



City of Miami Beach **Sea Level Rise Vulnerability Assessment Report**

DRAFT

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Acronyms

CDC	Center for Disease Control
DEM	Digital Elevation Model
FDEP	Florida Department of Environmental Protection
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
LiDAR	light detection and ranging
MHHW	Mean Higher High Water
NAVD88	North American Vertical Datum of 1988
NESDIS	National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
SWMM	Stormwater Modeling and Master Plan

Key Terms

10-year rainfall (10-percent annual chance rainfall): A rainfall event with a 10-percent chance of being equaled or exceeded in any given year. For this report, 8.75-inches of rainfall over a 24-hour period represents the 10-year (10-percent annual chance) rainfall flooding event as determined by the City of Miami Beach’s Stormwater Modeling and Master Plan.

100-year flood (1-percent annual chance flood): A flood event with a 1-percent chance of being equaled or exceeded in any given year. For this report, 6.2-feet (NAVD88) above mean sea level is used to represent the 100-year (1-percent annual chance) storm tide (storm surge) flooding event.

Adaptation: The process of adjustment to actual or expected stressors in order to moderate effects or exploit beneficial opportunities.

Adaptive Capacity: The potential or ability of an asset, system, or community to adapt to the effects or impacts of a stressor (e.g., climate change).

Asset: City owned or regionally significant infrastructure within the City of Miami Beach boundary as defined by the Resilient Florida grant program (§.380.093, F.S.).

Assessment: Sea Level Rise Vulnerability Assessment.

City: The City of Miami Beach.

Compact: Southeast Florida Regional Climate Change Compact

Compound Flooding: The combined effect of two or more flood sources (e.g., rainfall and king tide) occurring simultaneously.

Consequence: The severity of community impacts that would occur should the asset fail, incur significant damage, or become unusable due to flood exposure

Exposure: The presence of people, livelihoods, ecosystems, infrastructure, or other assets in places that could adversely affected.

Flood Scenarios: Term used to collectively refer to the twenty-one modeled flooding conditions used in the Vulnerability Assessment. Includes the existing conditions, NOAA Intermediate Low, NOAA Intermediate High, and NOAA High projections for each flood type for 2040 and 2070

Flooding: Temporary occurrence of water levels exceeding normally dry elevations; typically associated with an episodic event, such as a storm tide (storm surge).

Groundwater Flooding: The ponding of water in low-lying areas due to an elevated water table raising water to the surface.

Inundation: The process of normally dry areas being submerged.

King Tide: Higher than normal, but predictable, seasonal tides that occur each year during a new or full moon.

Mean Higher High Water: Average of the highest of two high tides occurring each day over the National Tidal Datum.

Resilience: Degree to which a system or asset rebounds, recuperates, or recovers from exposure to stressors.

Risk: Potential losses or impacts (consequences) that could occur if an asset or system is inoperable due to exposure.

Sea Level Rise: Refers to the increase in average global sea levels, often due to melting glaciers and thermal expansion.

Sensitivity: The likelihood an asset will fail, incur significant damage, or become unusable due to flood exposure.

Social Vulnerability: Refers to the demographic and socioeconomic factors (such as poverty, lack of access to transportation, and crowded housing) that adversely affect communities that encounter hazards and other community-level stressors.

Socially Vulnerable Neighborhood: A census tract classified by the CDC's Social Vulnerability Index as being in the Top-25% (quartile) of social vulnerability.

Storm Tide: Temporary, short-term increase in sea level above predicted astronomical tide levels due to atmospheric pressure changes, wind, and/or freshwater inflows. Also referred to as storm surge.

Stressor: Events and trends, both climate-related and not, that have an important effect on an asset or system that can increase risk and vulnerability.

Tidal Flood Days: The frequency of nuisance flooding conditions (i.e., frequent, minor flooding during high tides)

Vulnerability: The predisposition of an asset or system to be adversely affected by climate change. It is typically defined by a combination of exposure, sensitivity, and adaptive capacity.



1. Introduction

1.1 Project Overview

The City of Miami Beach (City) has long been a leader in recognizing the threat posed by sea level rise and taking proactive adaptation actions to establish a resilient City, ready for a changing future. The City has been, and will continue to be, at the forefront of sea level rise impacts due to the relatively low elevations and porous geology found in this region of Southeast Florida. **Figure 1.1** conceptually illustrates the various sources of flooding impacting the City and how future sea level rise will raise the baseline of flooding events.

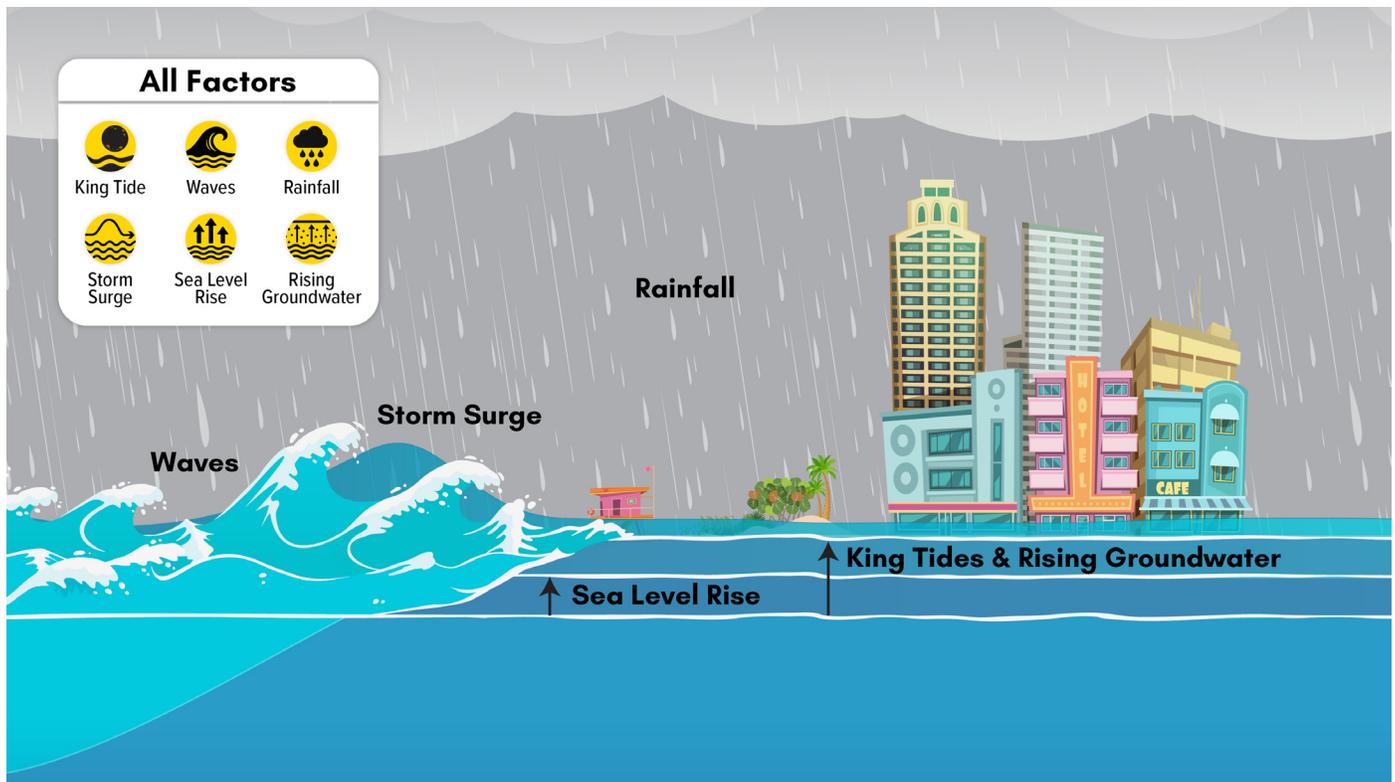


Figure 1.1: Representation of contributing flood scenarios in compound flooding.

In recent decades, the City has begun to face the impacts of sea level rise. This has included more frequent flooding of coastal roadways and low-lying areas during king tide events and more widespread ponding during heavy rainfall events. These events cause travel disruptions, damage to City infrastructure and private property, and during extreme events, can pose threats to life and safety. Future sea level rise is projected to increase flooding scale and severity, as coastal floodwaters become more likely to overtop current shoreline infrastructure and elevated bay and ocean water levels further decrease the effectiveness of the existing stormwater drainage system.

To more comprehensively understand the risk that future sea level rise poses, the City conducted this Sea Level Rise Vulnerability Assessment (Assessment) to identify the City-owned and regionally significant assets most vulnerable to different flood sources across a range of current and future sea level conditions. The Assessment provides a means for the City to identify and prioritize assets most vulnerable to impacts of sea level rise. The Assessment highlights key vulnerabilities that will inform the City's ongoing adaptation planning efforts.

The objectives of the Assessment include:

- Identification and prioritization of critical City assets at risk to current and future flood events;
- Identification of critical assets that serve the City's most socially vulnerable communities;
- Engagement of the public and stakeholders and incorporation of feedback into the Assessment methodology and prioritization criteria and;
- Development of outreach materials to communicate the findings of the Assessment to City department leads and the public.

The Assessment was developed to be compliant with Section 380.093 of the Florida Statute (§.380.093, F.S.), which defines a coordinated statewide effort organized through the Resilient Florida Program to adapt communities to the risks associated with increased precipitation, extreme weather, and sea level rise. Completion of the Assessment meets the requirements outlined in §.380.093, F.S. and allows the City to remain eligible for funding assistance for implementation projects that address specific flood vulnerabilities identified in the Assessment.

1.2 Project Area and Setting

Bordered by the Atlantic Ocean to the east and Biscayne Bay to the west, the City is a narrow barrier island and thus is vulnerable to flooding hazards from all directions, including from groundwater underneath the City. Ground elevations throughout the City are relatively low, particularly on the west side where elevations average only five feet above sea level. Strong coastal flooding events, such as king tides and storm tides (storm surges) from tropical storms, can overtop low shorelines and create pathways for floodwaters to other low-lying areas. Elevated coastal water levels can also prevent stormwater drainage at coastal outfalls, creating rainfall ponding throughout the City during heavy rainfall events, particularly on roadways or low-lying areas. The City's porous limestone bedrock also allows king tides to elevate groundwater to the surface, flooding low-lying areas and impeding natural stormwater infiltration.

The City is comprised of three regions: North Beach, Mid Beach, and South Beach. Within these regions, the City is divided into 14 major neighborhoods (**Figure 1.2**). The findings of the Assessment will be discussed in the context of these well-established geographic areas to more easily communicate results.

The City is heavily urbanized, which exacerbates flood impacts. Buildings, roadways, and other impervious surfaces impede stormwater drainage and accelerate runoff to low-lying areas. The City is reliant on its stormwater infrastructure to capture and convey stormwater away from critical assets. Much of the City's existing stormwater infrastructure is projected to become overwhelmed by future flooding conditions due to sea level rise which will further worsen flooding impacts in the City.

In recent decades, the increasing frequency of flooding has forced both the South Florida region and the City specifically to evolve its relationship with water. Beginning in 2010, the Southeast Florida Regional Climate Change Compact (Compact) was established to coordinate flooding mitigation and adaptation activities across all counties in the Southeast Florida region. The City continues to rely on the Compact's work to influence sea level rise planning efforts, including this Assessment.

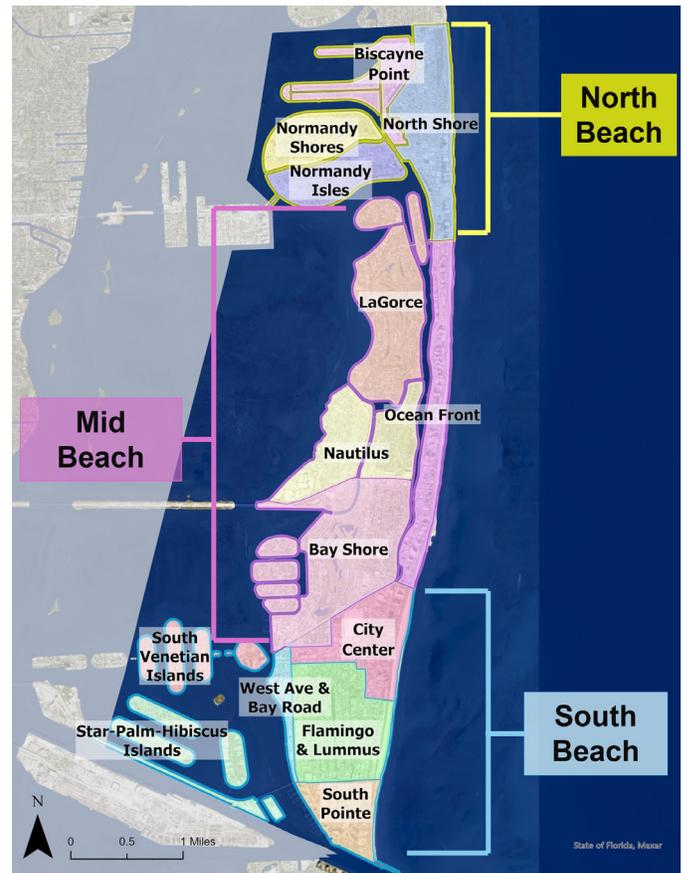


Figure 1.2: Miami Beach regions and neighborhoods

In 2014, the Blue Ribbon Panel on Flooding and Sea Level Rise was established by the City Commission to provide localized planning recommendations and ordinance updates to adapt the City's shorelines to sea level rise. The City has utilized guidance from these organizations to take several physical actions to respond to sea level rise, including elevating frequently flooded roadways such as Alton Road, installing stormwater pump stations, and enacting multiple, forward-planning initiatives such as increasing seawall minimum height requirements. Future adaptation strategies developed from the findings of this Assessment will provide the opportunity for the City to continually increase its sea level rise resilience and preserve its culture and way of life as a coastal city.

