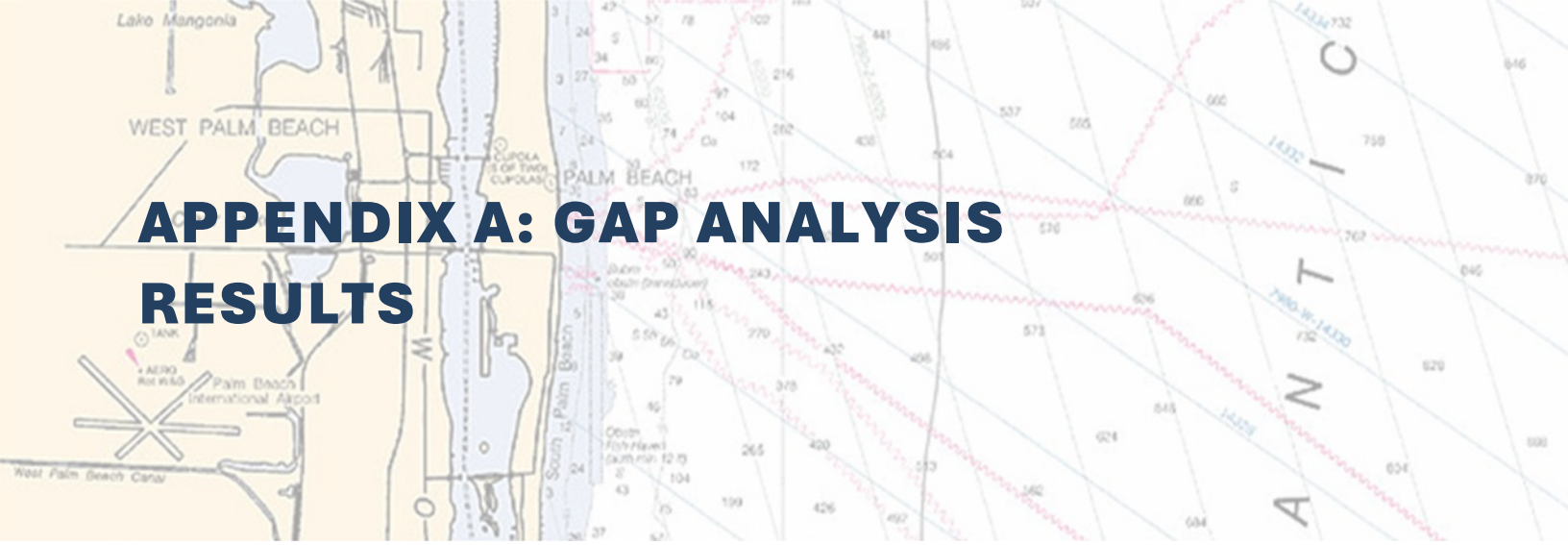
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APPENDIX A: GAP ANALYSIS RESULTS

Early on, the project team provided the City of West Palm Beach with a Data Request (provided under separate cover as Appendix A.1) detailing the types, categories, and specific qualities of information that would be needed to conduct this Vulnerability Assessment thoroughly and in compliance with State of Florida statutory guidelines.

Following collection and submittal of that information by the City, the project team then conducted a Gap Analysis (provided in full under separate cover as Appendix A.2) to identify areas where data were insufficient or missing. This analysis played a crucial role in identifying regions and parameters that required additional data or alternative approaches to fill the gaps.

By pinpointing data deficiencies, the assessment team was able to prioritize efforts to collect missing data or explore alternative methods to estimate the required information. This iterative process allows for continuous refinement of the data collection strategy and ensures the assessment is built on the most reliable and comprehensive data available.

The analysis focused on comparing available data against the information required for effective vulnerability assessment. The identified gaps can be broadly categorized into five challenges, with potential solutions to each.

- **INSUFFICIENT GEOSPATIAL DATA:** Geospatial data provides a geographic dimension to the analysis. The data was insufficient or missing in certain regions, impacting the ability to map and visualize spatial relationships between different entities, such as transportation networks, critical infrastructure, and natural resources. Another example of this is seemingly more relevant to older communities and is exemplified in areas where infrastructure (like stormwater systems) may have been installed but are not mapped within presently available datasets.

    - **Solution to Consider:** Create maps of the areas missing asset data to direct field teams. Utilize permitting systems where possible to extract geospatial data and fill gaps where practicable (for example: stormwater management systems).

- **INCOMPLETE INFRASTRUCTURE AND FACILITIES DATA:** Data within attribute tables were incomplete. This gap affects the assessment of potential vulnerabilities these critical infrastructures may face due to changing environmental conditions. Including more specific components about each asset within geospatial databases allows for those components to be analyzed in similar studies.

    - **Solution to Consider:** Perform department specific assessments on most frequently utilized data, encourage data stewardship, and assign specific "owners" for maintaining data quality. Additionally, assigning a data owner enables the public to interact with a particular person, division, branch, or department rather than the general organization.

- **LACK OF UPDATED NATURAL, CULTURAL, AND HISTORIC RESOURCES DATA:** The existing data for some natural, cultural, and historic resources might be outdated or missing, creating gaps in assessing the impact of climate change and sea-level rise on these resources. This data is traditionally limited to land use inventories, protected species inventories, and protected structures.

    - **Solution to Consider:** Solicit community input on identifying/locating socially and/or culturally significant natural areas, cultural assets, and historic resources within the community. Connecting with people and understanding the landscape from a "boots on the ground" perspective is critical.

- **TERMINOLOGY AND NAMING CONVENTION DISCREPANCIES:** A significant challenge that arose during the gap analysis was discrepancies in naming conventions and terminologies across different data sources. For instance, certain datasets might refer to an asset under a different name or categorize it under a different heading. This inconsistency makes it difficult to ascertain whether a critical asset is truly missing from the data, or whether it is simply listed under a different term.