1.3 Community Perspectives of Sea Level Rise Hazards



Figure 1.3: City staff discussing how the City floods with residents at a pop-up event.

Early in the Assessment process, the City engaged in conversations with community members to integrate local knowledge on flood hazards into the planning process. Community engagement events included a series of eight small focus group interviews with residents and business owners and three pop-up engagement workshops (**Figure 1.3**) that coincided with ongoing community events. At each event, participants were provided an opportunity to detail how flooding events currently impact their life and what assets or infrastructure they consider the most valuable in their community. These community engagement opportunities and conversations influenced the Assessment by:

- Providing an understanding of community flood concerns,
- Identifying the populations most vulnerable to flood hazards,
- Recording areas where flooding has been worsening over time, and
- Identifying City assets highly valued by the community.

Public input informed asset vulnerability ratings in the Assessment and prioritization criteria for ongoing infrastructure needs described in the accompanying Adaptation Plan. Key themes raised across all community engagement events included:

- **Recognition of higher flood vulnerabilities along Biscayne Bay:** City infrastructure located along the western Biscayne Bay shore experience more flooding than those located near the eastern dune areas. The increase in flood exposure is due to two main factors: lower land elevations along the Bay allow for more shoreline overtopping and groundwater flooding and decrease the ability for gravity-based stormwater systems to drain efficiently.
- **Importance of roadway access:** Dependable roadway access throughout the City, and to the mainland via bridges and causeways, was consistently identified as a vulnerability. Residents and business owners frequently expressed concerns about limited mobility and inaccessible roadways during annual flood events, impeding their ability to access homes, businesses, and basic amenities. These events commonly produced frustrating traffic congestion, which participants believe will be exacerbated by sea level rise and increased precipitation intensity in the future.
- **Community facilities and public spaces are already at risk:** Residents identified several community facilities and public spaces (e.g., Scott Rakow Youth Center, Flamingo Park, and Fisher Park) that already experience flooding. Parks and other outdoor spaces significantly contribute to quality of life in highly urbanized Miami Beach and serve as a social hub for many residents. Several public schools (e.g., Biscayne Elementary and Nautilus Middle School) were also noted as frequently flooded, which affects school pick up/drop off.
- **Concern over long-term real estate and property value:** Homeowners and business owners expressed concern about the potential effect of sea level rise on property values, insurance, and local investment in the City. Many residents have experienced sharp increases in insurance rates in the last few years, and fear that they will be forced to leave the City due to high property and insurance costs even before the City becomes unlivable due to the physical effects of sea level rise (if no action is taken).
- **Aging flood protection structures:** The City's sea level rise issues are compounded by a reliance on an aging flood protection network. Large portions of the City currently depend on a system of seawalls and gravity-based stormwater drainage infrastructure that was designed in the early to mid-1900s without consideration of changing climate conditions. Property owners noted that seawater commonly seeps through cracks in their seawalls, particularly during high tides. Many interviewees also noted ponding water due to undersized and aging stormwater inlets and pipes.
- **Vulnerable populations are most at risk:** Community members noted that flooding vulnerabilities are unequally distributed across the City. Many hospitality and service industry employees are more likely to rely on bus and non-motorized forms of transportation, such as bicycles and walking, to access jobs and City amenities, and thus experience longer commute times during flood events. Elderly residents also face higher vulnerabilities as flooding and ponding water limit mobility, increase the likelihood of flood-related medical emergencies (e.g., slip or fall), and can increase social isolation.
- **Need for coping mechanisms on an individual scale:** Many residents have already been forced to adopt coping mechanisms to adapt to flooding on a personal level. Examples include raising the elevations of homes, docks, and private seawalls, purchasing high-clearance vehicles to drive through flooded streets, cleaning debris built up around local storm drains, and carrying flip-flops or rubber boots in the summer to commute on flooded sidewalks.

The public engagement events assisted the City in identifying additional assets to include in the Assessment that were highly valued by the community. The experiences and impacts voiced by the community align with the key vulnerabilities identified by the Assessment, and key themes captured through community engagement are integrated throughout the Assessment. A more detailed description of the community engagement process is provided in Appendix A.

1.4 Sea Level Rise Resilience Goals and Approach

This Assessment represents the City’s latest step forward in achieving its flood resilience vision. Assessment findings will lead to better protection of the City’s critical infrastructure from future sea level rise, alleviate travel disruptions during heavy rainfall events, and ensure that community valued assets are safeguarded into the future.

The City established the following goals specific to this approach:

- Increase the resilience of the City to immediate and long-term sea level rise challenges.
- Protect and enhance City infrastructure, natural resources, and the overall quality of life for all.
- Prioritize adaptation strategies for locations that align with communities that may experience inequitable impacts of sea level rise.

This Assessment is the first phase in this approach (**Figure 1.4**). In Phase 1, the City’s critical assets were assessed for vulnerability to current and future flooding. The Assessment resulted in a list of key assets and areas most vulnerable to sea level rise. The key vulnerabilities informed the development of several adaptation pathways to reduce asset risk and community impacts from flooding in the City’s Adaptation Plan (Phase 2). The City will use the findings from this plan and the pathways developed in the Adaptation Plan to design policies and projects that address the key vulnerabilities identified (for example, through annual grant applications to the Resilient Florida program or other sources of state and federal funding) (Phase 3).

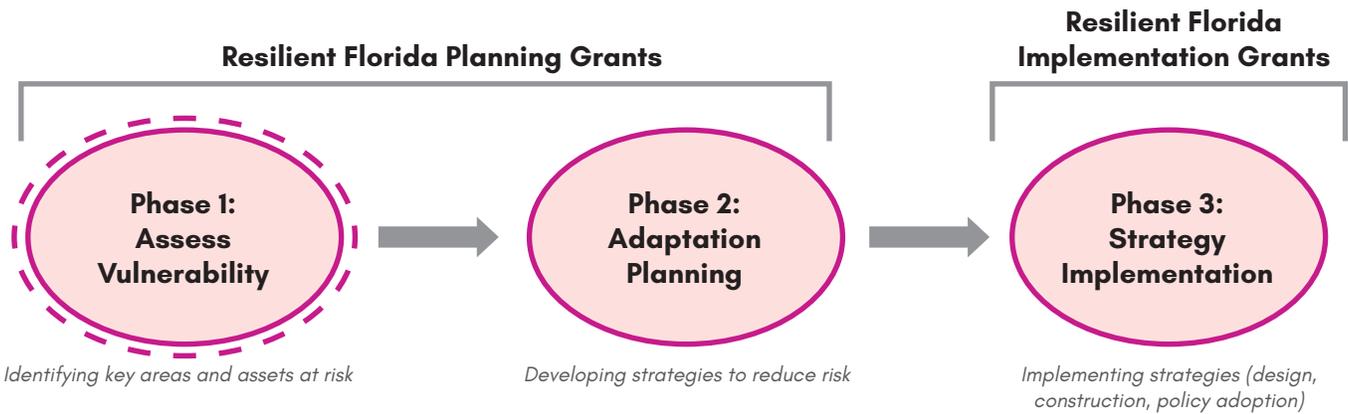


Figure 1.4: Vulnerability Assessment and adaptation planning process.

1.5 Planning Context and Coordination

This Assessment is positioned within a broader history of City plans and projects focused on addressing sea level rise impacts. The findings from this Assessment and the accompanying Adaptation Plan will add to and progress these ongoing initiatives. While climate change considerations are embedded in many City plans and projects, the following plans are the primary documents that guide the City's vulnerability and adaptation planning process:

- **Stormwater Modeling and Master Plan (SWMMP, 2024):** The SWMMP conducted a comprehensive assessment of the City's existing stormwater drainage infrastructure and water management features to identify capacity, water quality, and potential flooding issues. The SWMMP modeled the anticipated flood impacts from the interaction of a 10-year, 24-hour rain event and varying levels of sea level rise through 2060. The SWMMP model incorporated recently completed stormwater projects and proposed stormwater pumps to determine their impact on flooding issues. The SWMMP provides incremental adaptation actions in critical areas, which can be adapted to changing future changing conditions and are designed to be implemented over 10 years. The findings from this Assessment can be incorporated into the planning and design of these initial adaptation actions to reduce stormwater flooding risk to highly vulnerable assets in the identified critical areas.
- **Sea Level Rise Vulnerability Assessment Guidebook (Guidebook, 2017):** The City's 2017 Sea Level Rise Vulnerability Assessment provided an initial prioritization of assets for adaptation planning and identified key vulnerable assets within each City department. This Assessment builds upon the Guidebook by identifying vulnerable critical assets, refining the vulnerability assessment methodology, and placing a stronger emphasis on the incorporation of public input. The updated Assessment also maintains the City's compliance with Section 380.093 of the Florida Statute (§.380.093, F.S.), and allows the City to apply for implementation funds based on the findings.
- **Neighborhood Project Prioritization Report (Jacobs 2020a):** This report evaluated and prioritized the City's future capital infrastructure projects based on the projected flood risk, threats to public safety, and the need to maintain key City services. The recommendations include incentivizing nature-based solutions into project design to address water quality issues and improve floodplain management. The findings from this report and the Assessment can be utilized cooperatively to identify adaptation pathways that incorporate green infrastructure aspects into projects to protect key City assets from future sea level rise.

A list of additional complementary City initiatives and their relevance to the Assessment is included in Appendix B.

1.6 Report Organization

This report describes the approach to complete the Assessment and key findings. The report is organized as follows:

- **Section 1. Introduction:** project overview, project area and setting, community perspectives, resilience goals and approach, planning context and coordination, and report organization.
- **Section 2. Sea Level Rise Vulnerability Assessment:** vulnerability assessment approach, critical assets, sea level rise hazard mapping, and key vulnerability findings.
- **Section 3. Next Steps:** summary of Assessment purpose and the City's planned use of key findings.

Section 2 of the report is intended to serve as an overview summary of the Assessment methodology and findings. Appendices provide more technical details on the methodology for each Section 2 subsection. The Appendix structure is as follows:

- **Appendix A:** Stakeholder Engagement
- **Appendix B:** Gap Analysis
- **Appendix C:** Asset Inventory
- **Appendix D:** Review Sea Level Rise Science and Flood Hazard Mapping
- **Appendix E:** Vulnerability Assessment
- **Appendix F:** Asset Exposure Matrix and Flooding Severity Maps



2. Sea Level Rise Vulnerability Assessment

2.1 Vulnerability Assessment Approach

Climate vulnerability assessments provide a systematic approach to evaluate a community's risk to future climate conditions. This Assessment provides information about the potential timing, extent, and consequence of future flooding events influenced by sea level rise. The objective of the Assessment is to identify the City assets most vulnerable to future flooding scenarios, so that these assets can be prioritized for future adaptation actions. The findings of this Assessment informed the development of the City's Adaptation Plan that includes strategies to integrate sea level rise adaptation into City planning, design, and operations.

The approach for this Assessment began with extensive community engagement (Appendix A) to gather stakeholder perspectives on current flooding impacts and highly valued assets. The City then collected information on critical City assets and regionally significant assets (Appendix C) and identified which are projected to be exposed to future flooding conditions (Appendices D & E). In addition to general flood exposure, the Assessment also considered an asset’s function and importance to the community to evaluate its relative sea level rise vulnerability (Appendix E). For each asset, vulnerability was determined by evaluating the following measures:

- **Exposure** - “How many flooding scenarios impact the asset?” Exposure is associated with the number of scenarios under which an asset would be flooded.
- **Sensitivity** - “What are the impacts and potential damage to the asset if it is flooded?” Sensitivity is associated with the likelihood an asset will fail, incur significant damage, or become unusable for any duration of time due to flood exposure.
- **Consequence** - “What are the community impacts if the asset fails?” Consequence is associated with the severity of community impacts that would occur should the asset fail, incur significant damage, or become unusable.

A scoring methodology (more information in Section 2.4 and Appendix E) was developed to quantify each of these three vulnerability criteria. Scores for each were summed to establish a total vulnerability score for each asset (**Figure 2.1**). Assets were then organized into a list ranked by total vulnerability scores to establish the City’s most vulnerable assets. These assets had the highest combined exposure, sensitivity, and consequence scores.

Additional information for each of the principal steps in this approach are provided in Sections 2.2 and 2.3. Section 2.4 provides the key vulnerability findings from the Assessment.



Figure 2.1: Vulnerability Assessment methodology.

2.2 Critical Assets

An important first step in understanding an asset's flood vulnerability is accurately capturing the asset's location and characteristics. This information is necessary to analyze the asset's exposure to current and future flood scenarios, and sensitivity to and consequences of flooding. Completing this analysis required the compilation and organization of relevant City asset datasets from previous vulnerability assessments and from other City departments and partners (see Appendix B for more information on data sources and gap analysis). This inventory was also supplemented by assets identified during the community engagement events.

The final asset inventory included nearly 60,000 City-owned and regionally significant assets. Inventoried assets were classified into four categories¹ based on asset function and the managing entity responsible for their maintenance. A more detailed description, including the full list of inventoried assets within each category, and supporting data sources are described in Appendix C.



Source: Adobe Stock Photo.

Figure 2.2: Alton Road, South Beach.



Source: Adobe Stock Photo.

Figure 2.3: Aerial image of the Venetian Islands, showing bridge connections.