    - **Solution to Consider:** Coordinate with data providers to clarify what assets are included in each data category. Develop a standardized nomenclature and taxonomy for the assets and facilities. This approach can help reduce ambiguity and ensure a consistent understanding across all data sources. Additionally, consider creating

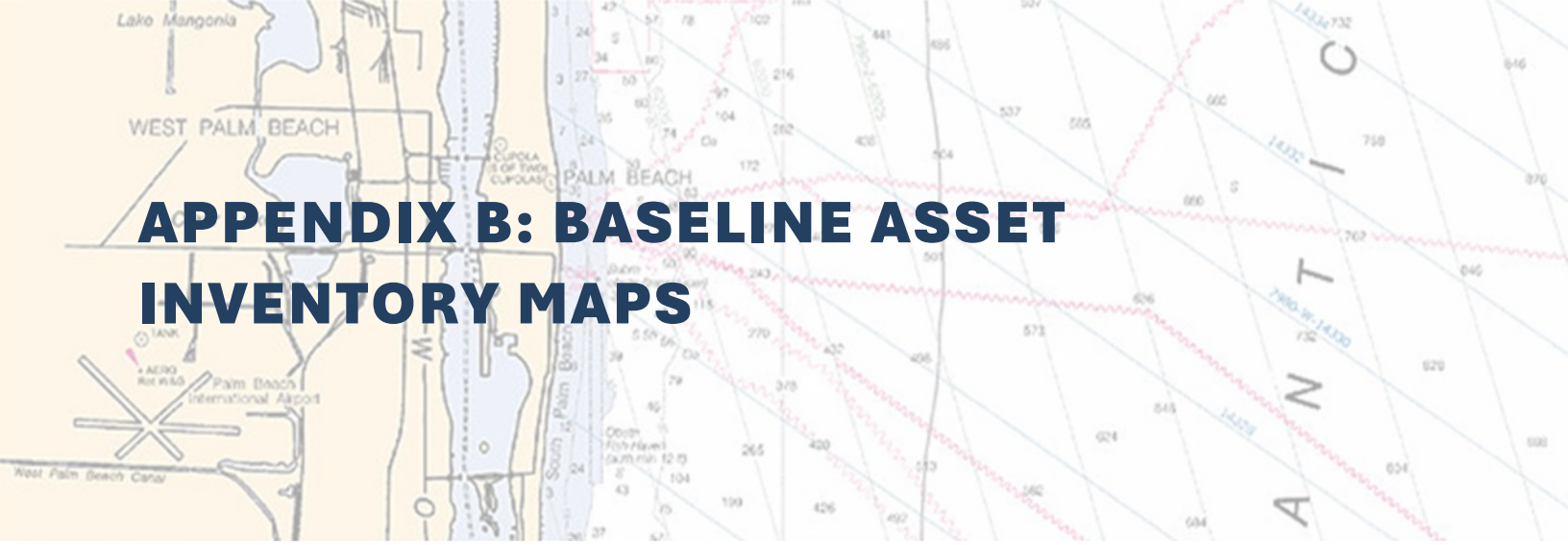
a cross-reference glossary of terminologies used by different data sources to mitigate the risk of overlooking critical assets due to naming discrepancies. This can be done in collaboration with data providers to ensure the terminologies align with industry standards and local context. Information within associated metadata would help future analytics teams.

- **INCONCLUSIVE DATA COVERAGE AND METAINFORMATION:** In some cases, it is unclear whether certain databases include certain types of critical assets. For example, bus stops and routes may be included under the general heading of 'Bus Routes' or 'Streets,' but without more specific information, it is difficult to be sure.

    - **Solution to Consider:** If the data is not available, consider commissioning targeted surveys or studies to gather the necessary data. The development of metadata, providing detailed information about each dataset, can be a great way to enhance understanding of data coverage. Consider including a percentage of total assets mapped under that specific data type as an element of this metadata to help outside consultants understand if they are working with a dataset that contains 25%, 50%, 75%, or some other percentage of that particular asset.

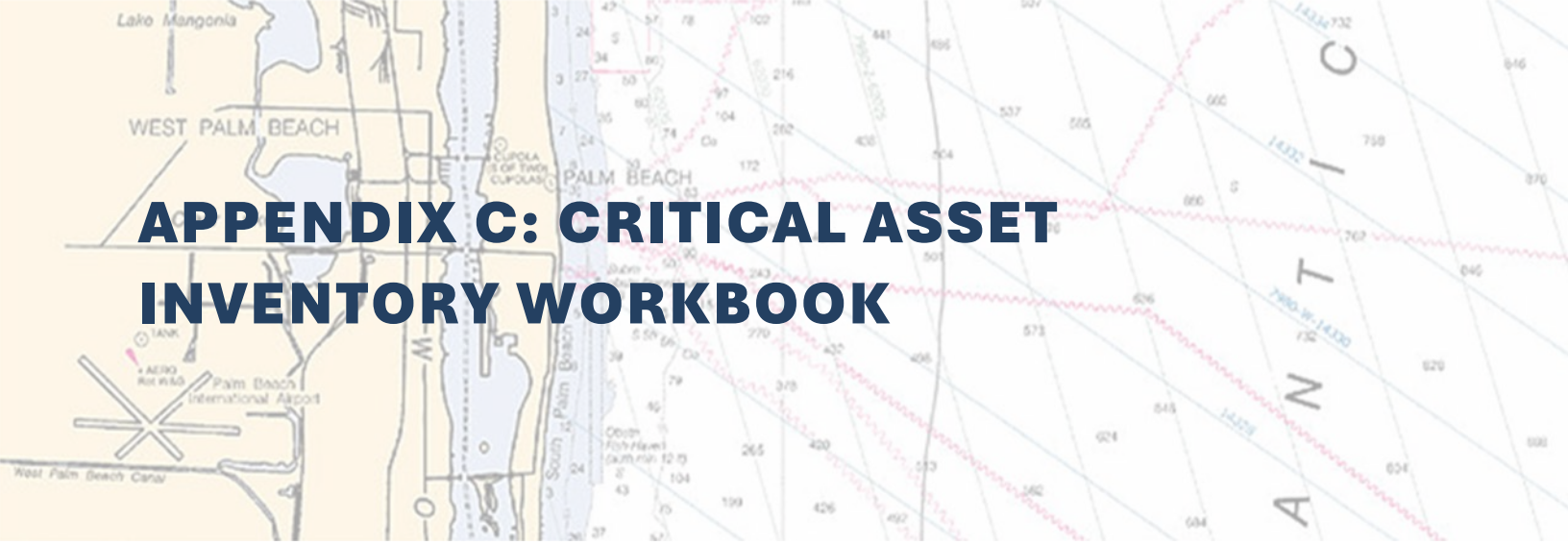
Considering these gaps, the project team utilized a range of strategies to fill as many data voids as practicable within the assessment timeline. This included tapping into additional data sources not previously considered, such as satellite imagery for geospatial data, government records for infrastructure and facilities data, conservation databases for natural, cultural, and historic resources data, and census data for socioeconomic data. Furthermore, the team may have leveraged methods like statistical estimation or modeling to fill in gaps when direct data collection was not feasible. This comprehensive approach ensures a robust, reliable, and inclusive vulnerability assessment.

As noted above, the Data Request is provided under separate cover as **Appendix A.1**, and the Gap Analysis Results are provided as **Appendix A.2**.



APPENDIX B: BASELINE ASSET INVENTORY MAPS

Under separate cover.



APPENDIX C: CRITICAL ASSET INVENTORY WORKBOOK

Critical Assets and Regionally Significant Assets

Subsection 380.093, F.S. Compliance

The Assessment process aligns with Subsection 380.093, F.S., utilizing the Florida Department of Environmental Protection's Critical Asset List. The categories of data collected, organized into four primary categories, are directly correlated with statutory compliance:

- **Transportation Assets** and evacuation routes, including airports, bridges, bus terminals, ports, major roadways, marinas, rail facilities, and railroad bridges.

Layer Name	Asset Type	Geometry	Count	Regionally Significant	Source
Bus stations	Bus	Point	2	Y	City of West Palm Beach
Intermodal transit center	Rail	Point	1	Y	City of West Palm Beach
Rail stations	Rail	Point	5	Y	City of West Palm Beach
Heliports	Aviation	Point	5		City of West Palm Beach

Port facilities	Water	Point	3	Y	City of West Palm Beach
Rail facilities	Rail	Point	11	Y	City of West Palm Beach
Railroad crossing	Rail	Point	58		City of West Palm Beach
Railroad bridges	Rail	Point	3		City of West Palm Beach
Railroads	Rail	Polyline	12	Y	Homeland Security
Streets	Road	Polyline	4452	Y	City of West Palm Beach
Marinas	Water	Point	9		FWC
FDOT bridges	Road	Polyline	62		FDOT
Evacuation zones	Road	Polygon	7		City of West Palm Beach
Evacuation routes	Road	Polyline	22	Y	FDEM
Bus stops	Bus	Point	361		City of West Palm Beach
Bus routes	Bus	Polyline	15		City of West Palm Beach
Boat ramps	Bus	Point	2		FWC

- **Critical Infrastructure**, including wastewater treatment facilities and lift stations, stormwater treatment facilities and pump stations, drinking water facilities, water utility conveyance systems, electric production and supply facilities, solid and hazardous waste facilities, military installations, communications facilities, and disaster debris management sites.

Layer Name	**Asset Type**	**Geometry**	**Count**	**Regionally Significant**	**Source**
Industrial facilities	Industrial facilities	Point	8		City of West Palm Beach

National guard	Military installations	Point	1		City of West Palm Beach
Electrical infrastructure	Electric production and supply facilities	Point	16	Y	City of West Palm Beach
Wastewater treatment infrastructure	Wastewater infrastructure	Point	7		City of West Palm Beach
Formerly used defense sites	Military installations	Point	1		Homeland Security
swWeir structure	Stormwater infrastructure	Point	9		City of West Palm Beach
swInlet	Stormwater infrastructure	Point	13427		City of West Palm Beach
swDischarge point	Stormwater infrastructure	Point	1479		City of West Palm Beach
swManhole	Stormwater infrastructure	Point	4589		City of West Palm Beach
swCulvert	Stormwater infrastructure	Polyline	71		City of West Palm Beach
swGravity Main	Stormwater infrastructure	Polyline	20071		City of West Palm Beach
swCasing	Stormwater infrastructure	Polyline	9		City of West Palm Beach
swFitting	Stormwater infrastructure	Point	222		City of West Palm Beach

swDetention	Stormwater infrastructure	Polygon	177		City of West Palm Beach
swBasins	Stormwater infrastructure	Polygon	559		City of West Palm Beach
Wastewater treatment plant	Wastewater infrastructure	Point	1	Y	City of West Palm Beach
ssLift station	Wastewater infrastructure	Point	201		City of West Palm Beach
Pump stations	Wastewater infrastructure	Point	8		City of West Palm Beach
Control structures	Wastewater infrastructure	Point	16		City of West Palm Beach
Culverts	Wastewater infrastructure	Polyline	109		City of West Palm Beach
Canals	Wastewater infrastructure	Polyline	13		City of West Palm Beach
wSystem valve	Potable water infrastructure	Point	14903		City of West Palm Beach
wControl valve	Potable water infrastructure	Point	1801		City of West Palm Beach
wNetwork structure	Potable water infrastructure	Point	66		City of West Palm Beach
wMain	Potable water infrastructure	Polyline	27173		City of West Palm Beach

Wellfield zones	Potable water infrastructure	Polygon	173		Palm Beach County
Cellular towers	Communication facilities	Point	4		Homeland Security
Communication towers	Communication facilities	Multipoint	1		Palm Beach County
DHL facilities	Communication facilities	Point	24		Homeland Security
Disaster debris management sites	Solid and hazardous waste facilities	Point	44		FDEP
Electrical substations	Electric production and supply facilities	Point	14		Homeland Security
Electric power transmission line	Electric production and supply facilities	Polyline	25		Homeland Security
FedEx facilities	Communication facilities	Point	51		Homeland Security
FM transmission towers	Communication facilities	Point	5		Homeland Security
Formerly used defense sites	Military installations	Polygon	2		Homeland Security
Land mobile broadcast towers	Communication facilities	Point	20		Homeland Security
Land mobile commercial transmission towers	Communication facilities	Point	8		Homeland Security
Microwave service towers	Communication facilities	Point	124		Homeland Security
Natural gas pipelines	Electric production and supply facilities	Polyline	1		Homeland Security