Below are descriptions of the four categories:

- Transportation Assets and Evacuation Routes** The City's transportation network links residents and visitors with community facilities, jobs, recreation, and neighborhoods. It also provides critical connection points to the mainland and evacuation routes. Evaluated assets in this category include roadways, evacuation routes, bridges, marinas, and bus stops. Transportation assets include those owned by the City, Miami-Dade County, and the Florida Department of Transportation.
- Critical Infrastructure** The City is responsible for the preservation of public welfare and providing basic services for residents and visitors. To accomplish this goal, the City relies on a network of utility infrastructure, including wastewater, electrical, stormwater, potable water, and communication assets. Critical infrastructure included in the Assessment represent a combination of individual assets owned and maintained by the City, private telecommunication companies, and Florida Power and Light. This asset category also includes disaster debris management sites, which provide a temporary staging area for post-storm debris collection and removal.

¹ The four categories align with the requirements established by the Resilient Florida grant program (s.380.093 F.S.).



Source: Google Maps.

Figure 2.4: West Ave Substation, showing infrastructure elevated to protect against flooding.

- **Critical Community and Emergency Facilities** The City includes numerous public facilities that provide community services promoting the safety, health, and well-being of residents and visitors. These include public safety facilities, such as fire stations, law enforcement, hospitals, City administrative buildings, schools, libraries, affordable housing areas, and community centers.

- **Historical, Cultural, and Natural Resources** There are numerous public sites that are significant to the City's social livelihood and multicultural community. This includes the City's park system which was repeatedly noted by residents to increase their quality of life in the City during the community engagement events. Environmental resources, such as the coastal dune system, also enhance local ecosystems and provide natural resilience to flood hazard events. Resources evaluated in the assessment include parks, natural shorelines, historical sites, art, and cultural points of interest.



Source: Miami Herald.

Figure 2.5: Fire Station #1.



Source: Miami Herald.

Figure 2.6: Police Headquarters.



Source: Adobe Stock Photo.

Figure 2.7: Flamingo Park

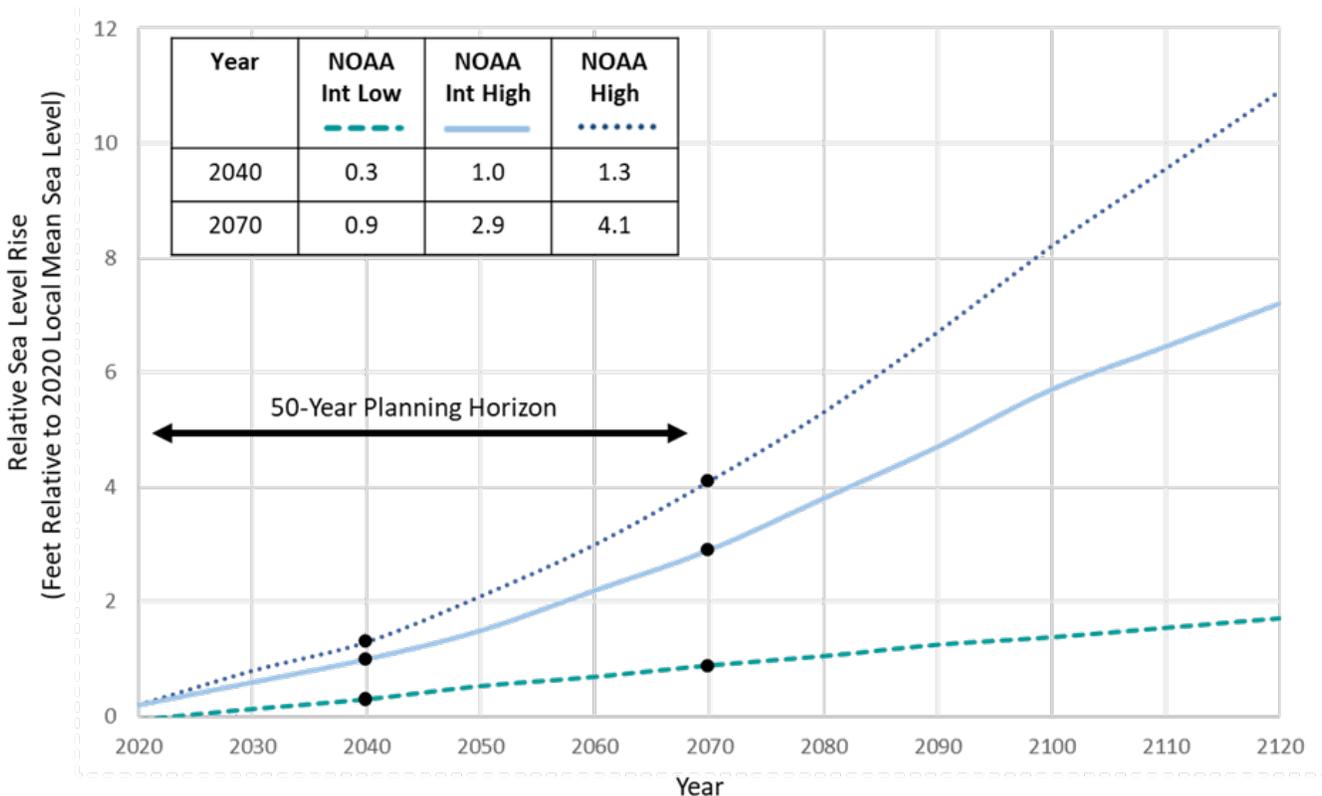
2.3 Sea Level Rise Hazard Mapping

As sea levels rise, flood extents are projected to increase for both expected events, such as annual high tides and heavy rainfall events, as well as for unexpected events, such as coastal storms (e.g., hurricanes). As flooding extents increase due to rising sea levels, so too will the number of impacted City assets. To understand the potential worsening impacts, the City created a series of flood hazard maps that could be compared to the locations of inventoried assets. Each map considered one primary flood source (king tide, compound flooding, and coastal storms) and included the potential flooding extent based on existing water levels or several future water levels due to continued sea level rise.

Three sea level rise scenarios and associated sea level rise amounts were selected to estimate the extent of future flooding at select future dates (**Figure 2.8**). The years 2040 and 2070 were chosen because they represent a near- and long-term planning horizon, respectively. Two of the sea level

rise scenarios (NOAA 2017 Intermediate Low and NOAA 2017 Intermediate High) were selected to comply with the Resilient Florida program². The City included a third scenario (NOAA 2017 High), which represents a more rapid rise in future sea level, as a more extreme scenario that can potentially be used for developing adaptation strategies for critical infrastructure (e.g., emergency facilities)³.

The following subsections further describe the three considered flood sources and how rising sea levels will worsen flooding impacts for each. Each section includes an example flood hazard map with the 2040 NOAA Intermediate High scenario (1 foot of sea level rise) to detail the increase in flood extents compared to existing conditions. More detailed information and documentation of the methodology used to create the mapped flood hazard layers and a full set of maps showing the progression of flooding from existing conditions to 2070 for each flood source is provided in Appendix D.



Note: A 0.4-foot offset was applied to the NOAA projections to adjust the baseline year from 2000 to 2020. This is based on Compact guidance that states 0.3 feet of sea level rise occurred from 2000 to 2017, which extrapolates to 0.4 feet from 2000 to 2020.

Figure 2.8: NOAA Sea level rise scenarios considered in the Vulnerability Assessment. Sea level rise values are in feet (NAVD88).

² http://www.leg.state.fl.us/statutes/index.cfm?App_mode=Display_Statute&Search_String=&URL=0300-0399/0380/Sections/0380.093.html

³ The use of the NOAA High Curve is also recommended by the Unified Sea Level Rise for this purpose: (<https://southeastfloridaclimatecompact.org/initiative/regionally-unified-sea-level-rise-projection/>)

2.3.1 King Tide Flooding

King tides in the City occur annually in late fall and generate the highest regularly occurring tides each year and may persist for several days. During king tide events, elevated coastal waters can overtop low-lying shorelines and can also cause groundwater

to emerge on the ground surface, flooding low-lying inland areas. Sea level rise will further elevate coastal water levels during these annual events. This will allow tidal waters to more frequently overtop shoreline areas and flood low-lying coastal areas.



Figure 2.9: High tide (king tide of 1.8 ft (NAVD, 88)) flooding map example and 1.0 ft of sea level rise (2040 NOAA Intermediate High scenario).

Baseline (i.e., existing) king tide flooding extent was determined from the City's median annual king tide water elevation from 1994 to 2020 (1.8-foot NAVD88) determined by tidal elevation data at the National Oceanographic and Atmospheric Administration's (NOAA) Virginia Key Tide Gauge. Future high tide flood extents were created by adding the projected sea level rise amounts (**Figure 2.8**) to baseline king tide conditions. King tide flooding in 2040 (baseline king tide conditions + 1.0 ft of sea level rise) is shown in **Figure 2.9**. Depths of flooding are shown in blue shades, with darker shades indicating deeper depths. Groundwater flooding areas are shown in purple and shoreline areas projected to be overtopped in this scenario are yellow.

In the 2040 Intermediate High scenario, king tide flooding is primarily concentrated along the west side of the City adjacent to Biscayne Bay and canals. This is similar to existing king tide flooding patterns but is more extensive. In this scenario, tidal water levels overtop many of the City's existing public and privately-owned seawalls, providing a pathway for coastal flooding to move inland and impact properties and infrastructure. Throughout most of the City, flood depths do not exceed 1 foot. However, several low-lying streets (e.g., Alton Rd, North Bay Rd, Crespi Blvd, and 5th St) may have flood depths of up to 2 feet. Groundwater flooding areas are less prominent than during the existing king tide scenario as these previously disconnected areas are now flooded by king tide. Groundwater flooding is still the main source of flooding projected for southern portions of the Ocean Front neighborhood.

Additional areas of interest exposed to the 2040 Intermediate High scenario are further described by City region and neighborhood below. The letter before each description is paired to a text box on the map (**Figure 2.9**) identifying the area of interest.

North Beach

- [A] The most extensive flooding and shorelines projected to be overtopped occur in Normandy Isles and Normandy Shores. Many low-lying roadways in these neighborhoods could be exposed to flooding, but depths are not anticipated to be greater than one foot.
- [B] Overtopping of the Tatum Waterway could cause flooding as far west as Hawthorne Ave. in the Biscayne Point neighborhood and as far east as Harding Ave. in the North Shore neighborhood. Streets and property in the northwest area of the La Gorce neighborhood are also exposed to flooding.

- [C] Groundwater flooding is concentrated in Biscayne Point, North Shore, and the northern areas of the La Gorce neighborhood.

Mid Beach

- [D] The majority of the king tide (+1 foot of sea level rise) flooding extent is anticipated to be concentrated on the west side of Mid Beach.
- [E] Nearly all roadways within the Nautilus neighborhood north of Mt. Sinai Hospital are exposed to flooding. The Bay Shore neighborhood is projected to experience flooding along much of Royal Palm Ave. The northern two Sunset Islands (Sunset Islands I and II) are also exposed to flooding, especially along the low-lying roadways.
- [F] Collins Ave between 26th St. and W 41st St. are exposed to groundwater flooding. Roads within the Sunset Harbor neighborhood that have not been elevated and the roadways of the southern-most Sunset Island (Sunset Island IV) are also projected to be impacted by groundwater flooding.

South Beach

- [G] The western half of South Beach has the most exposure to expansive king tide flooding due to its uniform low elevation.
- [H] Once king tides overtop shoreline areas in this scenario, flooding is projected to impact most of the West Ave neighborhood. This is also projected to flood many of the roadways in the western portion of the Flamingo and Lummus neighborhood, extending as far east as Pennsylvania Ave. The deepest areas of flooding (depths of 1-2 feet) occur in the southern portion of the Flamingo and Lummus neighborhood. Belle Isle and the western half of Palm Island are also exposed to flooding from king tide water levels overtopping the shoreline.
- [I] Groundwater flooding areas include the Venetian Islands, Palm Island, and the South Shore area bounded by Alton Rd., Washington Ave., and 1st St.

Although flooding due to king tides is temporary, it can last for several hours before and after peak high tide cycles and occur over a period of several days, causing sustained flooding if floodwaters are unable to drain between successive high tides. This may result in depths and extents that exceed mapped projections.

Tidal Flood Days

In addition to mapping king tide flood extents, the City also examined the frequency of existing nuisance flooding conditions (i.e., frequent, minor flooding during high tides) and how this frequency may change due to future sea level rise.

An hourly record of historical tidal observations⁴ from the Virginia Key tide station was used to reflect existing and future (2040, 2070) water level conditions for the NOAA Intermediate Low, Intermediate High, and High sea level rise projections. Future tidal levels were estimated by adding the sea level rise amounts for each scenario to the existing king tide baseline (+1.8 ft NAVD88) and were overlaid onto Citywide ground elevations. The average number of days that areas may be tidally flooded was calculated for each of the 2040 and 2070 scenarios (**Figure 2.8**). The number of average annual tidal flood days was classified by frequency (**Table 2.1**).

Figure 2.11 shows an example Tidal Flood Days map considering the 2040 NOAA Intermediate High scenario (baseline king tide conditions + 1.0 ft of sea level rise). Areas with the most frequent tidal flooding days are located along the City’s western shoreline adjacent to Biscayne Bay. These areas are also reflective of the baseline king tide tidal flooding map and were noted in the community engagement events to be commonly impacted by high tide flooding already.

The most frequent ‘high’ and ‘very high’ risk tidal flood days are concentrated along low-lying roadways, including the majority of Alton Rd. throughout the Flamingo and Lummus and Bay Shore neighborhoods and the southern portion of Collins Ave. in the Ocean Front neighborhood.