Power plants	Electric production and supply facilities	Point	2	Y	Homeland Security
Solid waste facilities	Solid and hazardous waste facilities	Point	19		Homeland Security
UPS facilities	Communication facilities	Point	43		Homeland Security

- **Critical Community and Emergency Facilities**, including schools, colleges, universities, community centers, correctional facilities, disaster recovery centers, emergency medical service facilities, emergency operation centers, fire stations, health care facilities, hospitals, law enforcement facilities, local government facilities, logistical staging areas, affordable public housing, risk shelter inventory, and state government facilities.

Layer Name	**Asset Type**	**Geometry**	**Count**	**Regionally Significant**	**Source**
Hospice	Non-emergency medical	Point	2		City of West Palm Beach
Ballpark	Recreational facilities	Point	1		City of West Palm Beach
Private college university	Education	Point	2		City of West Palm Beach
Government buildings	State government facilities	Point	5	Y	City of West Palm Beach
Adult family care home	Housing	Point	1		City of West Palm Beach
Primary care facilities	Non-emergency medical facilities	Point	2		City of West Palm Beach

City hall	Local government facilities	Point	1	Y	City of West Palm Beach
Adult day care	Non-emergency medical facilities	Point	3		City of West Palm Beach
Post office	Local government facilities	Point	3		City of West Palm Beach
Residential treatment facilities	Non-emergency medical facilities	Point	1		City of West Palm Beach
Residential health facilities	Non-emergency medical facilities	Point	2		City of West Palm Beach
Emergency management	Emergency	Point	1	Y	City of West Palm Beach
Charter schools	Education	Point	6		Palm Beach County
Health departments	Non-emergency medical facilities	Point	1	Y	Homeland Security
Ambulatory and surgical center	Emergency	Point	6	Y	City of West Palm Beach
Call center	Emergency	Point	1		City of West Palm Beach
Urgent care	Non-emergency medical facilities	Point	6		Homeland Security
Dialysis center	Non-emergency medical facilities	Point	7		City of West Palm Beach

Courthouses	Law	Point	3		Palm Beach County
Nursing homes	Housing	Point	8		Homeland Security
Abortion clinic	Non-emergency medical facilities	Point	1		City of West Palm Beach
Performing arts center	Recreational facilities	Point	1		City of West Palm Beach
Corrections	Law	Point	1	Y	City of West Palm Beach
Police department	Law	Point	1	Y	City of West Palm Beach
Shopping center	Community facilities	Point	1	Y	City of West Palm Beach
Pharmacies	Non-emergency medical facilities	Point	30	Y	Homeland Security
Supplemental colleges	Education	Point	1		Homeland Security
Colleges and universities	Education	Point	2		Homeland Security
Child care centers	Education	Point	49		Homeland Security
Public school	Education	Point	24		Palm Beach County
College and university campuses	Education	Polygon	1		Homeland Security
Development projects public view	Housing	Point	22		HUD

Senior communities	Housing	Polygon	34		Palm Beach County
Government facilities	Local government facilities	Point	18		City of West Palm Beach
Libraries	Local government facilities	Point	1		City of West Palm Beach
National shelter system facilities	Emergency	Point	10	Y	Homeland Security
Mobile home parks	Housing	Point	2		Homeland Security
Local law enforcement	Law	Point	2	Y	City of West Palm Beach
Hospitals	Emergency	Point	4	Y	City of West Palm Beach
EMS stations	Emergency	Point	10	Y	Homeland Security
Fire stations	Emergency	Point	10	Y	City of West Palm Beach
Communication infrastructure	Communication facilities	Point	34	Y	City of West Palm Beach
Sheriff's office	Law	Point	1	Y	City of West Palm Beach
Specialty law enforcement	Law	Point	1	Y	City of West Palm Beach
Private school	Education	Point	11		Homeland Security

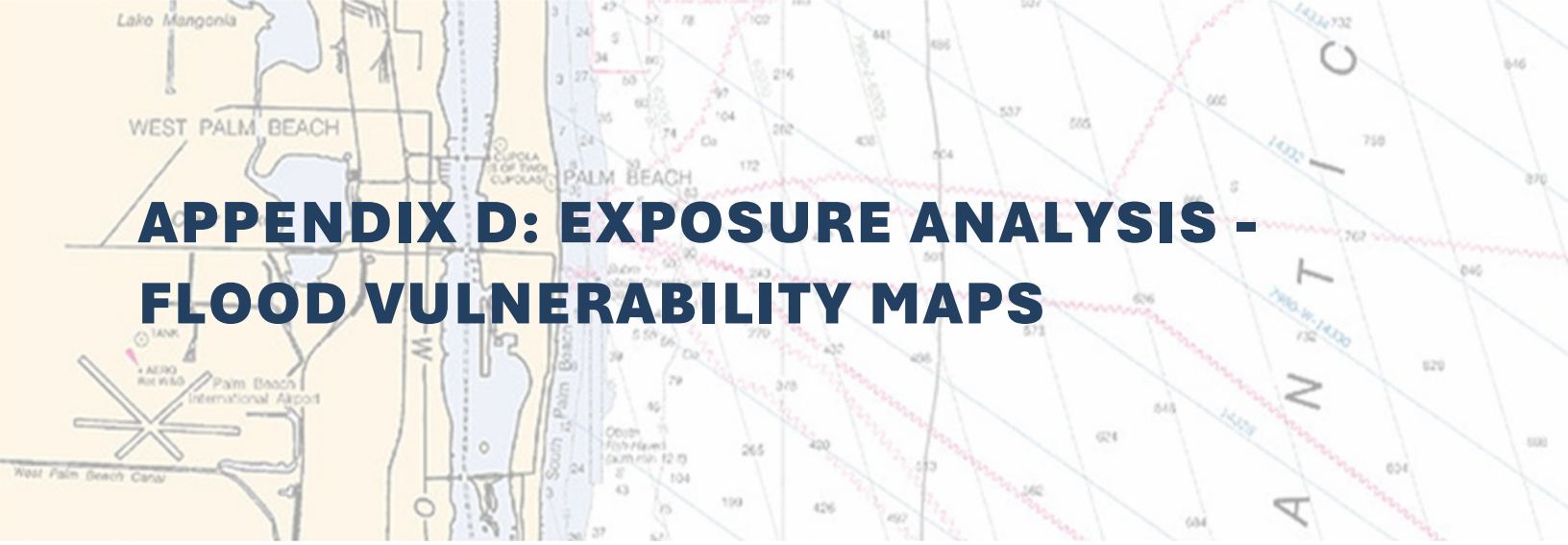
Convention centers	Community facilities	Point	1		City of West Palm Beach