Multiple residential roads in the Bay Shore, La Gorce, and West Ave and Bay Rd. neighborhoods, and three of the City’s golf courses are projected to see tidal flooding over 52 times per year. The narrow eastern edge of the city, which has the highest local ground elevations, is not affected by tidal flood days under this scenario.

Table 2.1: Frequency classification for Tidal Flood Days.

Tidal Flood Day Frequency	Description
> 52 days per year (Very High)	Tidal flooding occurs more than once a week.
< 52 days per year (High)	Tidal flooding impacts occurs multiple times per month.
< 12 days per year (Moderate)	Tidal flooding occurs almost once a month, likely during high tide events.
< 1 day per year (Low)	Tidal flooding in these areas is rare and may only occur during the highest of high tide events (king tides).



Figure 2.10: King Tide Flooding.

⁴ Tidal observations were obtained from the Virginia Key tide station (NOAA #8725214)

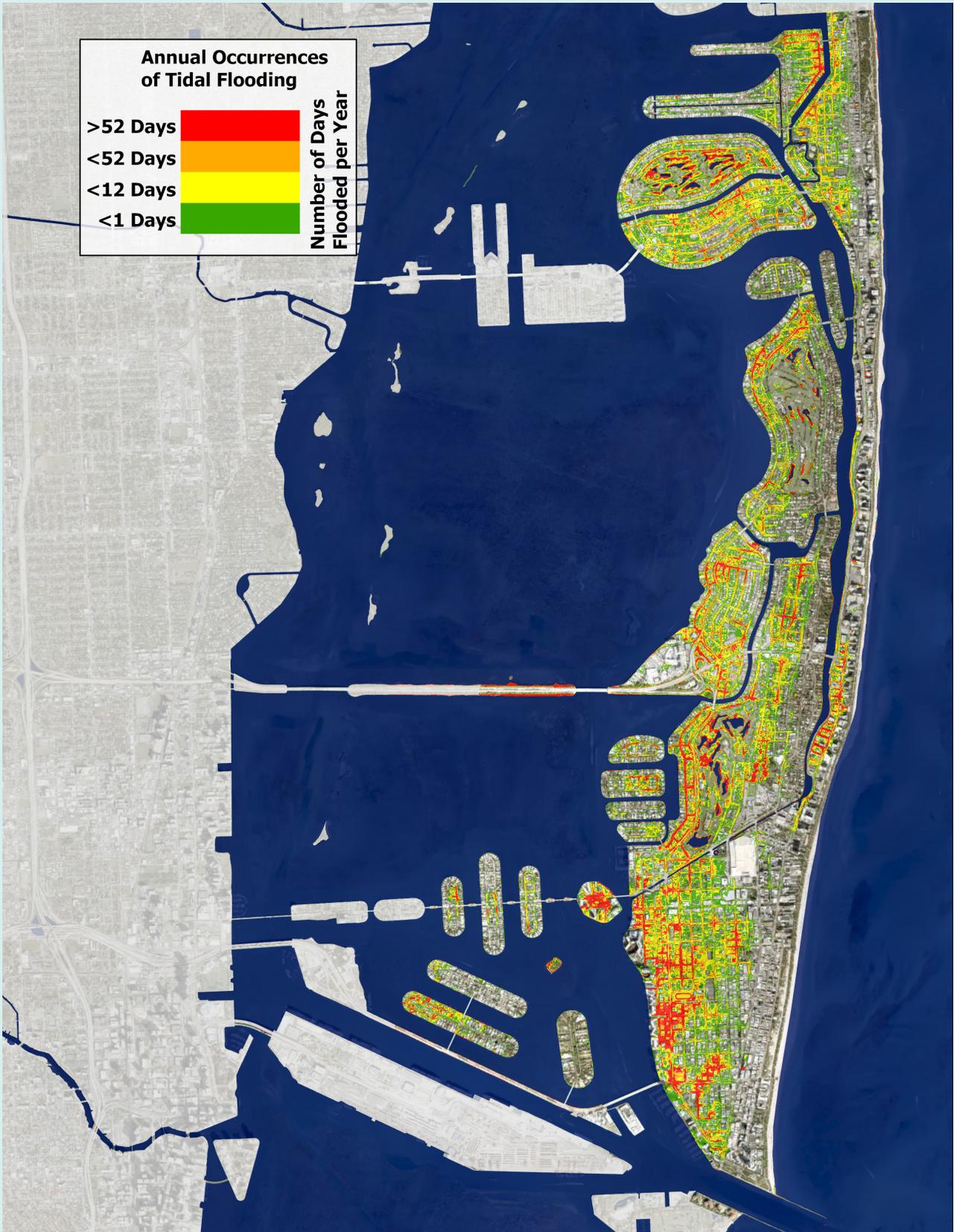


Figure 2.11: Example 2040 Tidal Flood Days flood map (NOAA 2040 Intermediate High scenario).

2.3.2 Compound Flooding

Compound flooding refers to a flooding event caused by two or more flood sources happening at the same time (e.g., a heavy rainfall event during a king tide). Compound flood events increase the flood extents and depths beyond what would be expected for a single flood source. High-intensity rain events can generate runoff that exceeds the City’s existing stormwater network capacity, leading to flooding of low-lying areas. Intense rainfall flooding is further worsened during a king tide, as elevated coastal water levels restrict stormwater discharge at coastal outfalls (**Figure 2.12**). In some areas, high tides can also backflow into the stormwater system and reduce storage capacity of the stormwater pipe network or flow to the ground surface through storm drains. This results in rainfall ponding in areas where stormwater infrastructure is unable to drain runoff efficiently.

In this Assessment, the existing compound flooding event was represented by the simultaneous occurrence of a 10-year⁵, 24-hour rainfall event (8.75 inches⁶) and a king tide. Future compound flood extents were considered by adding projected sea level rise amounts (**Figure 2.8**) to existing king tide water levels but maintained the same rainfall event for all scenarios. The compound flooding extent for the 2040 NOAA Intermediate High scenario (10-year, 24-hour rainfall event + 1.8 ft king tide + 1.0 ft of sea level rise) is shown in **Figure 2.13**.

King tide extents (shown in blue shades) and groundwater ponding areas (purple) will match those found in **Figure 2.9** as the coastal flood source (i.e., 2040 NOAA Intermediate High king tide) is the same. The pink areas represent the increased flood extent due to rainfall ponding.

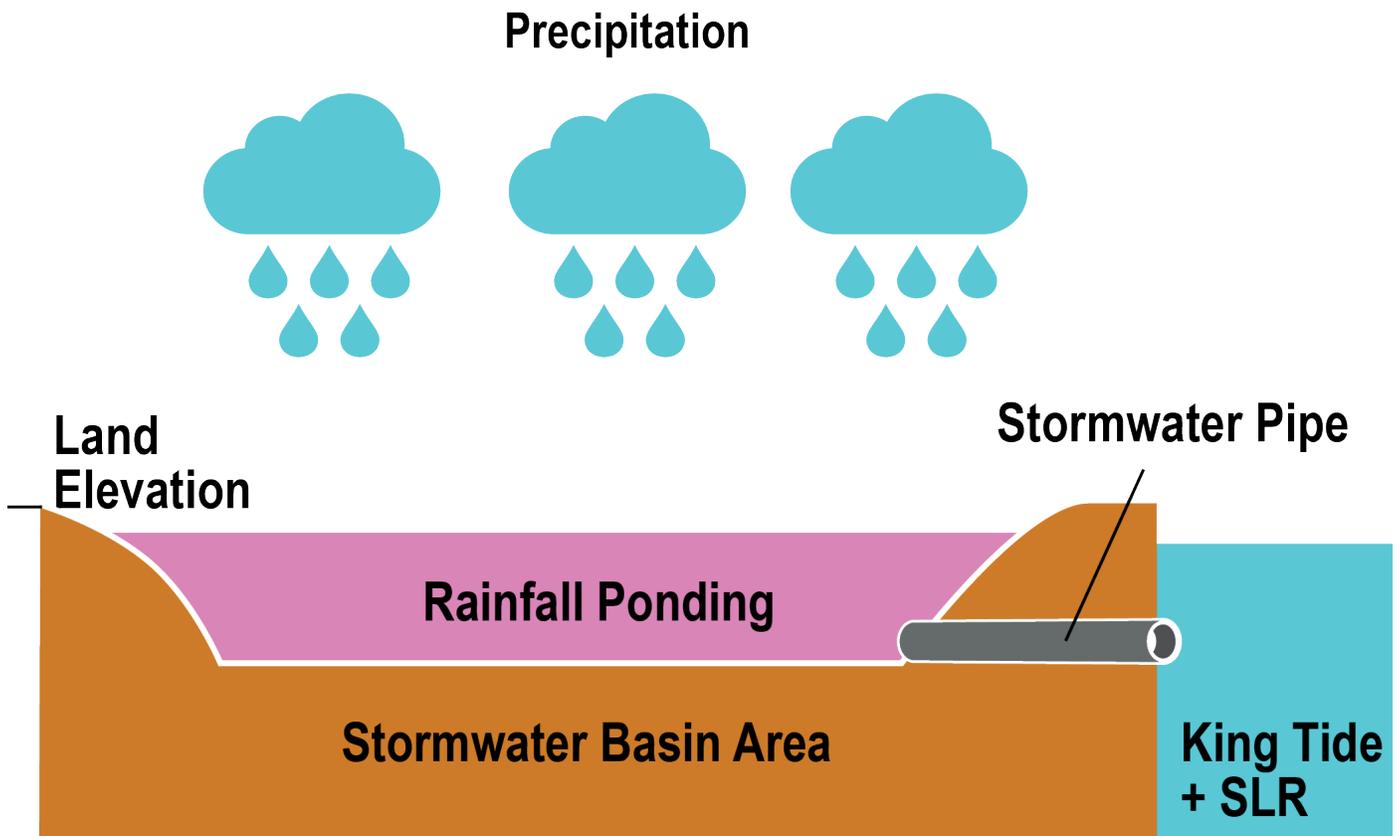


Figure 2.12: Conceptual diagram of compound flooding.

⁵ The 10-year rainfall event has a 10 percent chance of occurring in any given year.

⁶ The total Design Storm rainfall event is 8.75-inches, which was derived by multiplying the South Florida Water Management District published value of 7.00-inches for the Miami Beach area multiplied by a factor of safety of 1.25 (CDM Smith, 2017).



Figure 2.13: Compound flooding map example with a 10-year, 24-hour rainfall event (8.75 inches), king tide of 1.8 ft (NAVD, 88), and 1.0 ft of sea level rise (2040 NOAA Intermediate High Sea Level Rise).

Additional areas of interest exposed to the 2040 scenario are further described by City region below. The letter before each description is paired to a text box on the map (**Figure 2.13**) identifying the area of interest.

North Beach

- [A] Compound flooding impacts are the most extensive in the Biscayne Point neighborhood along Daytonia Rd., Cleveland Rd., and Stillwater Dr. Although this neighborhood is projected to experience limited flooding during high tide conditions, the combination of rainfall and high tide inhibits efficient stormwater drainage, flooding low-lying streets.
- [B] In the North Shore neighborhood, the addition of rainfall increases the flooding extent to the east, roughly doubling the projected flooded area compared to king tide flooding alone. The expanded flooding extent would affect important north-south connector roadways such as Dickens Ave. and Harding Ave.
- [C] The Normandy Isles neighborhood is projected to experience a greater increase in flood extents due to additional rainfall ponding on Normandy Shores, which is likely caused by more impervious surfaces and development on Normandy Isles.

Mid Beach

- [D] The addition of rainfall flooding more than doubles king tide-only flood extents in the La Gorce neighborhood, affecting large areas of the La Gorce Golf Course and La Gorce Dr., which is a major connector roadway on the island.
- [E] Rainfall flooding also expands flood extents in the eastern Nautilus and Bay Shore neighborhoods. All major roads in these neighborhoods, including the full length of Pine Tree Dr., are exposed to flooding with the addition of rainfall flooding.

South Beach

- [F] The addition of rainfall ponding to king tide extents increases the areas exposed to flooding to include the South Pointe neighborhood and several major roadways, including South Pointe Dr. and 2nd St.
- [G] Rainfall ponding expands flood extents to include the eastern areas of the Flamingo and Lummus neighborhood, affecting at least a portion of every major roadway in these neighborhoods.



Figure 2.14: 100-year (1-percent annual chance) storm tide (surge) flood map example at 6.2-feet above mean sea level with 1-foot of sea level rise (2040 NOAA Intermediate High scenario).

2.3.3 Storm Tide (Storm Surge) Flooding

Storm tide (or storm surge) flooding is caused by the high onshore wind speeds and low atmospheric pressure of large tropical storms and hurricanes, which temporarily elevate coastal water levels. Due to the City's low elevation and flat topography, even small increases in water levels during coastal storms can allow storm tide (storm surge) flooding to overtop shoreline protections and spread far inland, creating significant flooding impacts to the City's roadways and other coastal infrastructure.

The baseline (i.e., existing) storm tide (storm surge) flooding extent is represented by the Federal Emergency Management Agency (FEMA)⁷ 1-percent annual chance (i.e., 100-year) coastal water elevation⁸ (6.2 feet NAVD88). Future storm tide (storm surge) flood extents were considered by adding projected sea level rise amounts (**Figure 2.8**) to the baseline existing 1-percent annual chance coastal water elevation. Coastal storm flooding for the year 2040 (baseline 1-percent annual chance coastal water elevation + 1.0 ft of sea level rise) is shown in **Figure 2.14**. Depths of flooding are shown in shades of blue, with darker shades indicating deeper flooding. Shoreline areas projected to be overtopped are shown in yellow.