- **Natural, Cultural, Historical Resources**, including conservation lands, parks, shorelines, surface waters, wetlands, and historical and cultural assets.

Layer Name	Asset Type	Geometry	Count	Regionally Signficant	Source
Grassy waters	Aquatic	Polygon	1	Y	City of West Palm Beach
Cemeteries	Historical and cultural assets	Polygon	8		FDHR
Religious license	Historical and cultural assets	Point	75		City of West Palm Beach
House of worship	Historical and cultural assets	Point	128		City of West Palm Beach
Natural and artificial reefs	Aquatic	Point	2		Palm Beach County
Seagrass	Aquatic	Polygon	63049		FWC
State manatee protection zone	Aquatic	Polygon	7		FWC
ESI marine mammal habitat	Aquatic	Polygon	1		FWC
NHD waterbody	Surface waters	Polygon	448510		USGS
Natural area trails	Terrestrial	Polyline	10		Palm Beach County
Shoreline (WPB)	Shorelines	Polyline	72	Y	City of West Palm Beach
Seawall	Shorelines	Polyline	33	Y	City of West Palm Beach
ESI shoreline classification (FWC)	Shorelines	Polyline	23	Y	FWC

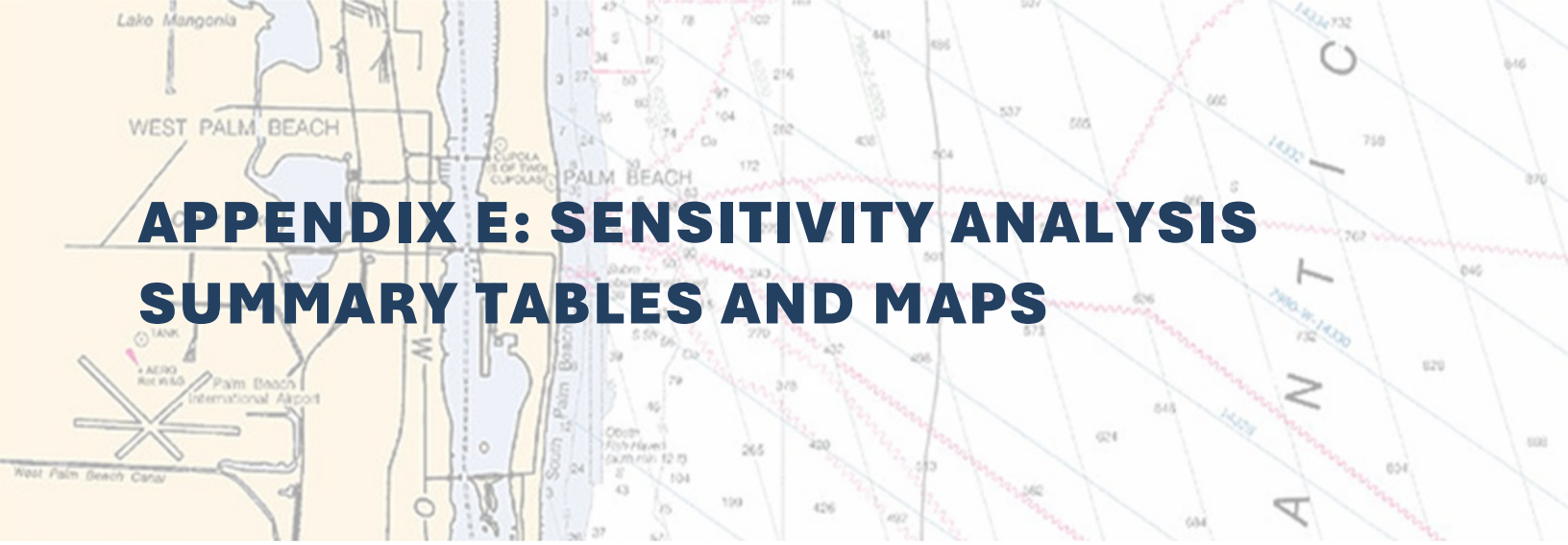
Municipal parks	Terrestrial	Polygon	168		Palm Beach County
Parks and recreation areas	Terrestrial	Polygon	60	Y	City of West Palm Beach
Historic bridges	Historical and cultural assets	Polyline	3		FDHR
National registry list	Historical and cultural assets	Polygon	29		FDHR
Resource groups	Historical and cultural assets	Polygon	42		FDHR
Historic structures	Historical and cultural assets	Point	6000		FDHR
All places of worship	Historical and cultural assets	Point	133		Homeland Security
Conservation tier	Terrestrial	Polygon	7		Palm Beach County
Habitat regions	Terrestrial	Polygon	1		FWC
Wetlands	Surface waters	Polygon	1305		USFWS
Mangroves	Aquatic	Polygon	8380		FWC
Palm beach county natural areas	Terrestrial	Polygon	2	Y	Palm Beach County
Salt marsh	Aquatic	Polygon	14664		FWC
Tidal flats	Aquatic	Polygon	18242		FWC
Water bodies	Surface waters	Polygon	395		USGS

This tabulation informs the resulting asset lists generated within the hot spots within this Vulnerability Assessment. Collaboration with local government entities will facilitate further identification of critical and regionally significant assets, ensuring a comprehensive assessment of potential climate risks and effective planning for the City's future.