Under this scenario, storm tide (storm surge) water levels overtop most shoreline areas and widespread flooding occurs across the entire City, except for small portions of the eastern ridge where land elevations are the highest. Similar to the high tide flood maps (**Figure 2.9**), the bay side of the City experiences the deepest flood depths due to the lower relative elevation in this area of the City.

Additional areas of interest exposed to this future scenario are further described by City region below. The letter before each description is paired to a text box on the map (**Figure 2.14**) identifying the area of interest.

North Beach

- [A] Shorelines adjacent to Biscayne Bay and the canals are overtopped during this event, resulting in extensive flooding in all neighborhoods of North Beach. The Biscayne Point, Normandy Isles, and Normandy Shores neighborhoods experience large areas of deep floodwaters (>5 ft).

- [B] North Shore's eastern shoreline is largely protected by the high elevations of the coastal dune system. However, most of the neighborhood is still affected by flooding from the west.

Mid Beach

- [C] All shorelines adjacent to Biscayne Bay and the canals are overtopped with expansive flooding of the entire area, except for the Mt. Sinai Hospital complex. The western areas of the La Gorce, Nautilus, and Bay Shore neighborhoods experience the greatest flood depths (>5 feet).
- [D] The Ocean Front neighborhood is partially protected due to the higher elevation of the coastal dune system. While flooding is still present through this narrow coastal neighborhood, flood depths are projected to be slightly lower.

South Beach

- [E] Similar to North and Mid Beach, shorelines along Biscayne Bay and the canals are overtopped in this scenario, resulting in widespread flooding across all South Beach neighborhoods. Flood depths are the deepest (>5 feet) in the Flamingo and Lummus, West Ave. and Bay Rd., and South Pointe neighborhoods. Flooding depths of four-to-five feet may extend as far inland as Washington Ave.
- [F] Shoreline overtopping and extensive flooding is also projected for the Venetian Islands and the Star, Palm, and Hibiscus Island neighborhoods.
- [G] Only a narrow area on the east side of the City Center, Flamingo and Lummus, and South Pointe neighborhoods are projected to avoid flooding.

The duration of flooding due to a coastal storm event was not modeled as part of this mapping approach. Flood depths associated with an extreme coastal storm can cause flooding that persists for several hours to a week. These storms are also often associated with strong winds that generate large waves, which could cause shoreline erosion and more extensive and deeper flooding than indicated on the maps.

⁷ FEMA South Florida Flood Insurance Study Report

⁸ The 1-percent annual chance coastal storm elevation has a 1-percent chance of occurring in any year. This projected flood level does not include the effect of waves.

2.4 Vulnerability Assessment and Key Findings

With the critical assets identified and flooding scenarios mapped, the next step was to analyze the overlap between the two data sources to evaluate each asset’s vulnerability to future sea level rise. As outlined in Section 2.1 and shown in **Figure 2.1**, a scoring methodology was developed to quantify the relative vulnerability of the City’s assets and allow for comparison among assets. The three primary measures of this methodology were: exposure, sensitivity, and consequence. Additional information, including how scores were captured for each, is provided below.

Flood Exposure

Exposure scores were established by summing the number of flood scenarios that would impact an asset. If a modeled flood scenario extent overlapped with an asset’s location, the asset was considered exposed and would receive a point (1) for that scenario. As there were three flood sources (king tide, compound flooding, storm tide (storm surge)) modeled for seven sea level rise scenarios⁹, exposure scores ranged from 0–21. An asset projected to be exposed to all flood scenarios would receive an exposure score of 21.

Sensitivity and Consequence

While an asset’s exposure measure was determined quantitatively, the sensitivity and consequence measures were evaluated and scored based on qualitative classifications. For sensitivity, an asset was classified and scored based on the likelihood that it would fail, incur significant damage, or become unusable due to flood exposure. Assets more likely to be sensitive when exposed to floodwaters received higher scores. The classifications were rated: Not Sensitive, Low, Moderate, or High. Sensitivity scores were based on a maximum score of 21 to maintain equality with the exposure measure. Scoring classifications¹⁰ are shown in **Table 2.2**.

For consequence, an asset was classified based on the severity of community impacts that would occur should the asset fail, incur significant damage, or become unusable due to flood exposure. Assets more likely to generate significant, widespread community impacts due to their failure received higher scores. No assets were determined to have

Table 2.2: Sensitivity classifications and scoring used in the Vulnerability Assessment.

Classification	Score
Not Sensitive	0
Low	7
Moderate	14
High	21

Table 2.3: Consequence classifications and scoring used in the Vulnerability Assessment.

Classification	Score	Within a Socially Vulnerable Neighborhood
Low	7	
Moderate	14	+1
High	21	

‘No Consequence’ of failure, so consequence classifications could be: Low, Moderate or High. Consequence scores were also based on a maximum score of 21 (**Table 2.3**), however an asset received an additional point if it was located within a socially vulnerable neighborhood (**Figure 2.15**).

⁹ The seven sea level rise scenarios for each flood source were: Existing conditions, the NOAA 2040 Intermediate (Int.) Low, 2040 Int. High, 2040 High, and 2070 Int, Low, Int. High, and High scenarios.

¹⁰ Most assets were scored based on the sensitivity and consequence classification applied at the Asset Type (e.g., Stormwater Pump Stations), as individual asset information was not available for all assets (See Appendix E.3 for additional information).



Figure 2.15: Miami Beach Socially Vulnerable Neighborhoods.

Socially vulnerable neighborhoods were identified as the City census tracts in the Top 25% of the Center for Disease Control's Social Vulnerability Index (SVI). These census tracts have larger populations of the elderly, children, individuals with a disability, lower-income families, residents without access to a personal vehicle, or other demographic and household characteristics that make it harder for these individuals to properly prepare for and recover from natural hazard events, such as flooding (CDC, 2020).

During the stakeholder engagement events (see Appendix A), several participants noted that socially vulnerable populations are already being disproportionately impacted by current flooding events. Impacts mentioned included a higher risk of injury for elderly residents, increased social isolation for these individuals, and longer commute times for those who lack personal vehicles and are dependent on public transportation. The additional point added to the consequence score of assets in the socially vulnerable neighborhoods provides the City an opportunity to identify assets that serve the City's most disadvantaged residents and account for the increased impacts to these communities should the asset fail.

2.5 Vulnerability Assessment Key Findings

The Assessment resulted in a ranked list of the nearly 60,000 considered assets based on vulnerability scores. The assets with the highest vulnerability scores were wastewater pipelines located in socially vulnerable neighborhood areas. Older wastewater pipelines, particularly those installed more than 70 years ago, received high sensitivity and consequence classifications and scores due to their older age and critical service provided to the City's residents and businesses. The distributed nature of these assets also led to many wastewater pipeline segments in low-lying areas to be exposed to most, if not all, of the considered flooding scenarios. The high scores received across all Assessment measures resulted in these wastewater pipeline segments receiving the highest vulnerability scores among City assets and representing the only assets to receive the maximum possible vulnerability score of 64. The two assets

Vulnerability Score

Scores for each of the Assessment measures (exposure, sensitivity, and consequence) were then totaled per asset to determine an asset-specific vulnerability score. Vulnerability scores could range from '7' to '64' and assets were ranked by their associated score from highest to lowest. The assets with higher scores indicated a greater vulnerability to future sea level rise and represent the City's key vulnerabilities to this hazard. (For additional information on the Assessment methodology and scoring, see Appendix E). The following section provides an overview of these key vulnerabilities, including the most vulnerable City assets throughout different areas of the City.

with the lowest vulnerability scores of 14 were two minor roadways (Pennsylvania Ct. and Alton Rd/I-195 onramp) with no projected exposure to any of the considered flood scenarios.

Identifying the most vulnerable assets is useful for the City to prioritize adaptation measures that address these key vulnerabilities. However, the sheer number of assets throughout Miami Beach considered in the Assessment can make it difficult to determine and discuss vulnerabilities beyond those at the top of the list. Therefore, additional Assessment findings have been organized based on Asset Type and geographic location to more easily understand the City's most vulnerable assets and areas. The following sections provide the key findings of the Assessment in the context of this organization. More information on each is provided below.

Asset Subcategories

The City’s asset inventory includes a mix of single location assets (e.g., buildings, pumps), distributed infrastructure assets (e.g., roadways, pipelines), and site-based assets (e.g., parks). The dimensional differences (i.e., location vs. length vs. area) make it difficult to describe flooding exposure, and therefore vulnerability, collectively. Assessment findings in this section are organized based on like-footprints

(i.e., location vs. length vs. area) and findings are referred to in the context of three generalized asset subcategories: ‘Structures & Facilities’ for single location assets, ‘Roadways & Pipelines’ for distributed infrastructure assets, and ‘Natural Resources’ for site-based assets. **Table 2.4** provides a crosswalk of which Asset Types are included in each of these subcategories.

Table 2.4: Crosswalk of Asset Types in each Vulnerability Assessment Subcategory

FDEP Asset Category	Asset Subcategory	Asset Types Included	
Critical Infrastructure	Structures & Facilities	<ul style="list-style-type: none"> Wastewater Lift Stations Electrical Substations Potable Water Pump Stations Potable Water Storage Tanks 	<ul style="list-style-type: none"> Stormwater Pump Stations Telecommunication Towers Disaster Debris Management Sites
	Roadways & Pipelines	<ul style="list-style-type: none"> Wastewater Pipelines 	<ul style="list-style-type: none"> Drinking Water Pipelines
Critical Community and Emergency Facilities	Structures & Facilities	<ul style="list-style-type: none"> Schools Colleges and Universities Community Centers Emergency Operations Centers Fire Stations 	<ul style="list-style-type: none"> Hospitals Law Enforcement Facilities Local Government Facilities Logistical Staging Areas Affordable Public Housing State Government Facilities
Natural, Cultural, and Historical Resources	Structures & Facilities	<ul style="list-style-type: none"> Historical and Cultural Assets 	
	Natural Resources	<ul style="list-style-type: none"> Parks 	<ul style="list-style-type: none"> Living Shorelines
Transportation Assets and Evacuation Routes	Structures & Facilities	<ul style="list-style-type: none"> Bridges Bus Stop 	<ul style="list-style-type: none"> Marinas
	Roadways & Pipelines	<ul style="list-style-type: none"> Major Roadways 	

City Subregions

Additionally, due to the number of assets considered in the Vulnerability Assessment, key vulnerabilities will be discussed geographically based on the City’s three main regions (i.e., North, Mid, and South Beach)

and at a subregional (i.e., neighborhood) scale. The neighborhoods contained in each subregion are shown in **Table 2.5** (Refer to **Figure 1.2** for neighborhood locations).

Table 2.5: City subregions and neighborhoods used to describe Vulnerability Assessment findings

City Region	City Subregion	Neighborhood(s) Included
North Beach	A	Biscayne Point
	B	Normandy Shores Normandy Isles
	C	North Shore
Mid Beach	A	La Gorce
	B	Nautilus Bay Shore
	C	Ocean Front
South Beach	A	South Venetian Islands Star-Palm-Hibiscus Islands
	B	West Ave & Bay Road City Center Flamingo & Lummus
	C	South Pointe

The following discussion of key vulnerabilities will first be framed by introducing each City region with a high-level overview of the assets located there and where the assets with higher vulnerability scores are located. Following this, the specific assets with higher vulnerability in each subregion will be provided.

Higher vulnerability assets are those with scores in the highest quantile of vulnerability scores (Refer to Appendix E.7 for additional information). Each subsection will conclude with the key vulnerabilities of each City region. City-wide key takeaways will be provided at the end of this section.

2.5.1 North Beach Vulnerability

The North Beach region includes areas north of W 63rd St to the City’s northern border, known as the North Shore neighborhood, and the island neighborhoods of Normandy Isles, Normandy Shores, and Biscayne Point to the west. For ease in discussing

the key findings of the Vulnerability Assessment, these areas of North Beach have been divided into three subregions based on neighborhood boundaries (**Table 2.5**) and are shown in **Figure 2.16**.



Figure 2.16: North Beach subregions and neighborhoods for Vulnerability Assessment.

North Beach Higher Vulnerability Assets

North Beach includes 118 (22%) of the City's Structures & Facilities, 154 miles (24%) of the City's Pipelines & Roadways and 16 (33%) of the City's Natural Resources. The region has the largest number of community centers and affordable public housing in the City. The

largest socially vulnerable neighborhood areas are also in North Beach and represent the entire Normandy Isles neighborhood and nearly all of the North Shore neighborhood. **Figure 2.17** shows the locations of North Beach assets with higher vulnerability¹¹.



Figure 2.17: Map of higher vulnerability assets in North Beach.

¹¹ Higher vulnerability assets were those in the top 33% of vulnerability scores for Structures & Facilities and Natural Resources subcategories, but the top 10% of vulnerability scores for Pipelines & Roadways due to the number of pipeline and roadway feature segments.

In addition to having the most assets for the region, the North Shore neighborhood also has the highest proportion of higher vulnerability assets, except for Pipelines & Roadways (Table 2.6). Table 2.7 through Table 2.9 provide the higher vulnerability assets within each North Beach subregion. The North Beach Structures & Facilities that are characterized to have higher vulnerability are primarily located in areas adjacent to the Biscayne Bay canals of the North Shore and Biscayne Point neighborhoods.

All segments of higher vulnerability Pipelines & Roadways are represented by wastewater pipelines because of the higher sensitivity and consequence classifications for these assets relative to drinking water pipelines and roadways. All of the higher vulnerability wastewater pipeline sections were installed over 70 years ago. These are primarily located along roadways that are parallel to Biscayne Bay or canal shorelines. However, there are also higher vulnerability wastewater pipelines further inland from the shoreline in both the North Shore and Normandy Shores and Normandy Isles neighborhoods.

All North Beach higher vulnerability Natural Resources areas are in socially vulnerable neighborhoods and are all located on or only one street away from Biscayne Bay or a canal shoreline.

North Beach Assets with Highest Vulnerability Scores



Structure & Facility:

Stormwater Pump Station #23 located at 86th St. and Hawthorne Ave. in Biscayne Point (Score = 61).



Pipeline & Roadway:

Wastewater pipelines located at the end of Bay Dr. in the Normandy Isles neighborhood (64).



Natural Resource:

North Shore Park and Youth Center in the North Shore neighborhood (55).

Table 2.6: City subregions and neighborhoods used to describe Vulnerability Assessment findings.

	A (Biscayne Point)	B (Normandy Shores + Normandy Isles)	C (North Shore)	Total
 Structures & Facilities	9 sites	6 sites	11 sites	26 sites
 Pipelines & Roadways	2 miles	11 miles	10 miles	22 miles
 Natural Resources	1 area	2 areas	4 areas	7 areas

Higher vulnerability assets were those in the top 33% of vulnerability scores for Structures & Facilities and Natural Resources subcategories, but the top 10% of vulnerability scores for Pipelines & Roadways due to the number of pipeline and roadway feature segments.

Table 2.7: North Beach Subregion A (Biscayne Point) higher vulnerability assets.

Asset Type	Asset Name/ Mileage	Vulnerability Score (max = 64)
Affordable Public Housing	Madeleine Village Apartments 1	40.5
	Madeleine Village Apartments 3	41
	Madeleine Village Apartments 4	40.5
Bridges	SST61308	47
Bus Stop	85th ST & Crespi Blvd	41
Natural Resources	Stillwater Park	48
Stormwater Pump Stations	#23	61
	#30	51
Wastewater Pump Stations	PS 24	53
Wastewater Pipelines*	1.5 miles	64*

* Due to the number of higher vulnerability assets for this Asset Type, only the highest score is shown.

Table 2.8: North Beach subregion B (Normandy Shores and Normandy Isles) higher vulnerability assets.

Asset Type	Asset Name/ Mileage	Vulnerability Score (max = 64)
Bus Stop	71st & Rue Notre Dame	41
Community Centers	Fairway Park Pavilion	48
	Coral House Senior Center	44
Natural Resources	Fairway Park	48
	Normandy Shores Park	48
Wastewater Pump Stations	PS 22	54
	PS 21	49
Water Pump Station	Normandy Isle	57
Wastewater Pipelines*	11 miles	64*

* Due to the number of higher vulnerability assets for this Asset Type, only the highest score is shown.

Table 2.9: North Beach Subregion C (North Shore) higher vulnerability assets.

Asset Type	Asset Name/ Mileage	Vulnerability Score (max = 64)
Affordable Public Housing	Lottie Apartments	40.5
Bridge	SST61313	47
Bus Stops	85th St & Byron Ave	42
Electrical Substations	Harding Ave Substation North	60
	Harding Ave Substation	54
Fire Station	#4	45.5
Law Enforcement Facility	Sailport/Police Substation	41
	Brittany Bay Park	48
Natural Resources	North Beach Oceanside Park	52
	North Shore Park and Youth Center	55
	Tatum Park	48
School	Biscayne Elementary	50
Wastewater Pump Stations	PS 19	52
	PS 23	55
	PS 29	50
Water Pump Station	75th Street	54
Wastewater Pipelines*	9 miles	64*

* Due to the number of higher vulnerability assets for this Asset Type, only the highest score is shown.



North Beach Key Vulnerabilities

- North Beach assets with higher vulnerability scores are primarily located near canal shorelines, such as those along Crespi Blvd. in the Biscayne Point neighborhood and the Tatum Waterway Dr. and Indian Creek Dr. roadways in the North Shore neighborhood. At these locations, these assets are projected to be impacted by king tide flooding when sea levels rise by one foot (2040 NOAA Intermediate High scenario).
- Many North Beach critical assets, such as electrical substations, water pump stations, stormwater pump stations and wastewater pump stations, are highly vulnerable to future sea level rise. Without adaptation measures, sea level rise impacts to these assets could make it challenging for them to continue providing service to residents.
- North Beach has the largest proportion of higher vulnerability wastewater pipelines in the City. All of these pipeline segments were installed over 70 years ago (or have an unknown age) and are primarily located in socially vulnerable neighborhood areas.
- The North Beach region includes the largest socially vulnerable neighborhood areas and the greatest number of assets within these neighborhoods, primarily in the North Shore neighborhood. More than half of the community centers in North Beach are in socially vulnerable areas, including the Coral House Senior Center which is classified with higher vulnerability.

2.5.2 Mid Beach Vulnerability

The City's Mid Beach region includes areas north of Dade Blvd. and south of W 63rd St. and is comprised of the La Gorce, Nautilus, Bay Shore and Ocean Front neighborhoods. To more easily discuss

Assessment findings, the neighborhoods have been organized into the subregions shown in **Table 2.5** and **Figure 2.18**.



Figure 2.18: Mid Beach subregions and neighborhoods for Vulnerability Assessment.

Mid Beach Assets

The Mid Beach region includes 199 (38%) of the City's total Structures & Facilities, 261 miles (41%) of all Pipelines & Roadways and 16 (33%) of the Miami Beach's Natural Resource areas. This region includes both City emergency operations centers, Mt. Sinai Hospital and three fire stations. The region also

includes the greatest number of bridges among the three regions, connecting the multiple neighborhoods. Socially vulnerable neighborhood areas are limited to the southern Ocean Front neighborhood. **Figure 2.19** shows the locations of Mid Beach assets with higher vulnerability¹².

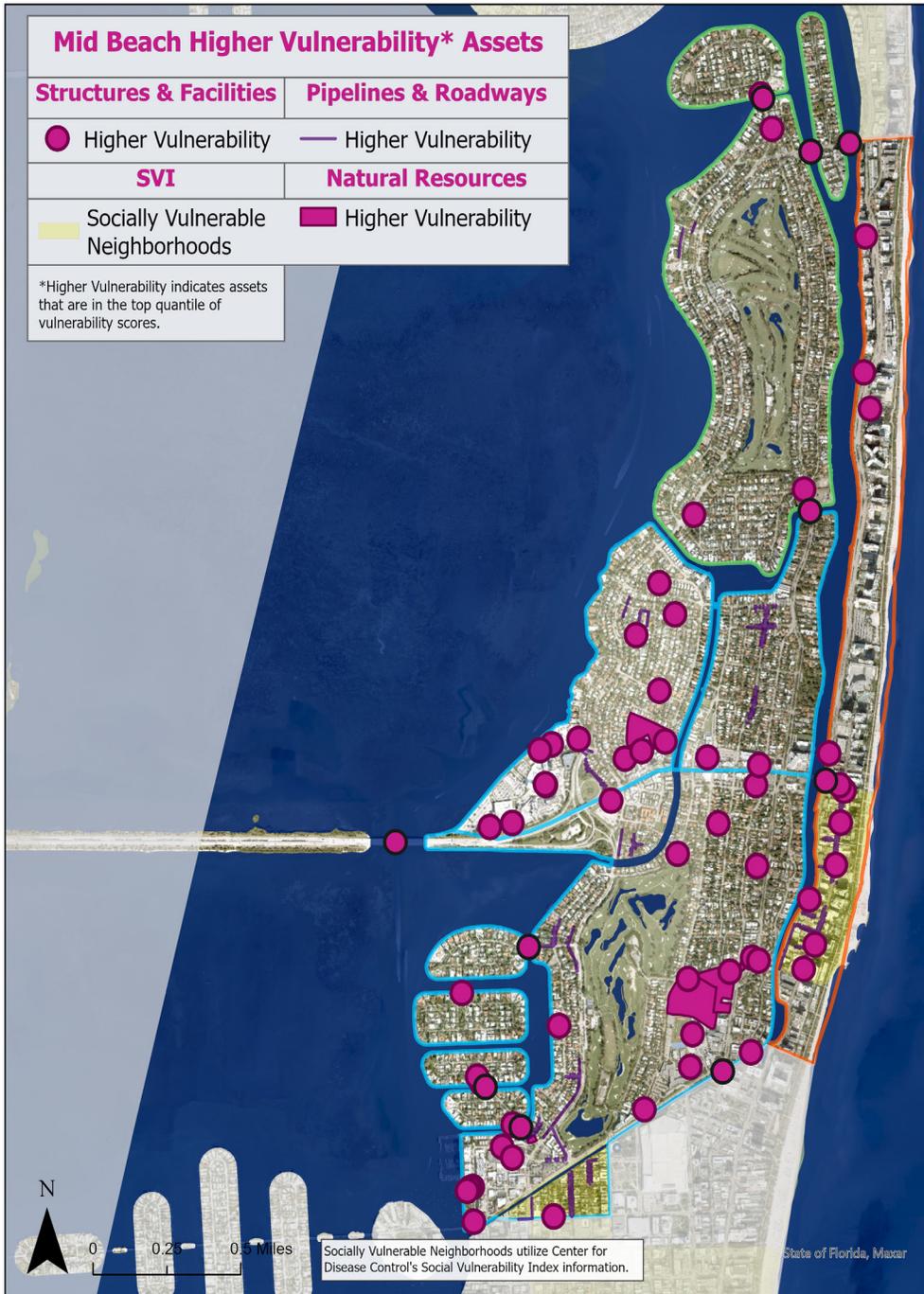


Figure 2.19: Map of higher vulnerability assets in Mid Beach.

¹² Higher vulnerability assets were those in the top 33% of vulnerability scores for Structures & Facilities and Natural Resources subcategories, but the top 10% of vulnerability scores for Pipelines & Roadways due to the number of pipeline and roadway feature segments.

The Nautilus and Bay Shore subregion includes both the greatest number of Mid Beach assets and the largest number of those with higher vulnerability in the Mid Beach region. The La Gorce and Ocean Front neighborhoods have the fewest higher vulnerability assets among City subregions (Table 2.10). In Subregion B, the higher vulnerability Structures & Facilities are generally spread throughout the neighborhoods, including inland away from Biscayne Bay or canal shorelines.

As with North Beach, all higher vulnerability Pipelines & Roadways are represented by wastewater pipelines due to the higher sensitivity and consequence scores. All of these wastewater pipeline sections were installed over 70 years ago. These segments of wastewater pipelines are distributed throughout Mid Beach’s neighborhoods, but most segments are located near Biscayne Bay or canal shorelines.

Four of the five Mid Beach’s Natural Resource areas classified to have higher vulnerability are in the southern Nautilus or Bayshore neighborhood.

Table 2.10: Number of higher vulnerability assets per Mid Beach subregion.

	A (La Gorce)	B (Nautilus + Bay Shore)	C (Ocean Front)	Total
 Structures & Facilities	7 sites	46 sites	13 sites	66 sites
 Pipelines & Roadways	< 1 mile	4 miles	1 mile	5 miles
 Natural Resources	1 area	4 areas	0 areas	5 areas

Higher vulnerability assets were those in the top 33% of vulnerability scores for Structures & Facilities and Natural Resources subcategories, but the top 10% of vulnerability scores for Pipelines & Roadways due to the number of pipeline and roadway feature segments.

Tables 2.11 through 2.13 provide the higher vulnerability assets within each Mid Beach subregion.

Table 2.11: Mid Beach Subregion A (La Gorce) higher vulnerability assets.

Asset Type	Asset Name/ Mileage	Vulnerability Score (max = 64)
Bridges	SST61319	49
	SST61320	44
	SST61348	49
Community Centers	La Gorce Park Pavilion	47
	Fisher Park Pavilion	47
Natural Resources	La Gorce Park	41
Wastewater Pump Stations	PS 18	49
	PS 15	53
Wastewater Pipelines	<1 mile	63

Mid Beach Assets with Highest Vulnerability Scores



Structure & Facility:

Two stormwater pump stations (#11, #13) located in the Nautilus neighborhood and one (#22) located in Bay Shore (Score = 62).



Pipeline & Roadway:

Wastewater pipelines located in the Ocean Front socially vulnerable neighborhood area (63).



Natural Resource:

Scott Rakow Youth Center Grounds and Park Area in Bay Shore (55). This specifically refers to the greenspaces and larger footprint of the Scott Rakow grounds. It currently includes portions of what will be Bayshore Park.

Table 2.12: Mid Beach subregion B (Nautilus and Bay Shore) higher vulnerability assets.

Asset Type	Asset Name/ Mileage				Vulnerability Score (max = 64)
Bridges*	SST61326		SST61330		51*
	SST61328*		SST61335		
	SST61329				
Bus Stop	17th St. & Lennox Ave.				42
Community Centers	Scott Rakow Center				45
	Jewish Learning Center				47
Electrical Substations	West Ave. Substation				61
	W 40th St. Substation				59
Hospital	Mt. Sinai Hospital Buildings				50
Law Enforcement Facilities	Marine Patrol Building				41.5
Schools	Miami Beach Senior High School				44
	Nautilus Middle School				49
	North Beach Elementary School				48
Stormwater Pump Stations*	#1	#9	#14	#21	62*
	#2	#10	#17	#22*	
	#2A	#11*	#18	#24	
	#3	#12	#19	#43	
	#8	#13*	#20	#44	
Natural Resources	Scott Rakow Youth Center Grounds and Park Area				55
	Bay Shore Park				49
	Polo Park				48
	20th St. Pocket Park				42
Wastewater Pump Stations	PS 14				51
	PS 13				53
	PS 28				53
Water Pump Station	41st St.				60
	25th St.				51
Wastewater Pipelines	4 miles				63

* Due to the number of higher vulnerability assets for this Asset Type, only the highest score is shown.