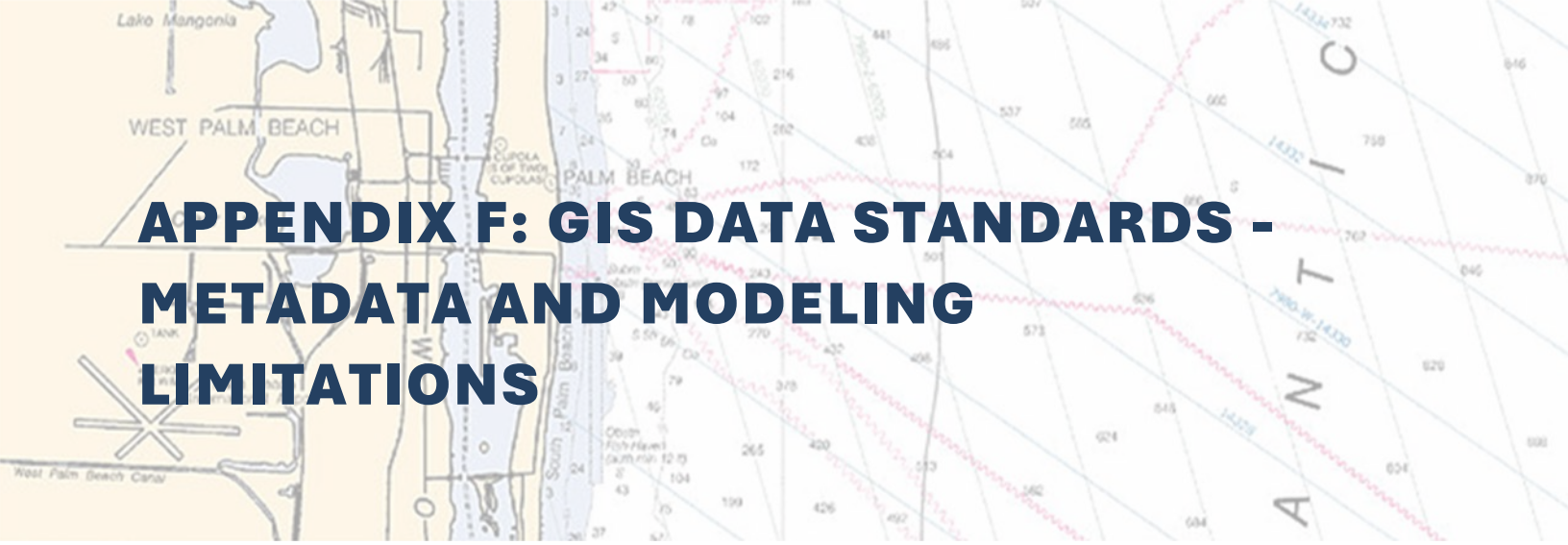
APPENDIX D: EXPOSURE ANALYSIS - FLOOD VULNERABILITY MAPS

Under separate cover.



APPENDIX E: SENSITIVITY ANALYSIS SUMMARY TABLES AND MAPS

Under separate cover.



APPENDIX F: GIS DATA STANDARDS - METADATA AND MODELING LIMITATIONS

Resilient Florida Planning Grants GIS Data Standards

This appendix outlines the Geographic Information System (GIS) data standards, metadata requirements, and modeling limitations pertinent to flood climate projections. Adhering to these standards ensures that all geospatial data used in vulnerability assessments are consistent, accurate, and compatible with the Florida Department of Environmental Protection's (FDEP) GIS infrastructure. The document serves as a reference for stakeholders involved in resilience planning, flood risk management, and emergency preparedness.

Pursuant to Section 380.093 (3)(c), Florida Statutes, grantees who receive funding to complete a vulnerability assessment shall submit to the Florida Department of Environmental Protection (FDEP) all electronic mapping data used to illustrate the flooding and sea level rise impacts identified in the assessment. The grantees shall also submit the associated metadata for each geospatial item. These items must be compatible with FDEP's Geographic Information System (GIS) infrastructure and tools and mapping coordinate reference systems. To aid in the compliance with this requirement, the following list has been compiled of acceptable digital data formats, metadata standards and required mapping datums.

Digital File Formats:

- Vector Data Formats:

- File Geodatabase Feature Class - Feature classes are homogeneous collections of common features, each having the same spatial representation, and containing both the geometric shape of each feature as well as descriptive attributes. Feature classes can only be stored inside a geodatabase. This is an Esri proprietary format.

- Raster Data Formats:

  - File Geodatabase Raster - Native data model for storing raster datasets inside a geodatabase. This is an Esri proprietary format.

Datums and Coordinate Reference Systems:

- Geospatial data shall be delivered projected into the appropriate Florida State Plane Coordinate System.

- Horizontal Datum: North American Datum of 1983 with 1990 Adjustments (NAD83/90), or later.

- Vertical Datum: North American Vertical Datum of 1988 (NAVD88).

Metadata Standards:

- Metadata shall be compliant with the *Content Standard for Digital Geospatial Metadata* (CSDGM) developed by the Federal Geographic Data Committee (FGDC). Acceptable formats are:

  - File Geodatabase FGDC-CSDGM Metadata - format for creating and editing the metadata of Esri items. The metadata is embedded in the item it describes. This is an Esri proprietary format.

- The Department encourages metadata to include the following information, as applicable:

  - Title - Name for the dataset.

  - Summary - Short summary of what the dataset represents.

  - Description - Basic information about the dataset and its purpose.

  - Process Summary - Steps in creating the dataset or layer.

  - Dates of Data Collection - Collection date of the dataset.