Table 2.13: Mid Beach Subregion C (Ocean Front) higher vulnerability assets.

Asset Type	Asset Name/ Mileage	Vulnerability Score (max = 64)
Bridge	SST61324	54
	SST61329	43
Bus Stops	Collins Ave & 38th St.	42
	Collins Ave & 29th St.	42
	Collins Ave & 27th St.	42
	Collins Ave & 41st St.	42
	Collins Ave & 35th St.	43
	Collins Ave & 41st St.	42
	Electrical Substations	Collins Ave Substation
Fire Station	#3	41.5
Stormwater Pump Stations	#29	61
	#50	59
Wastewater Pump Station	PS 27	53
Wastewater Pipelines	1 mile	63



Mid Beach Key Vulnerabilities

- Mid Beach assets with higher vulnerability are primarily located in the southern part of the region, in the Nautilus, Bay Shore, and Ocean Front neighborhoods. These assets are roughly split between being located near the shoreline and more inland.
- All of Mid Beach's emergency response facilities are considered to have higher vulnerability including Mt. Sinai Hospital, Fire Station #3, and the marine patrol building.
- Several of the bridges connecting the neighborhoods in this region are classified with higher vulnerability. Should these assets become inaccessible due to flooding, residents and commuters may become stranded.
- The City's most vulnerable bus stop locations are in the socially vulnerable neighborhood area in Ocean Front. These bus stops are projected to be exposed to groundwater flooding under existing conditions and all future sea level rise scenarios as well.
- Mid Beach has the largest number of Pipelines & Roadway mileage in the City but has half of the higher vulnerability mileage of North Beach. Similar to North Beach, all the wastewater pipelines with higher vulnerability were installed over 70 years ago. The Mid Beach segments are more distributed than in North Beach, however there are several in the Ocean Front socially vulnerable neighborhood area.

2.5.3 South Beach Vulnerability

The South Beach region of the City is comprised of areas south of Dade Blvd to South Pointe, which includes the City Center, West Ave & Bay Road, Flamingo and Lummus, and South Pointe neighborhoods. This region also includes the western island neighborhoods of the South Venetian Islands and the Star-Palm-Hibiscus Islands.

The South Beach neighborhoods have been organized into the subregions shown in **Table 2.5** and **Figure 2.20** to describe the findings of the Assessment for this area of the City.

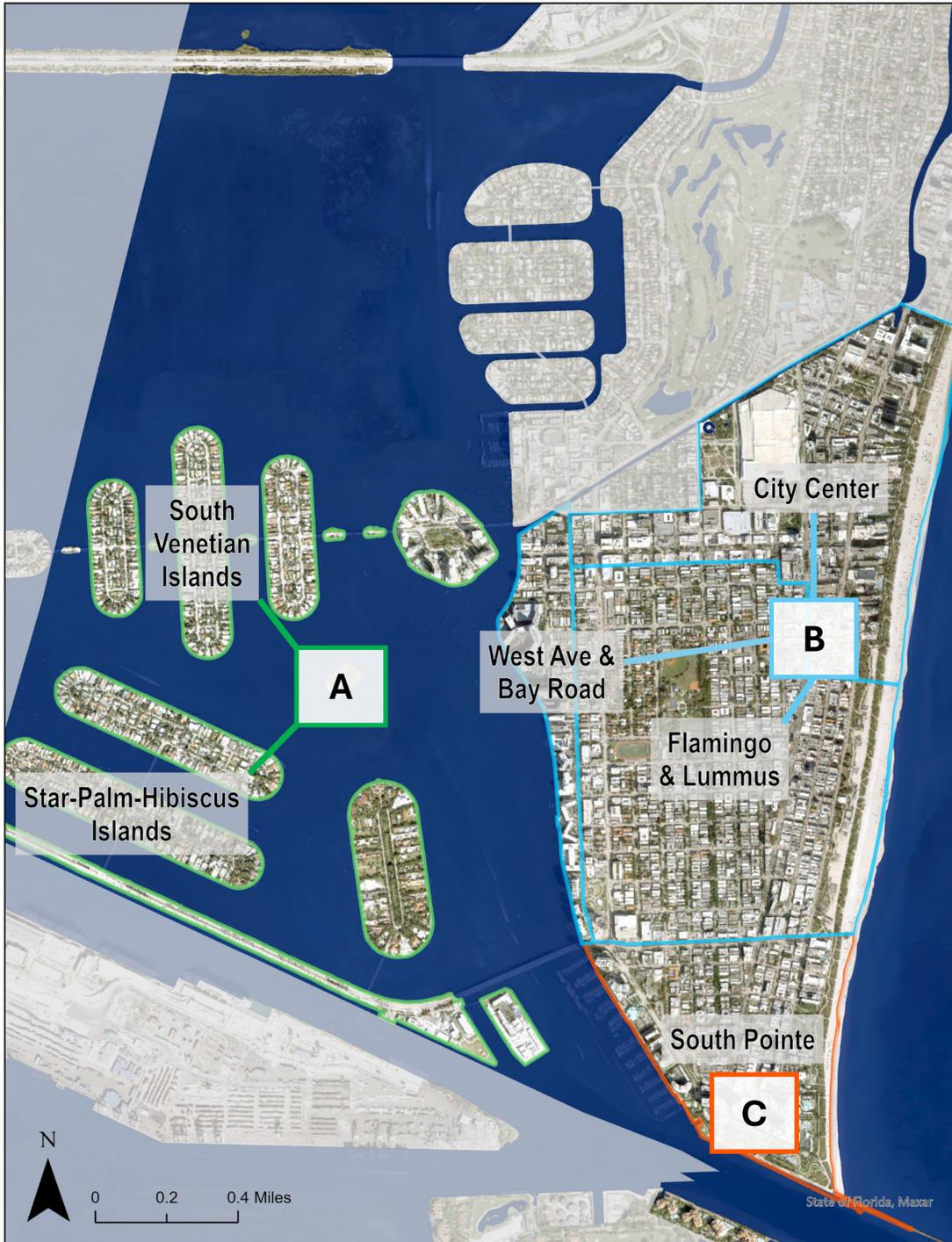


Figure 2.20: South Beach subregions and neighborhoods for Vulnerability Assessment.

South Beach Assets

South Beach includes the largest proportion of the City’s Structures & Facilities with 213 (40%), 220 (35%) miles of Pipelines & Roadways, and 16 (33%) Natural Resource areas. The main police headquarters, Fire Station #1, the Convention Center and most local government buildings are located in South Beach. The region also includes

the greatest number of stormwater and wastewater pumps stations. South Beach’s socially vulnerable neighborhood areas are primarily located in the north and south of the Flamingo and Lummus neighborhoods. **Figure 2.21** shows the locations of assets with higher vulnerability¹³ in South Beach.

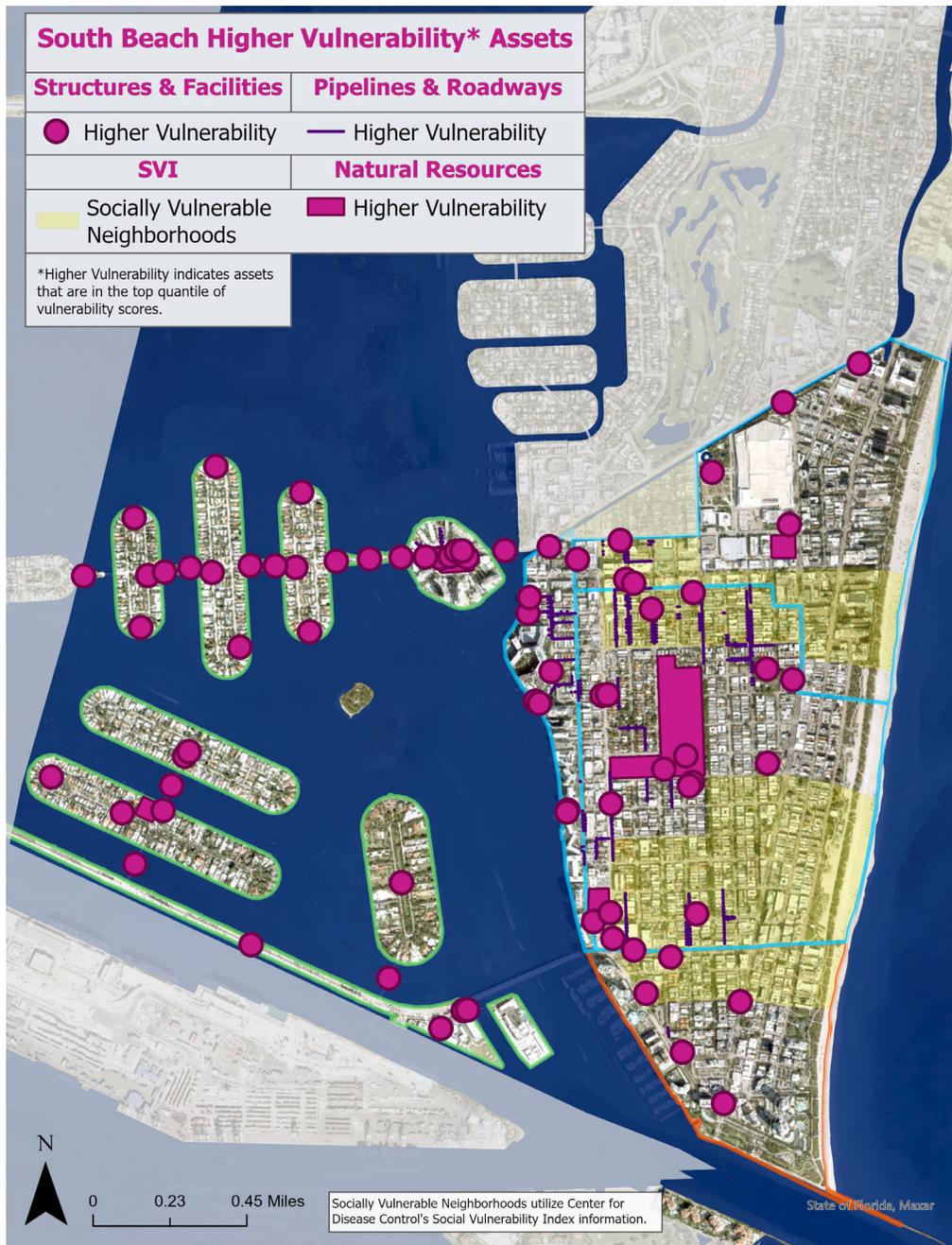


Figure 2.21: Map of higher vulnerability assets in South Beach.

¹³ Higher vulnerability assets were those in the top 35% of vulnerability scores for Structures & Facilities and Natural Resources subcategories, but the top 10% of vulnerability scores for Pipelines & Roadways due to the number of pipeline and roadway feature segments.

Table 2.14 provides an additional breakdown of where these higher vulnerability assets are in each South Beach subregion. Subregion A includes the greatest number (37) of higher vulnerability Structures & Facilities, of which 13 are bridges connecting the island neighborhoods. Subregion B also has a large proportion of South Beach’s higher vulnerability Structures & Facilities and the greatest percentage of Pipelines & Roadways and Natural Resource areas.

Similar to the other two City regions, all of South Beach’s higher vulnerability Pipelines & Roadways are wastewater pipeline segments due to the high sensitivity and consequence classifications for the Asset Type. These pipeline segments are located in the West Ave. and Bay Rd. neighborhood and the northern socially vulnerable neighborhood area of the Flamingo and Lummus neighborhood.

Flamingo Park is the most vulnerable Natural Resource area in South Beach and the City. The South Beach region includes five of the Natural Resource areas with the highest vulnerability scores in the City. None of these natural resource areas are located within South Beach’s socially vulnerable neighborhood areas.

South Beach Assets with Highest Vulnerability Scores

 **Structure & Facility:** Stormwater pump station (#33) located at the end of Bay Rd. in the West Ave. and Bay Rd. neighborhood (Score = 63).

 **Pipeline & Roadway:** Wastewater pipelines located in the West Ave. & Bay Rd. neighborhood and the socially vulnerable neighborhood area of the Flamingo and Lummus neighborhood (63).

 **Natural Resource:** Flamingo Park in the Flamingo and Lummus neighborhood (56).

Table 2.14: Number of higher vulnerability assets per South Beach subregion.

	A (South Venetian Islands + Star-Palm-Hibiscus Islands)	B (West Ave. & Bay Rd + City Center + Flamingo & Lummus)	C (South Pointe)	Total
 Structures & Facilities	37 sites	33 sites	6 sites	76 sites
 Pipelines & Roadways	< 1 mile	5 miles	<1 mile	5 miles
 Natural Resources	2 areas	3 areas	0 areas	5 areas

Higher vulnerability assets were those in the top 33% of vulnerability scores for Structures & Facilities and Natural Resources subcategories, but the top 10% of vulnerability scores for Pipelines & Roadways due to the number of pipeline and roadway feature segments.

Tables 2.15 through 2.17 provide an overview of the higher vulnerability (i.e., highest quantile) assets within each South Beach subregion.

Table 2.15: South Beach Subregion A (South Venetian Islands + Star-Palm-Hibiscus Islands) higher vulnerability assets.