- Date of Publication - Date of publishing or last update of the dataset.
- Contact Person - Person responsible of the maintenance of the dataset.
- Credits - Person or entity responsible for the compiling the dataset.
- Use Limitation - Restrictions or legal prerequisites to using the dataset.

Critical Assets Attributes

- To standardize information for all the critical assets across the state, delivered critical asset datasets should have following attributes, as applicable:
  - Entity Name - Name of entity (i.e., County, city, local government, etc).
  - Asset Name - Asset label or description (i.e., hydrant, stormwater pipe, cell tower, etc).
  - Asset Type - Statutory asset type (i.e., airports, bridges, roadways, marinas, etc).
  - Asset Class - Statutory asset group (i.e., transportation and evacuation route, critical infrastructure, critical community and emergency facilities, etc).
  - Asset Owner/Operator - The owner or maintainer of the asset.
  - Asset Elevation - Elevation of the asset.
  - Asset Size/Capacity Data (i.e., capacity for wastewater facilities, acres, etc.)
  - Asset Unique ID - Unique identifier of the asset.

Pursuant to 380.093(2) Definitions, **Asset Type** refers to the individual asset, and **Asset Class** refers to the broader asset category. See classification table below:

Asset Type	**Asset Class**
Airports	Transportation and Evacuation Routes
Bridges	Transportation and Evacuation Routes
Bus Terminals	Transportation and Evacuation Routes
Ports	Transportation and Evacuation Routes
Major Roadways	Transportation and Evacuation Routes
Marinas	Transportation and Evacuation Routes
Rail Facilities	Transportation and Evacuation Routes
Railroad Bridges	Transportation and Evacuation Routes
Wastewater Treatment Facilities and Lift Stations	Critical Infrastructure
Stormwater Treatment Facilities and Pump Stations	Critical Infrastructure
Drinking Water Facilities	Critical Infrastructure
Water Utility Conveyance Systems	Critical Infrastructure
Electric Production and Supply Facilities	Critical Infrastructure
Solid and Hazardous Waste Facilities	Critical Infrastructure
Military Installations	Critical Infrastructure
Communications Facilities	Critical Infrastructure
Disaster Debris Management Sites	Critical Infrastructure
Schools	Critical Community and Emergency

	Facilities
Colleges and Universities	Critical Community and Emergency Facilities
Community Centers	Critical Community and Emergency Facilities
Correctional Facilities	Critical Community and Emergency Facilities
Disaster Recovery Centers	Critical Community and Emergency Facilities
Emergency Medical Service Facilities	Critical Community and Emergency Facilities
Emergency Operation Centers	Critical Community and Emergency Facilities
Fire Stations	Critical Community and Emergency Facilities
Health Care Facilities	Critical Community and Emergency Facilities
Hospitals	Critical Community and Emergency Facilities
Law Enforcement Facilities	Critical Community and Emergency Facilities
Local Government Facilities	Critical Community and Emergency Facilities
Logistical Staging Areas	Critical Community and Emergency Facilities
Affordable Public Housing	Critical Community and Emergency Facilities
Risk Shelter Inventory	Critical Community and Emergency Facilities

State Government Facilities	Critical Community and Emergency Facilities
Conservation Lands	Natural, Cultural, and Historical Resource
Parks	Natural, Cultural, and Historical Resource
Shorelines	Natural, Cultural, and Historical Resource
Surface Waters	Natural, Cultural, and Historical Resource
Wetlands	Natural, Cultural, and Historical Resource
Historical and Cultural Assets	Natural, Cultural, and Historical Resource

Compliance with FDEP Standards

Both geodatabases adhere to the Florida Department of Environmental Protection (FDEP) standards:

- **Digital Formats:**
    - **Analysis Rasters Geodatabase:** Uses File Geodatabase Raster format.
    - **Critical Asset Inventory Geodatabase:** Uses File Geodatabase Feature Class format.
- **Coordinate Systems:**
    - Both geodatabases are projected into the appropriate Florida State Plane Coordinate System.
    - **Horizontal Datum:** NAD83/90 or later.
    - **Vertical Datum:** NAVD88.

- **Metadata Standards:**
    - Metadata complies with the Content Standard for Digital Geospatial Metadata (CSDGM) by the Federal Geographic Data Committee (FGDC).
    - Provided within the geodatabases, attached to feature classes/rasters, and as separate XML files.
- **Critical Asset Attributes:**
    - The Critical Asset Inventory includes all required attributes to standardize information across the state, facilitating consistent analysis and reporting.
- By complying with these standards, the datasets ensure compatibility with FDEP's GIS infrastructure, supporting effective flood risk management, resilience planning, and emergency preparedness efforts.

Provided Geodatabases and Metadata

Here is an overview of the compliance efforts and where to find the relevant data:

Analysis Rasters Geodatabase

Title: Analysis Rasters (.gdb)

Content: This geodatabase contains flood projection data utilized for exposure analysis in the flood vulnerability assessment. It includes raster layers representing various flood scenarios, such as sea-level rise projections, high tide flooding frequencies, storm surge events, rainfall-induced flooding, and compound flooding assessments.

Location: "Analysis_Rasters.gdb" in the project files.

Metadata: Detailed metadata is included for each raster layer within the geodatabase. Metadata provides information on data sources, processing methods, scenario descriptions, and usage limitations.

Format: File Geodatabase Raster (Esri proprietary format)

Projection: Florida State Plane Coordinate System

Horizontal Datum: North American Datum of 1983 with 1990 Adjustments (NAD83/90) or later

Vertical Datum: North American Vertical Datum of 1988 (NAVD88)

Metadata Format: File Geodatabase FGDC-CSDGM Metadata (embedded within the geodatabase and available as separate XML files).

Additional Details:

- **Raster Layers:** The geodatabase includes raster datasets for multiple planning horizons (Present Day, 2040, 2070, and 2100) and sea-level rise scenarios based on NOAA (2017) Intermediate-Low (NIL) and Intermediate-High (NIH) projections. The naming convention indicates scenario parameters, such as sea-level rise projection, high tide flooding frequency, storm surge events, rainfall events, and combined flood events.