Asset Type	Asset Name/ Mileage	Vulnerability Score (max = 64)	
Bridges*	SST61341	SST61347	
	SST61342	SST61350	
	SST61343*	SST61351	56*
	SST61344	SST61352	
	SST61345	SST61353	
	SST61346	SST61354	
Bus Stop	Venetian Way & E Island Ave	42	
	Venetian Way & W Island Ave	42	
Electrical Substations	MacArthur Causeway Substation	58	
Natural Resources	Belle Isle Park	42	
	Palm Island Park	43	
Stormwater Pump Stations*	#5*	#39	
	#34	#40	
	#35	#41	61*
	#36	#42	
	#37		
Wastewater Pump Stations*	PS 2	PS 7	
	PS 4	PS 8	
	PS 5	PS 10*	61*
	PS 6	PS 30	
Water Pump Stations	Belle Isle	62	
	Terminal Isle	49	
Wastewater Pipelines*	< 1 mile	63*	

* Due to the number of higher vulnerability assets for this Asset Type, only the highest score is shown.

Table 2.16: South Beach subregion B (West Ave. & Bay Rd + City Center + Flamingo & Lummus) higher vulnerability assets.

Asset Type	Asset Name/ Mileage		Vulnerability Score (max = 64)
Affordable Public Housing	Neptune Apartments		50
Bridges	SST61332		58
Bus Stops*	5th St. & Lenox Ave. 6th St & Alton Rd. 14th St & Alton Rd. 10th St. & Alton Rd.	17th St. & Lenox Ave. 14th St. & Alton Rd. 16th St. & Michigan Ave. 5th St. & Michigan Ave.*	43*
Community Centers	Miami Beach Police Athletic League Facility		43
	South Shore Community Center		50
	Flamingo Park Tennis Center		43
Electrical Substation	Liberty Ave Substation		56
Fire Station	#1		49
Historical and Cultural Resources	Colony Theatre		42
Law Enforcement Facilities	Police Station HQ		46
Natural Resources	Flamingo Park		56
	Miami Beach Soundscape		51
	Canopy Park		49
Schools	Fienberg Fisher Adult School		49
	Fienberg Fisher Elementary School		50
Stormwater Pump Stations*	#4 #6 #15 #25 #26 #27	#28 #31 #32 #33* #45 #48	63*
Wastewater Pump Stations	PS 11		59
	PS 1		51
Wastewater Pipelines*	5 miles		63*

* Due to the number of higher vulnerability assets for this Asset Type, only the highest score is shown.

Table 2.17: South Beach Subregion C (South Pointe) higher vulnerability assets.

Asset Type	Asset Name/ Mileage	Vulnerability Score (max = 64)
Bus Stops	5th St. & Lenox Ave.	42
	5th St. & Michigan Ave.	43
Community Center	South Shore Branch Library	47
School	South Pointe Elementary	50
Stormwater Pump Stations	#16	59
Wastewater Pump Stations	PS 31	53
Wastewater Pipelines*	<1 mile	63*

* Due to the number of higher vulnerability assets for this Asset Type, only the highest score is shown.



South Beach Key Vulnerabilities

- The South Beach Structures & Facilities classified with higher vulnerability are primarily located in two areas. The first is on the island neighborhoods of subregion A, where nearly all bridges connecting the islands, nine stormwater pump stations and eight wastewater pump stations are considered to have higher vulnerability. The second area is from the Biscayne Bay shoreline in the West Ave. and Bay Rd. neighborhood to Meridian Ave. An additional 13 stormwater pump stations are considered to have higher vulnerability in this area.
- The subregion B neighborhoods include several critical emergency facilities that are classified to have higher vulnerability, including Fire Station #1, the police station headquarters, and the Convention Center which serves as a logistical staging area during emergencies. The roadways surrounding these facilities are also projected to be flooded during higher sea level rise events which would complicate emergency response operations.
- Twelve of the City’s 48 stormwater pump stations are in subregion B and are classified to have higher vulnerability. Should these assets be damaged due to flood exposure, low-lying areas of South Beach are likely to be inundated with deeper floodwaters as current stormwater infrastructure may not be able to compensate for the increased volumes.
- There are several higher vulnerability wastewater pipelines located in the socially vulnerable neighborhood areas. Like the other two regions, all these segments were installed over 70 years ago.

Asset Group Profiles

The City recognizes the impacts from a failed asset are rarely contained to that single asset and the services it provides. Individual assets are one piece of a larger infrastructure system. For example, if one City stormwater pump station were to fail due to flood exposure, this could generate increased runoff conditions for adjacent stormwater pump stations, which may be unable to drain the increased volume. This could result in increased flooding impacts in areas larger than the area of the damaged stormwater pump drainage basin. Similar examples can be used to describe how flooding impacts to certain facilities (e.g., emergency response facilities, community centers, etc.) could result in unexpected impacts to related infrastructure.

To more comprehensively understand and visualize these infrastructure relationships, the City further organized the asset subcategories (**Table 2.4**) into 10 Asset Groups. The Asset Groups consist of closely related asset types that share similar functions or services. For example, the Emergency Facilities Asset Group includes the City's emergency response structures (e.g. fire stations, police stations, hospitals) and important recovery facilities, such as debris and logistical staging areas).

Table 2.18 provides an overview of the 10 Asset Groups and a description of the assets included.

The Asset Groups provide a refined assessment of the vulnerability of City-wide infrastructure systems. The organization of this information also allows for easier communication of system vulnerabilities to the public and City staff who may be responsible for the assets (e.g., the Department of Public Works). The Asset Group findings have been developed into profiles that provide additional details of the sea level rise vulnerability for assets within each group. These profiles can be found in Appendix E.7.

Table 2.18: Asset Groups and description of assets included.

Asset Group	Description of Assets Included
Community Centers	Includes assets that provide important community services, including recreational activities, extracurricular programs, and housing to City residents.
Critical Buildings	Includes assets that provide access services that are critical to daily function in the City, including places of business, schools, and local government offices.
Drinking Water	Includes assets responsible for the distribution and supply of drinking water to the City's residents and businesses.
Electrical & Communication	Includes electrical substations necessary for dependable electricity production for residents and businesses and communication towers.
Emergency Facilities	Includes emergency response and recovery facilities critical to ensuring access to medical care and protecting residents and businesses from risk and damages.
Natural Resources	Includes natural areas, such as parks, that serve as recreational spaces and community event spaces.
Public Transportation	Includes the public transportation network of bus stops and trolley stops.
Roads and Bridges	Includes the major transportation assets that enable the daily transport of people and goods throughout the City
Stormwater	Includes the stormwater pump stations necessary for the efficient movement of runoff from critical assets.
Wastewater	Includes the infrastructure assets responsible for the proper removal, conveyance, and disposal of wastewater

2.5.4 Key Takeaways

The Assessment conducted in this report allowed the City to identify and prioritize critical assets and infrastructure based on the projected impacts from future sea level rise. The City leveraged datasets from previous reports and City departments to develop an asset inventory of nearly 60,000 individual assets. The City also conducted several community engagement events in the early stages of the project to identify the assets most valued by residents and capture the flooding issues that are already impacting the community.

With this information, the City developed a scoring methodology to compare vulnerability among the considered assets. Flood maps were created to determine the projected flood exposure for each asset to seven sea level rise scenarios. To obtain a vulnerability score for each asset, the City determined each asset's sensitivity to flooding and the community consequences if the asset failed due to flooding. The Assessment resulted in a list of assets based on these vulnerability scores. Assets were organized into asset subcategories and asset group profiles to more effectively communicate the key findings of the Assessment, including where the most vulnerable assets are in the City.

These key findings are provided below:

- The City assets with higher vulnerability scores are often located near Biscayne Bay shorelines, particularly in South Beach in the West Ave. and Bay Rd. neighborhood. In North Beach, several of the higher vulnerability assets are located along the canal shorelines. These assets may be located near low-lying sections of shoreline or seawall that are projected to be more frequently overtopped due to future sea level rise. City assets located behind the eastern coastal dune area have relatively lower vulnerability than those in the western part of the City.
- The assets with the highest vulnerability scores are wastewater pipelines that were installed more than 70 years ago. This older infrastructure is often located in low-lying areas projected to be exposed to most sea level rise flooding scenarios. These sections of wastewater pipelines were also found in several of the City's most socially vulnerable neighborhood areas.
- Future sea level rise is projected to extend king tide flooding inland, generally following along roadways which are expected to serve as flood pathways. Sea level rise will also increase the extent of rainfall ponding areas during compound events in numerous City areas that currently do not tend to flood. As nearly the whole City is projected to be impacted during a storm tide (storm surge) event at current conditions, the flooded area will not increase significantly. However, storm tide (storm surge) flood depths will increase, likely exacerbating impacts to assets.
- Forty-two of the City's 48 stormwater pump stations are considered to have a higher vulnerability to future sea level rise. The City has taken several measures to assess the risk to this infrastructure, including the detailed analysis included in the SWMMP. The results of this assessment encourage continued efforts to adapt these critical flooding mitigation assets to future sea level conditions.
- The City's primary emergency response facilities (e.g., police station headquarters, Fire Station #1, Mt. Sinai hospital, and the Convention Center) are considered to have higher vulnerability. Previous efforts by the City, including road raisings and the elevation of critical equipment, have sought to mitigate flooding impacts at and near these facilities. This Assessment highlights the importance of continuing to develop adaptation measures to protect these critical facilities.
- The City's bridges connect the individual island neighborhoods of Miami Beach and the City to the mainland. The bridges also serve as primary evacuation routes during emergency events. More than half (24 of 47) of the City's bridges and nine-of-ten connecting the South Venetian Islands are classified to have higher vulnerability.
- Several of the City's community centers and affordable public housing assets are considered to have higher vulnerability, particularly in North Beach. Many are also located in the City's socially vulnerable neighborhood areas. Adaptation measures should be pursued to mitigate flooding impacts to these assets so that they may continue to provide services and resources to the City's disadvantaged populations.

- Anecdotal stories and experiences shared during community engagement activities aligned with the vulnerabilities and flood extents mapped in this study. These include:
 - Residents recognize higher flood vulnerabilities along Biscayne Bay.
 - Roadways are critical for daily travel, but several low-lying streets are already facing flooding impacts under existing conditions.
 - The City's parks and community centers are highly valued community assets, but several, including Flamingo Park and the Scott Rakow Youth Center, currently face frequent flooding impacts.
 - The City's aging flood protection structures (e.g., wastewater pipelines) should be replaced in order for the infrastructure to be designed for a higher sea level future.
 - The City's most vulnerable populations and neighborhoods are already withstanding sea level rise impacts and these are expected to worsen without proactive action.

Improving resilience City-wide, both now and into the future, will require a collection of adaptation strategies that can be applied to the varying flooding risks of numerous asset types located in every part of the City. As a step towards this goal, the key vulnerabilities identified by this Assessment have provided a foundation for developing the adaptation pathways outlined in the Adaptation Plan. The goal of these pathways is to integrate the findings of this Assessment into future City planning initiatives and infrastructure projects in order to reduce the City's vulnerability to future sea level rise and maintain the City's leadership in enacting forward-thinking climate adaptation actions.

By 2070, sea levels are projected to be high enough that nearly the entire City is expected to face some impacts from any of the three flooding sources assessed. However, these projections and assumptions are based on the City's current infrastructure and do not consider future City actions to mitigate flood impacts. The takeaways from this Assessment provide the City with a starting point for efficient adaptation efforts by highlighting which assets are currently the most vulnerable to sea level rise. Moreover, the ranking of vulnerability scores allows the City to identify the order in which to prioritize addressing assets before sea level rise impacts may cause them to fail.

This Assessment also highlights that there are regional and neighborhood differences in terms of the City's sea level rise vulnerability. For example, an additional foot of sea level rise by 2040 (NOAA Intermediate High scenario) is projected to produce relatively more extensive king tide flooding in South Beach than in North or Mid Beach. The City regions also include multiple types of critical assets and systems that will respond in different ways to more frequent flooding events. Addressing the potential impacts to these assets will therefore need more than one approach.

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3. Next Steps

The objective of this Assessment was to identify the City's assets and infrastructure that are most vulnerable to current and future flooding events. The Assessment considered an asset's exposure to flooding as well as the asset's flooding sensitivity and consequence to community to determine a vulnerability score. The Assessment resulted in a list of assets ranked by this vulnerability score. This list reflects City assets that are most at risk to future flooding due to sea level rise.

With these findings, and associated Asset Group Vulnerability Profiles, the City is well equipped to communicate to residents and other City departments the magnitude, extent, and severity of flooding impacts the City could expect from future sea level rise. The list of prioritized assets allows the City to pursue project funding for implementation, from sources such as the Florida Department of Environmental Protection (FDEP) Resilient Florida grant program, to develop targeted adaptation measures for identified flood susceptibilities across the City. These key vulnerability findings also served as the foundation for the adaptation pathways developed in the Adaptation Plan. The adaptation pathways incorporated City asset vulnerability information to develop place-based strategies that can evolve with changing conditions, such as future sea levels.

Finally, this Assessment represents the latest in the City's ongoing effort to understand, communicate, and prepare for a future influenced by climate change. The sea level rise vulnerabilities identified in this report fit into the City's resilience vision and this Assessment builds on the work of many previous City plan and initiatives. The vulnerabilities identified here expand the assets considered in the City's 2017 Vulnerability Assessment (Guidebook, 2017) and refine the methodology to improve how assets can be prioritized by the City. These findings also can be used in coordination with findings and actions outlined in other recent City plans, such as the SWMMP and Neighborhood Project Prioritization Plan. Additionally, the Vulnerability Assessment findings can inform future updates to the City's Local Hazard Mitigation Strategy, which describes the overall City approach to hazard protection and allows the City to maintain eligibility to receive pre-disaster mitigation grant funds from FEMA.

The completion of this Sea Level Rise Vulnerability Assessment provides the City and the State of Florida a comprehensive resource evaluating the vulnerability of its most critical assets to flooding and sea level rise. This Assessment will help guide the City's future planning and project efforts as it continues to adapt to the immense challenge of sea level rise.

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