- **Data Sources:** Developed using the most recent publicly available digital elevation models from the U.S. Geological Survey (USGS) National Elevation Dataset. Sea-level rise projections were calculated using the NOAA VDatum tool to transform Mean Higher High Water (MHHW) elevations from NAVD88 for each scenario year.

- **Usage:** Intended for planning-level vulnerability assessments to identify areas at risk under various future climate scenarios. Not suitable for site-specific engineering or detailed design applications.

- **Use Limitation:** Data is provided "as is" and based on best available information. Users should be aware of its limitations and not rely on it for detailed engineering analyses without further validation.

Critical Asset Inventory Geodatabase

Title: Critical Asset Inventory (.gdb)

Content: A comprehensive geodatabase containing:

- **Jurisdiction-wide Critical Asset Inventory:** Detailed information on critical assets across Marathon, categorized by asset type and class.

- **Exposure Analysis Results:** Assessments of assets exposed to projected flood scenarios.

- **Sensitivity Analysis Findings:** Evaluations of asset vulnerabilities based on sensitivity to flooding.

Location: "Critical_Asset_Inventory.gdb" in the project files.

Metadata: Every feature class in this geodatabase is accompanied by compliant

metadata. See original data providers for additional metadata information.

Additional Details:

- **Tags:** Vulnerability Assessment, Transportation Assets, Evacuation Routes, West Palm Beach, Florida, environment, location, planning cadastre, society, structure, transportation, economy, utilities, communication.
- **Summary:** Provides a comprehensive analysis of Marathon's critical assets for flood risk vulnerability assessment, aiding in resilience planning and emergency preparedness.
- **Use Limitation:** Data is provided "as is" based on the best available information. Intended for high-level vulnerability assessments and planning purposes, not for detailed engineering analyses.

Accessing Metadata

- **Within Geodatabases:** Open the geodatabases using GIS software (e.g., ArcGIS). Right-click on any layer or feature class to view properties and associated metadata.
- **Separate XML Files:** Metadata is also provided as separate XML files within the respective folders for easy viewing and sharing without specialized software.

Usage Considerations

- **Data Limitations:** Both datasets are intended for high-level planning and vulnerability assessments. They are not suitable for detailed engineering analyses or site-specific design without further validation.
- **Data Currency:** The datasets represent conditions as of the dates noted in the data request and gap analysis. Users should verify if more recent data is available for their specific needs.
- **Liability Disclaimer:** Data is provided "as is." Users accept all responsibility for interpretations or conclusions drawn from the data and release the creators from any liability.

Modeling Limitations

Understanding the limitations inherent in the modeling approaches used in this project is essential for interpreting the results, assessing the scope, and determining its applicability to other planning areas. Constraints such as the project's timeline, budget, scale, and objectives influenced the choice of modeling methods and the level of detail provided.

The project primarily relied on planning-grade hydrostatic (bathtub) modeling, which is often used for preliminary flood assessments. This approach offers a simplified representation of flood scenarios by identifying areas below a certain elevation that are susceptible to flooding, assuming uniform water levels. While this method provides a broad overview, it lacks the ability to account for the dynamic behavior of water, such as flow velocity, wave interactions, and stormwater drainage capacity. Consequently, the bathtub model can overestimate or underestimate flood extents, particularly in areas with complex topography or where localized drainage and runoff patterns play a significant role.

Hydrological Models

Hydrological models offer a macroscopic overview of water movement, focusing on broad-scale processes such as runoff, infiltration, and evapotranspiration. These models work within the spatial and temporal scales pertinent to the system being studied, but their assumptions about surface processes can lead to inaccuracies when trying to capture localized variations, abrupt changes in water movement, or highly urbanized environments. For instance, the model may not fully reflect the effects of impermeable surfaces or engineered drainage systems, which are critical in urban flood planning. While hydrological models are useful for understanding regional water behavior, they provide only a generalized picture, making them less effective for precise, site-specific flood assessments.

Hydrodynamic Models

In contrast, hydrodynamic models solve the fundamental equations of fluid motion (such as the Navier-Stokes equations) to simulate detailed water flow behaviors, including turbulence, wave interactions, and sediment dynamics. These models are highly detailed and require significant computational resources due to their focus on fine-scale processes. Although hydrodynamic models would offer a more nuanced understanding of flood behavior, especially in coastal or riverine environments, the constraints of this project's timeline, budget, and scope precluded their use. Their application would have provided deeper insights into the complex interactions of floodwaters, but the tradeoff in time and resource allocation was not feasible for this phase of the project.

Hydraulic Models

Hydraulic models specialize in analyzing water movement within controlled environments like channels, pipes, or engineered structures, providing insights into the hydraulic behavior of stormwater systems and other man-made drainage networks. However, they often rely on steady-state assumptions, which may not capture transient phenomena such as sudden storm surges or flash flooding. Additionally, many hydraulic models do not account for sediment transport, further limiting their ability to predict erosion or sedimentation impacts. As with hydrodynamic models, the detailed data required for accurate hydraulic modeling—such as high-resolution cross-sectional profiles of water bodies—was not fully available or feasible within the current project scope.

Data Gaps and Strategic Planning

One of the most significant challenges in this project was the lack of available hydrological and hydraulic modeling data, particularly for detailed flood-depth analysis under various future scenarios, such as rainfall-induced flooding or compound flood events. This gap underscores the need for future strategic efforts in data collection, interdepartmental collaboration, and model integration. By aligning the available models more closely with the city's resilience and adaptation goals, future assessments can address the current gaps, improve accuracy, and enhance the reliability of flood predictions.

While this project provided a critical starting point using bathtub modeling, it is important to acknowledge the limitations of this approach. Future efforts should aim to incorporate more advanced modeling techniques as resources allow, ensuring a more comprehensive understanding of flood risks across different scenarios and improving the city's overall flood resilience.



APPENDIX G: DRAFT AND FINAL LISTS OF CRITICAL ASSETS

Draft and final lists of critical assets are provided under separate cover.



APPENDIX H: OTHER SUPPORTING DOCUMENTATION

Under separate cover.